CHARLES UNIVERSITY

FACULTY OF PHYSICAL EDUCATION AND SPORT

DEPARTMENT OF PHYSIOTHERAPY

Effectiveness of Ankle and Foot joint mobilization for Improving Stability Analyzed by Computerized Dynamic Posturography.

MASTER'S THESIS

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Declaration of authorship

I declare that this work of this thesis entitled "Effectiveness of joint mobilization for Improving Stabilty Analyzed by Computerized Dynamic Posturography" is my own work, under the supervision of PhDr. Tereza Nováková, Ph.D.

Therefore, I hereby and declare that no invasive methods were used and the following study was performed with authorization approval of the subjects and the ethic committee.

"Rehabilitation is to show a patient what they can do for themselves."

Dr. Karel Lewit 1916-2014

Abstract in English

Effect of Ankle and Foot joints mobilization on Stability improvement, analyzed by Computerized Dynamic Posturography.

The aim of the study was to observe if joint mobilization of ankle and foot joints would improve the stability using the by Computerized Dynamic Posturography (neurocom) as a measurement tool. The methods that are used from the research are based on the knowledge which was obtained during the study of physiotherapy program at FTVS UK.

All the participants are between the ages of 20 to 30 years, with no specific diagnose. All the 40 participants were being randomly divide into 2 groups. The control group and the experimental group, each group will have their Stability tested twice on the CPD (NeuroCom). The control group will be measured first, and after 20 minutes they will be measured again without any examination or therapeutic intervention. The experimental group was measured twice, first before the examination of joint play and the therapy, then the examination of joint play was done and any restricted joints were noted and treated, later, the participants were measured again for possible improvement. Joint play examination and therapy take about 20 minutes. Stability analyses take about 20 minutes too. The project doesn´t include subjects with severe lower extremity injuries (eg, fractures, recurrent disorder last year), subjects with sensory disabilities, people with cerebral palsy, acute illness or injury and convalescence after illness or injury affecting research results.

As a result, the intervention of Ankle and Foot mobilization according to Lewit had positive effect on stability comparing with individuals of no- intervention group. Nevertheless, the one-time session of joint mobilization did not show substantial improvement on stability. Therefore, combined joint mobilization with other stability exercises and kinesiological and medical assessment in multi- sessions is suggested for preferable results of visual, proprioceptive and vestibular components to maintain postural stability.

Key words: Kinesiology, Manual Therapy, Proprioception, NeuroCom

Abstract in Czech

Vliv mobilizace kotníku a chodidla na zlepšení stability analyzované počítačovou dynamickou posturografií.

Cílem studie bylo sledovat, zda by mobilizace kloubů kotníku a chodidel zlepšila stabilitu pomocí Computerized Dynamic Posturography (NeuroCom) jako nástroje měření. Metody, které se používají při výzkumu, vycházejí z poznatků získaných během studia programu fyzioterapie na FTVS UK

Všichni účastníci byli ve věku 20 až 30 let, bez specifické diagnózy. Všech 40 účastníků bylo náhodně rozděleno do 2 skupin. Kontrolní skupina a experimentální skupina, každá skupina byla testována dvakrát na CPD (NeuroCom). Kontrolní skupina byla nejprve změřena a po 20 minutách byla opět změřena bez jakéhokoliv vyšetření nebo terapeutického zásahu. Experimentální skupina byla měřena dvakrát, nejprve před vyšetřením kloubní vůle a byly zaznamenány a léčena jakákoliv omezení kloubní vůle v kloubech, později byli účastníci opětovně změřeni pro možné zlepšení. Vyšetření a terapie blokád trvala asi 20 minut. Analýza stability trvala take asi 20 minut. Projekt nezahrnoval subjekty se závažnými zraněními dolních končetin v anamnéze (např. zlomeniny, poruchy funkce), subjekty se smyslovým postižením, akutním onemocněním nebo zraněním a rekonvalescenci po onemocnění nebo zranění ovlivňujícím výsledky výzkumu.

Výsledkem bylo, že intervence mobilizace kloubů kotníku a chodidla podle Lewita měla ve srovnání s jedinci bez zásahové skupiny pozitivní vliv na posturální stabilitu. Tato jednorázová mobilizace nicméně neprokázala nijak podstatné zlepšení. Proto se doporučuje kombinovat mobilizaci kloubů s jinými cviky rovnovážných funkcí na základě kineziologického rozboru a to ve vice jednotkách, aby se dosáhlo preferovaných výsledků vizuálních, proprioceptivních a vestibulárních složek k udržení nebo zlepšení posturální stability.

Klíčová slova: kineziologie, manuální terapie, propriocepce, NeuroCom

Table of Contents

1 Introduction

The maintenance of the body base of support for stability is proximately close to ankle joint playing an integral role for maintaining stability [5]. The ability to maintain stability during standing requires integrity of the visual, vestibular and nervous system. Along with the joint capsules, ligaments, muscles and skin all working together to generate functional intact and neural input for the stability to occur by the ankle and foot joint [26].

In addition, foot stability is necessary to provide a stable base for the body. The joints making up the foot interacts with the surrounding tissues [73]. The joints which provide the sufficient mobility and stability provide sufficient shock absorption too. The body in order to stabilize the postural stability reacts to the surface or ground contacting body with foot to maintain a solid stability. This mobile adapter to a rigid lever capacity of the foot and ankle joints helps in preventing any falls or propelling the body is such manner that would be injurious [60, 67].

The kinematics of maintaining the body stability by foot and postural stability together is a key role to keep the stability of the human body [10]. As foot and ankle are the primary sources of the locomotion continuously, the effect of this can cause the joints of the foot to be blocked which can limit or alter the mobility of the joints to maintain the stability of the body.

Stability is the ability to keep the body in equilibrium and to regain balance after the shift of body segments [43]. In relation, ankle foot joints are proposed to propelling body forward during locomotion, it needs to be in such structural manner to achieve appropriate kinematic movement of the bony skeletal structures, i.e. joints of the foot to be adaptable in movability in order to maintain stability.

Therefore, the aim of this study is to evaluate when the foot and ankle joints mobility is altered, how the treatment of this will affect the overall stability in relation to the joints. The main purpose of the study is to identify how the intervention of the foot and ankle joints mobilization according to Lewit will affect the stability of the body, when compared to the individuals without any joint mobilization.

2 Theoretical Background

2.1 Computerized Dynamic Posturography (CPD)

Stability is important for an upright hold of a musculoskeletal structure. These components disability can cause dizziness and stability problem experience in a lifetime. The elderly with age declination of stability are likely to multiple falls and people with chronic fatigue syndrome are tending to show increase occurrence of stability problems [33].

Therefore, stability evaluation is important for clinicians to diagnose vestibular system impairment early and to evaluate the effects of the interventions to treat these problems. An important tool for understanding static and Dynamic stability in clinical settings has evolved [9]. NeuroCom (CDP) as shown in Figure 2, is a quantitative method for assessing upright and displace stability function under a variety of tasks that effectively simulate the conditions encountered in daily life. The following are the three main conditions that were taken into consideration for this study.

The Sensory Organization Test (SOT) is a key test in the NeuroCom EquiTest System (a Dynamic posturography system) that provides information about the integration of the visual, proprioceptive, and vestibular components of Dynamic Stability. This includes the individual to stand quietly, with eyes open or closed and the platform and surroundings are fixed or moving according to the conditions. The SOT results in an outcome measure called the equilibrium score (ES), which is based on the maximum anterior-posterior (A-P) sway angles during SOT trials, reflecting the overall coordination of these components to maintain standing posture [11].

The two-dimensional quantity, limits of stability (LOS) defines the function of the sway direction from the center position of the maximum possible COG sway angle [59, 41]. The placement of the feet and the characteristics of the base of support define the LOS. In a normal adults standing on a flat, firm surface with feet spaced comfortably apart, the LOS perimeters can be described. The “limit of stability” cone relations the center of gravity (COG) sway angle.

Joint motions cause the COG sway angles, as shown in Figure 1 there is moving about the ankles and the other figure has more joint motions using the hip strategy. The COG height above the surface and foot length affects the limits of stability [25]. The person's height relative to the spacing between the feet affects the lateral LOS. When the feet of a person 70-inch tall are placed 4-inches apart, for example, the lateral dimension of the LOS ellipse is approximately 16° from the left to the rightmost points on the perimeter. For taller individuals, a wider spacing between the feet is required to produce a 16° ellipse, whereas shorter people can place their feet closer together [17]. Therefore, the person's LOS is effectively reduced in anterior posterior but not in the lateral dimensions.

Stability by Motor Control for the maintenance of the Dynamic Stability, the stiffness properties of the joints are involved which are regulated by the stretch reflex. As result, stretch reflex plays role in automatic active postural movement in response to the external stability perturbations, for maintaining stability when standing [40]. In some respects, the automatic postural movements resemble reflex responses, and voluntary movements in others.

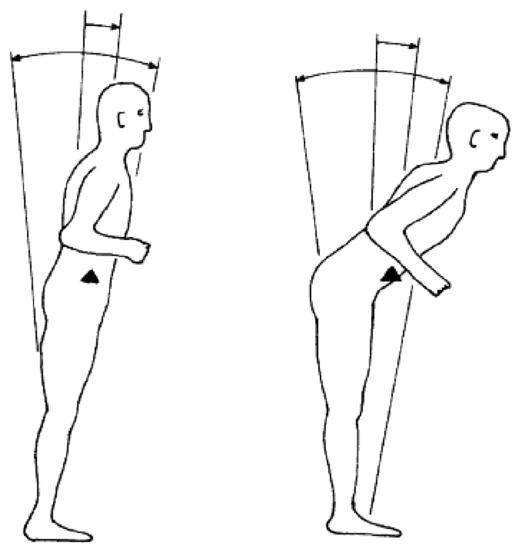


Figure 1 Limit of Stability cone [26]

Automatic movements are triggered by external stimuli, occur at fixed latencies, and are relatively stereotyped just as reflexes. Automatic responses like voluntary postural movements, involve the coordinated actions of many leg and trunk muscles, and the adaptation to the task conditions of the amplitude and patterns of automatic responses.

Nevertheless, the pathways mediating automatic postural movements are not clearly explained, the 90- to 100-ms latencies of electromyography (EMG) responses are sufficient to include significant brainstem and subcortical involvement [18, 44, 63].

Either in presence or absences of external stimuli voluntary postural movements occur, and in theory the variety of voluntary patterns in almost limitless. Voluntary movement when elicited by external stimuli are 150 ms under the simplest and well-practiced task conditions, but when the task is more complex it can take much more longer and when the person's level of attention is reduced [53]. Against an external object when a voluntary force is exerted by a freely standing person, automatic and voluntary activities are closely coordinated to provide a stable base of support for the voluntary movement,[6]. For these examples, first the automatic postural reactions occur, and accordingly delayed are the onset of the voluntary component [53].

Figure 2 Smart Balance Equitest System. [76]

The SMART Balance Master System (SBMS) (NeuroCom International Inc., Clackamas, OR) is used for the study, as shown in Figure 2. Sensory, motor and stability components are quantitatively assessed by the performance of computerized Dynamic posturography.

The system includes: NeuroCom Balance Manager Software Suite, Dynamic platform, Moveable visual surrounding plates with LCD monitors, high supporting bar holding the harness set, Windows-based computer, Colored printer, mouse and Ergonomic point-of-care cart.

SMART BMS machine has an 18" x 18" force plate with four transducers, in each corner of the force plate, two anterior and two posterior transducers, these sensors receive signals from applied vertical force of subject on the force plate.

There are three panels around subject, one in front and two on both sides to right and left. The force platform and visual surrounds are fixed or moveable according to conditions of tests, their movements are in sagittal plane in both anterior and posterior (AP) directions.

The System is connected to PC computer to run its software and to make stability assessment by choosing desired test, after entering the data of subjects to software system, and to extract the results post-testing. The data were collected at sampling frequency of 100 Hz, by using the system software Equitest.

- Dynamic and static stability

Computer Dynamic Posturography (CDP), SBMS NeuroCom, was used to assess the static and Dynamic stability, the evaluating protocols used were the Sensory Organization Test (SOT); Motor Control Test (MCT) for Dynamic stability and static stability in Limit of Stability Test (LOS).

- Sensory Organization Test (SOT)

The sensory systems are tested by the design of SOT test. The evaluation is done to assess the level of sensory process involved in Dynamic stability. The process is performed by altering the orientation information provided by the vestibular system, somatosensory system and visual system or mixed systems. Additionally, the level and quality of maintaining body stability are evaluated.

The SOT evaluated the body Dynamic stability and swaying of body in back and forth position in anterior and posterior directions from Center of Gravity in standing position. The evaluation is carried out by testing 6 conditions each having three trials, 18 in total, indicated in Table 1, Figure 3 shows the demonstration of the conditions on CDP.

The Composed stability is evaluated by SOT from the following conditions performance:

- Condition 1: eyes open, fixed visual surround and fixed platform.
- Condition 2: eyes closed and fixed platform.
- Condition 3: eyes open, moving visual surround and fixed platform.
- Condition 4: eyes open, fixed visual surround and mobile platform.
- Condition 5: eyes closed and mobile platform.

Table 1 SOT 6 conditions [47].

Condition	vision	surroundings	surface	sensory System
1	Open eyes	Mixed	Mixed	Somatosensory
2	Closed eyes	Fixed	Fixed	Somatosensory
3	Open eyes	Moving	Fixed	Somatosensory
4	Open eyes	Fixed	Moving	Visual
5	Closed eyes	Fixed	Moving	Vestibular
6	Open eyes	Moving	Moving	Vestibular

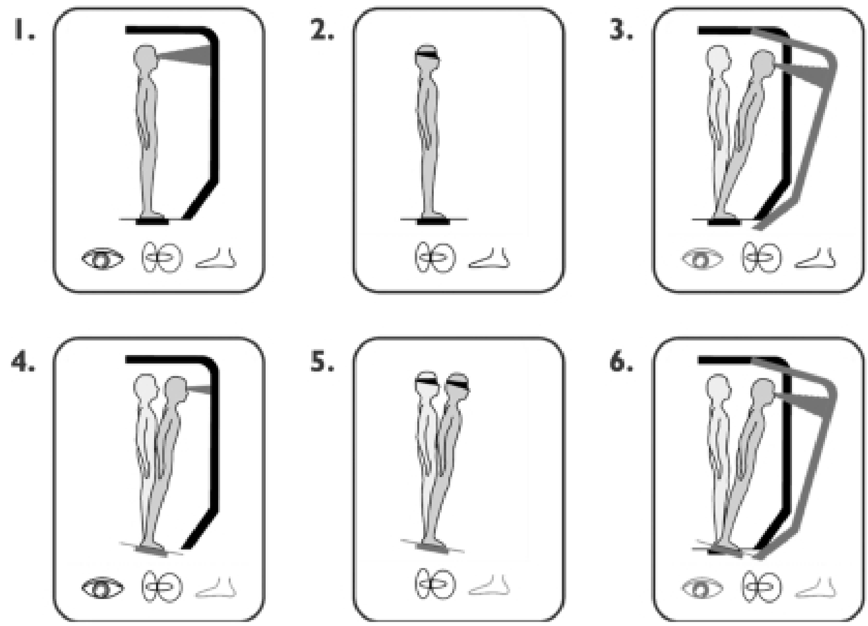


Figure 3 SOT conditions illustration [3].

- Motor Control Test (MCT)

The Dynamic stability is assessed by MCT to quickly recover following an unexpected external disturbance. The platform translation is scaled according to the height of the individual's height into sequences of small, medium or large in forward and backward directions are evoked automatic to postural responses.

The results of surface translation in one horizontal direction are the displacement of the COG away from the center in the opposite direction relative to the base of support. A quick movement of the COG back to the center position is required in order to restore normal stability. Illustration of the movement on the machine is represented in Figure 4.

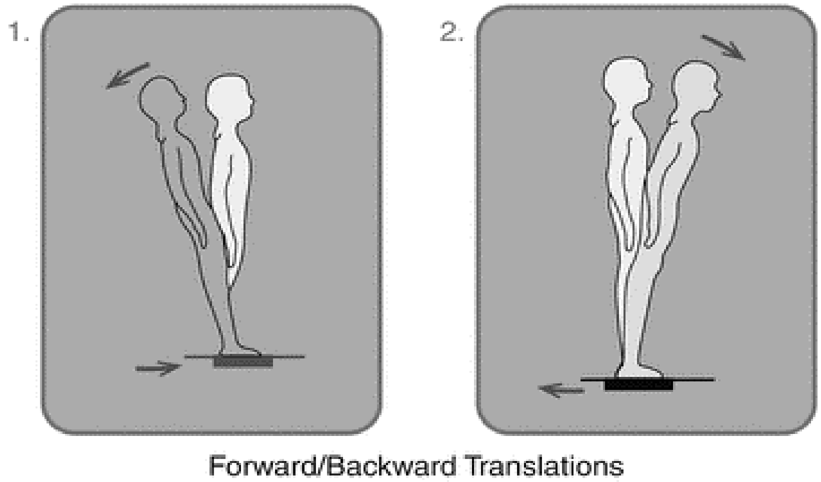


Figure 4 MCT demonstration on CDP [3]

- Limit of Stability test (LOS)

The protocol of LOS evaluates the individual's static stability and the ability to control and move the COG to the desired location. On the monitor the place is marked that the individual on the machine sees on the monitor screen in the machine. The "target sites" are spaced at 45 ° intervals around an oval shape that represents 100 % of the median position of the theoretical stability limits of the individual. The examined person is instructed to reach the given place and hold on to the position for 8 seconds, and then return to the starting position. Targets are highlighted clockwise during the measurements [57].

The eight directions are: forward (FW), backward (BW), right (RT), left (LT), forward-right (FWRT), forward-left (FWLT), backward-right (BWRT), and backward-left (BWLT) .For each direction the EquiTest software measured movement reaction time (ReT), movement velocity (MVL), endpoint excursion (EPE), maximum excursion (MXE), and movement directional control (DCL). The ReT in seconds reflects the onset of intentional movement toward the target as soon as the specific target appears on the screen. The MVL is the average speed of the center of gravity (COG) movement in degrees per second quantified for 5% to 95% of the distance from the center of the monitor (initial position) to the target [58]. Each sway towards the objective during testing calculated the parameters, as shown in Figure 5.

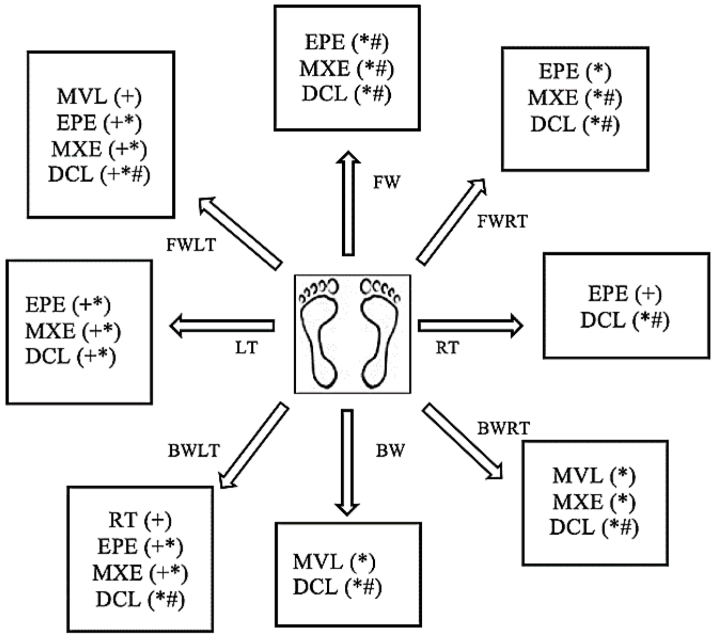


Figure 5 LOS evaluation of the COG to the conditions response [73].

2.2 Anatomy of Foot Joints

2.2.1 Talocrural Joint

The talocrural joint or the ankle joint, shown in the Figure 6, is the proximal joint of the foot. The uniaxial hinge joint is formed by the tibia and fibula conjoining (the tibiofibular joint); and the tibia and talus (tibiotalar joint). This joints structure allows stability rather than mobility [1]

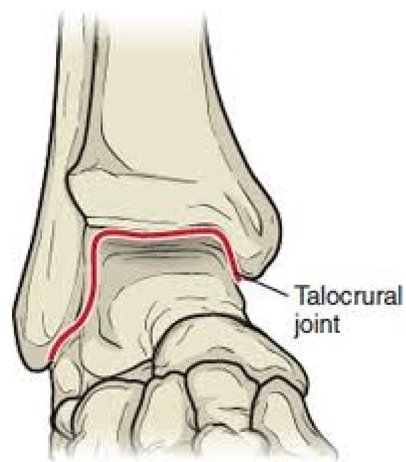


Figure 6 Talocrural Joint [1]

2.2.2 Subtalar Joint

The subtalar joint, or the talocalcaneal joint is distal from the talocrural joint. It consists of the articulation between the talus and the calcaneus, shown in Figure 7. The largest weight bearing bones in the foot are the talus and calcaneus and this form the hind foot.

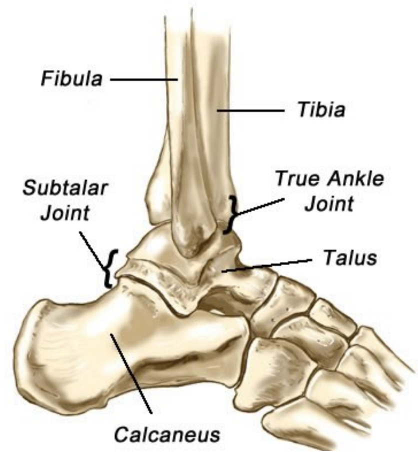


Figure 7 Subtalar joint [50]

The keystone of the foot is the talus link of the tibia and fibula of the foot. The moment arm calcaneus of the Achilles tendon accommodates the large impact of loads at the heel strike and high tensile forces from the gastrocnemius and soleus muscles during the gait. [2]

The subtalar joint's prime function is to absorb the rotation of the lower extremity during the support phase of the gait. The subtalar joint absorbs the rotation through the opposite actions of pronation and supination, when the foot is fixed on the surface and the femur and tibia is rotating internally at the beginning of the stand and externally at the end of the stance.

Pronation is the combination of dorsiflexion, abduction and eversion; whereas, supination is combination of plantarflexion, adduction and inversion. The subtalar joint absorbs rotation by acting as amitered hinge, allowing the tibia to rotate on a weight-bearing foot [2].

2.2.3 Midtarsal Joint

The midtarsal, or the transverse tarsal joint has the greatest functional significance. The two joints it consists of are, the calcaneocuboid joint on the lateral side and the talonavicular joint on the medial side of the foot. Together, they form an S- shaped joint with two axes, oblique and longitudinal, as shown in Figure 8.

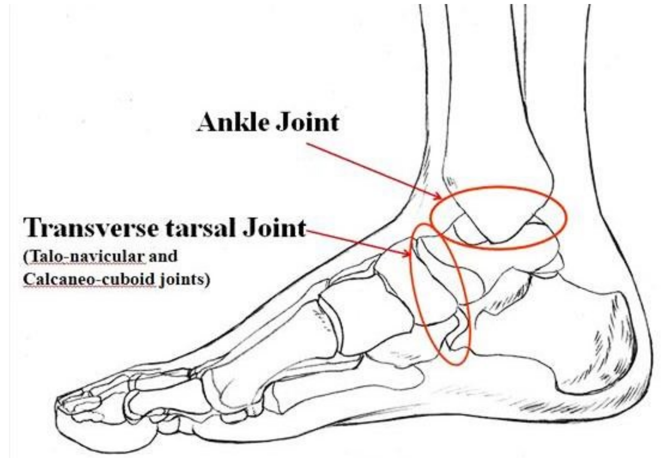


Figure 8 Midtarsal Joint [71]

The motion of the joints contributes to the inversion and eversion, abduction and adduction, and dorsiflexion and plantar flexion at the subtalar and ankle joints. Movement at the midtarsal joint depends on the subtalar joint position.

When the subtalar joint is in pronation, the two axes of the midtarsal joint are parallel, which unlocks the joint, creating hypermobility in the foot. For this reason, the foot is mobile in absorbing the shock of contact with the ground and also in adapting to uneven surfaces. When the axes are parallel, the forefoot is also allowed to flex freely and extend with respect to the rear foot [46].

2.3 Stability

The interaction of multiple sensory, motor and integrative systems is dependents of maintaining stability and performing functional tasks. These systems include vision, vestibular function, peripheral sensation, strength and reaction time [43].

Motions of the ankle, knee and hip joints are involved in stability movements; these are controlled by the coordinated actions of the muscles of ankle, thigh and lower trunk. Balancing with the feet in a static place, the position of the body's center of gravity (COG) must be maintained vertically over the base of support. These condition help an individual to both resist the destabilizing influence of gravity and actively move the COG [48].

2.3.1 Foot Contribution to Stability

The foot contributes to the maintenance of stability, as it is the only direct source of contact with the ground during weight-bearing tasks.

The two main ways to maintain stability includes; the osteroligamentouse architecture demonstrated in Figure 9 of both arches provides the mechanical support of the body and the lower limbs coordinated function of the muscles; the sensory information's delivery regarding the body position from plantar tactile mechanoreceptors. Therefore, deficits in the foot posture, flexibility, strength, or sensation impairing of this support function can prejudice to loss of stability, enhancing fall or injury [39].

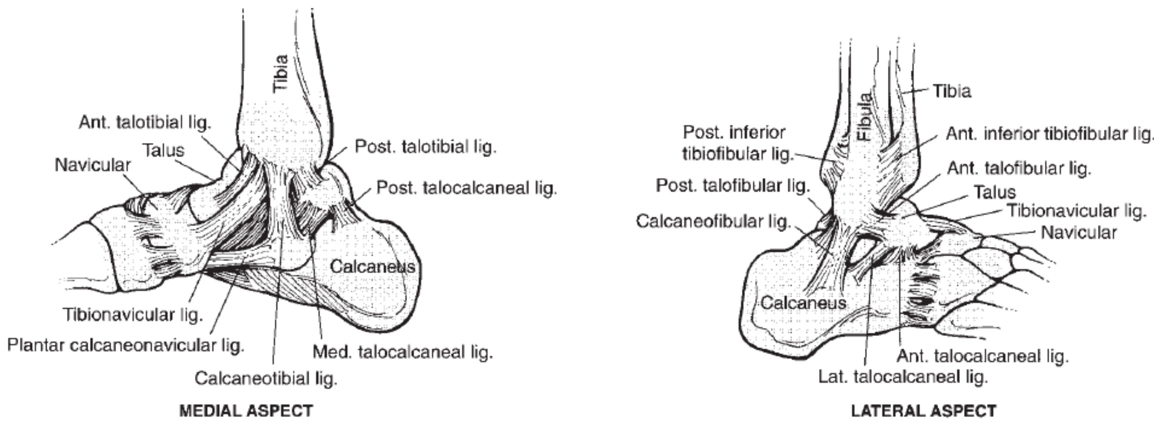


Figure 9 Foot Ligaments [23]

2.3.2 Stability effect by Ankle Joint Muscles

Maintaining stability during gait can be contributed by ankle joint muscles by modulating the center of pressure and ground reaction forces through an ankle moment. Especially, during the ankle plantar or dorsiflexion of the foot this modulation is effective in sagittal lane [40].

The ankle joints biomechanically work efficiently with the surrounding structures; the muscles imbalance can lead to physical blocked ankle joints. This can cause ankle strategy ineffectiveness to no functional contribution of the muscles to maintain stability during walking, nor would these muscles generate afferent output regarding ankle joint rotation for gait. As a result, the purpose of stability control would be expected to disappear by lack of ankle muscle activation along with blocked joint [40, 59].

These muscle imbalances can evoke changes in the proprioceptive information as afferent sensory information for the centralized regulation of stability control through ankle joint kinematics [71].

2.3.3 Ankle Joint Maintenance of Stability

Ankle mobility can be influenced by multiple factors, movement and stabilizing forces of the ankle contribute to the normal gait patterns and postural control. For instance, the contribution for the adequate joint motion at the ankle joint complex is for the lower extremity to function smoothly during upright gait. Approximately 30° of rotation occurs at the ankle joint during normal walking on the level. Approximately 10° of dorsiflexion during the swing phase of the gait is necessary for toe clearance ;for rapid propulsion of the body forward a strong ankle plantar flexion during the stance phase is needed; and the essential of subtalar rotations for the absorption of the rotational torques transferred from the proximal joints of the lower extremity during the stance phase .The meticulously controlled manner for all the movements to perform that adequate range of motion at the ankle joint complex is an important prerequisite to the precise, efficient gait execution required for just enough elevation to ensure toe clearance during the swing phase [50,66,70]

Muscular responses are used to maintain perturbation to stability, by necessary adequate ankle movements; as such as rapid compensatory stepping movements [35].

An integral component of many daily living activities is locomotion, the complex constant demand of these tasks are achieved by the mobility at the ankle joint. therefore, if any loss of flexibility at the ankle and subtalar joints with growing age may considerably influence on some mobility tasks of daily living in the elderly. These movements which may also be affected by the disorders as such a stroke or Parkinson's disease that impairs motor control, and even by poorly-fitted or flimsy footwear and walking aids [24].

2.4 The Sensorimotor System

The sensory and motor system makes up the sensorimotor system complex. The sensory system is relation of proper motor system function. It was described that proprioceptive dysfunction can cause joint instability rather than the ligamentous laxity. Repetitive joint functional instability can cause the neuromuscular aspect of the body stability to be disrupted [53]

The sensorimotor system, an adaptation of the 1997 Foundation of Sports Medicine Education and Research participants workshop, which described the sensory, motor and central integration and processing components involved in maintaining joint homeostasis during bodily movement for functional joint stability [53].

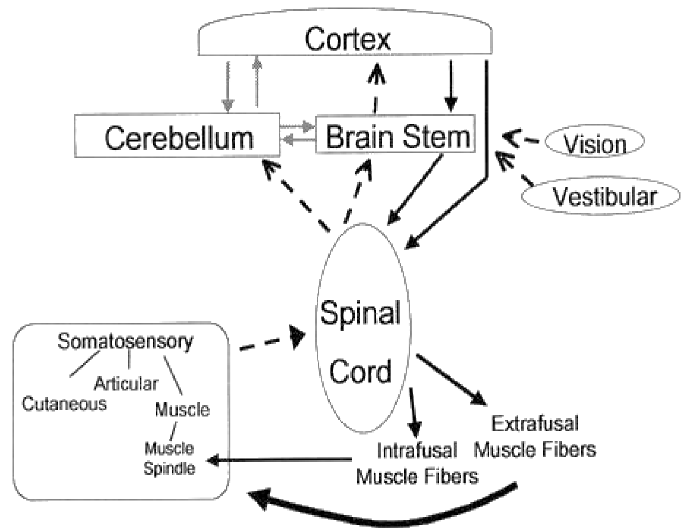


Figure 10 Sensorimotor System Pathways [53]

The sensorimotor system is considered as a subcomponent of the comprehensive motor control system of the complex system of body in combination with sensory input to function effectively. The rise to functional joint stability components must be flexible and adaptable to the appropriate tasks [63]. The sensorimotor system pathways are demonstrated in Figure 10.

The complex of sensorimotor system includes all the afferent, efferent, and the central integration and processing components involved in maintaining functional joint stability. The contributions of the system contain the visual, vestibular input and as well the peripheral mechanoreceptors.

The peripheral mechanoreceptors reside in the cutaneous, muscular, joint and ligamentous tissues. The afferent pathways transfer input to the three levels of the motor control and further associate with areas such as the cerebellum. The response for activation of the motor neurons may occur directly of peripheral sensory input (reflexes) or from descending motor commands; either might be regulated or modulated by the associated areas. From each motor control levels efferent pathways are converging by the alpha and gamma motor neurons located in the spinal cord ventral aspects.

The extrafusal and intrafusal muscle fibers cause contractions by the new stimuli to be presented to the peripheral mechanoreceptors [53].

The functional maintenance of the joint stability is accomplished by the static and Dynamic components. The static (passive) components, includes the ligaments, joint capsule, cartilage, friction, and the bony geometry. The feed forward and feedback neuromotor control over the musculoskeletal crossing of the joints is the Dynamic contribution. These characteristics underline the Dynamic restraints of the joints biomechanical and physicality for range of motion and muscle strength and endurance [29].

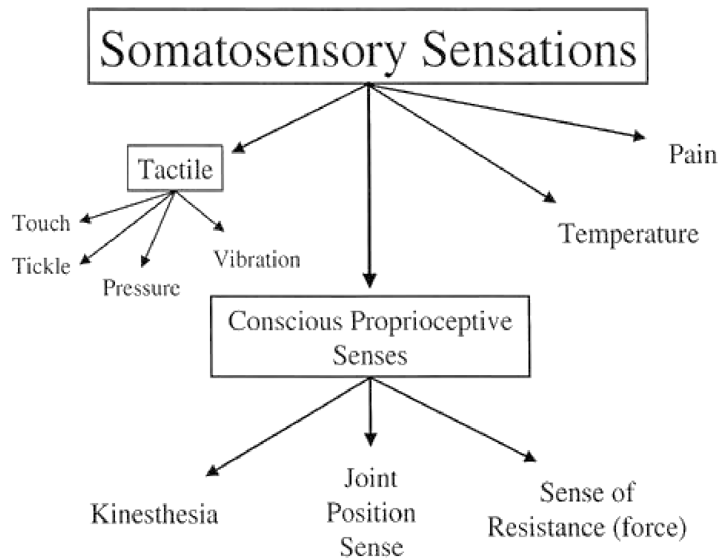


Figure 11 Somatosensory Sensations [65]

The subcomponent proprioceptive deficits can lead to both local and global dysfunctions. The CNS processing is affects by insufficient or improper afferent information, which in turn affects motor output and joint functions. Joint pathology can be changed by both muscle activation and stability strategies.

2.5 The Somatosensory Sensations

The mechanoreceptive, thermoreceptive, and pain information arising from the periphery are all encircle in a global somatosensory. The sensation of pain, temperature, tactile (touch, pressure etc), and the conscious sub modality proprioception sensation are conscious appreciation of somatosensory information. The conscious proprioceptive senses are perceived, such as with joint position, Kinesthesia and sense of resistance (force) Figure 11 illustrates the sensations [21, 65].

2.6 Biomechanics of Forces Acting in the Ankle and Foot Joint during Locomotion

In both walking and running the ankle and the foot are subjected to significant compressive and shear forces. During gait, at heel strike comes a vertical force 0.8 to 1.1 times a body weight. In the midstance the magnitude of this force decreases to about 0.8 times body weight to 1.3 times body weight at toe-off [4].

In addition, with the contraction forces of the plantar flexors, creates a compression force in the ankle. During gait, in the ankle joint the compression force can be as high as 3 times body weight at heel strike and 5 times body weight at toe-off [4,13].

Primarily as a result of the shear forces absorbed from the ground and the position of the foot relative to the body, a sheer force of 0.45 to 0.8 times body weight is also present [15]. The peak ankle joint forces during running are predicted to range from 9 to 13.3 times body weight. The peak Achilles tendon force can be in range of 5.3 to 10 times body weight [36]. The ankle joint is subjected to forces similar to those in the hip and knee joints.

The subtalar joint is subjected to forces equivalent to 2.4 times body weight, with the anterior articulation between the talus, calcaneus, and navicular recording forces as high as 2.8 times body weight. Large loads on the talus must be expected because it is the keystone of the foot. Loads travel into the foot from the talus to the calcaneus and then forward to the navicular and cuneiforms. During locomotion, forces applied to the foot from the ground are usually applied to the lateral aspect of the heel, travel laterally to the cuboid, and then transfer to the second metatarsal and the hallux at toe-off [20, 55, 57].

Figure 12 shows the forces applied to the foot during the gait loading. A. shows the plantar side during normal gait travel pattern from the lateral heel to the cuboid and across the first and second metatarsal. B. shows when the foot in is extreme positions and high loading which may associate in variety of injuries [57,23].

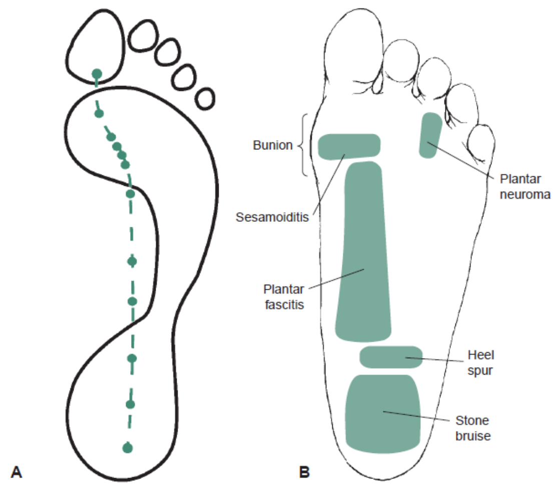


Figure 12 Foot Forces [23]

2.7 Joint Restriction

2.7.1 Blockage of the Joint

Joint contracture is result of increased joint stiffness which can alter the resting limb position, the; lengths of the muscle and the lever torque angle relation at the joint around which muscles act are affected [70].

Due to, the muscle imbalances occur as the force output of the muscles is altered; therefore, the muscles are no longer capable of complete range of motion the limb segment capability. Further, hanged movement stereotype patterns can cause the joints surrounding to restrict.

2.7.2 Mechanism of Joint Restriction

The most frequent causes of the reversible joint restrictions, is the occurrence and recurrence of the disturbed movement patterns and static overload. The reference of the joints in relation to the elasticity and mobility of the soft tissues along with muscles cause a barrier is defense to irrelevant mobility to prevent injuries [28].

The joint blockage is mainly the joint capsules are restricted. As joint falls out its proper alignment or becomes restricted (tight, locked up, loss of motion), the entire joint structure and its surrounding tissues are affected.

The intense reflexes reactions in all the structures may lead to effectiveness of the musculature in state of increased tension as such of trigger points or spasms; the skin lacks of folds and stretch and cause collision with soft tissues shifts and causing tension. All this, leads to limited mobility of the joints causing limited range of motion and lower neural responses due to the restrictions of the pathway which further effects the stability and balance of the posture.

2.7.3 Postural Stability Affected by Ankle Joint Blockages:

The line of gravity produces postural sway, by even simple body function, breathing can cause the oscillations, this force is counteracted by neuromuscular forces, some of which acts at the ankle joint.

In relation, balance must be maintained once voluntary movement is added in to the situation of changes and destabilizing conditions, for example walking, running, reaching, and lifting an object from the floor. The human neuromuscular system is capable of producing effective, controlling moments of force about the trunk and lower extremity joints, including both preplanned, feed forward adjustments, and rapid reflexive reactions to potential falls [70].

2.8 Joint play

For joint mobilization, musculo-tendinous units normally act at the segments of the joints to create oscillating movements; along with passive mobilization the articular surfaces gently glide for the movements of the joints.

To increase the functional activities, joint mobilization has been claimed to show improvements which helps in relieving pain and improving the range of motion of the injured or altered joints mobility.

Joint mobilization is defined as low velocity, high amplitude passive motion inducing intra-capsular movement at different amplitudes; on the other hand, joint manipulation is defined as a high velocity, low amplitude thrust motion [28, 62]. Maitland (1986) declared that different grades of mobilization according to the amplitude of the motion and resistance offered by the surrounding tissues. He has imposed that using the following classification Grade I and Grade II joint mobilizations are per- formed primarily to decrease joint pain, and Grade III and Grade IV joint mobilizations are used to increase joint ROM [62].

According to Karel Lewit, there are two types of joint movement and these can be affected by the following restrictions:

- Functional movement that is performed actively.
- Joint Play the movement of the joints done passively. This includes the translator sliding movements of one joint surface against the other, rotations and also distraction of the joint facets.

Dr. Lewit, presumed that manipulation treatment does not change the shape or the position of the structure, but the musculoskeletal system could change its function. He has developed the joint techniques that include self-treatment techniques as well for the individuals to keep up the mobilization technique in order to continuously prevent the joint blockages to occur frequently at the effected joint. By joint play mobilization in a technique following the principles the joint movement can be free from any blockages or restrictions disturbing the joint gliding [33].

The first is the positioning of the patient in such a manner that they are relaxed, and the joint objectified for the examination or treatment must be easily accessible. Next, the positioning of the practitioner should be fixed in such a manner that the articulating bones are easily held and palpated. The practitioner must be comfortable and in stable position too. Thirdly, fixation of the bones articulating in the joint being manipulated is fixed while the other is mobilized. The mobilization force to be effective the fixation force should not act across two joints. Then, the treatment of the joint is performed once the slack of the joint is taken up but not to overstretch the joint, taking the slack by reaching the physiological slack (slight resistant) and then the anatomical slack by engaging the barrier. Fifth is the manipulation after engaging the barrier by taking up the slack, the mobilization is done until the release phenomena is felt [33]. The directions to perform joint play sides against the joints are illustrated in Figure 13.

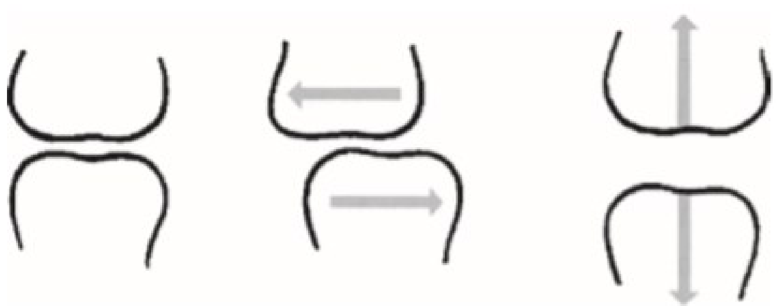


Figure 13 Direction of Joint Play slide [33]

2.8.1 Joint Mobilization of the Ankle & foot by Lewit

Table 2 Joint Mobilization according to Lewit [33]

Joint	Descreption	Dose
Metatarsophalangeal **Illustrated in Figure 24 (1)**	The pateint is sitting on the tratment table with kness slightly bent and heels resting on the table , with the practioner stands or sits at the end of the treatment table facing the pateint . The practiorner takes the pateint's metatarsl in both hands, with the thumb on the dorsal aspect and fingers on the planter aspect. Using the thumb , he spreads the dorsum of the foot over the fulcrum created by the fingers underneath.	Repetiton until the release of Joint restriction
Lisfranc and Chopart **Illustrated in Figure 24 (2)**	The practioner stands at the end of the treatment table facing the medial aspect of the foot to be treated. With the more cranial hand he fixes the dorsum of the pateint's foot above the Chopart's and Lisfranc's joints. With the other hand supinated with ulnar duction , the practioner takes up the slack using light pressure away from the plantar aspect . In this position springing is performed for moblization by the radial egde of the forefingers, with the thumb remaining on the dorsum of the pateint's foot .	Repetiton until the release of Joint restriction
Subtalar and talocalcaneonavicular **Illustrated in Figure 24 (3) and (4)**	The pateint in supine and the foot to be treated protruding over the treatment table . The practitioner cups one hand around the medial aspect of the pateint's heel while spanning the patient's instep with his other hand. With light pressure, the practitioner moves the joint in all possible directions: supination, pronation, plantar flexion and dorsiflexion of the foot.	Repetiton until the release of Joint restriction

Talocrural joint **Illustrated in Figure 24 (5)**	The pateints heel resting on the tratment table with the knee slightly bent. The practitioner should fix the pateint's foot by grasping the planter aspect and holding it at right angle to lower leg. With the othe hand he takes hold of the lower leg above the ankle from the front . For moblization, springing is performed.	Repetiton until the release of Joint restriction
Distal and Proximal interphalngeal **Illustrated in Figure 24**	Dorsoplantar shift, distraction and laterolateral shift are used for mobilizatio and examination . The practioner fixes the phalanx between the the thumb and forefinger of one hand and taking the pateint's distal phalanx between the thumb and forefinger of the other hand , the practitioner mobilizes the distal phalanx in one of the above direction . always applying distration at the same time.	Repetiton until the release of Joint restriction

3 Goal & Hypothesis

3.1 Objective

The goal of this experiment is to encounter the effect of one-time manual therapy (Ankle and foot joints mobilization) in improving the stability.

Therefore, encourages the sensory, motor and stability functions for better stability in healthy young adults, in order to obtain the statistical quotient between prior (PRE) and POST the Ankle and foot joints mobilization intervention compared with control group (no specific intervention) on Computerized Dynamic Posturography (CPD) machine Figure 2.

3.2 Research question

Immediate effect of ankle and foot joints mobilization techniques by Dr. Lewit resulting in stability improvement when evaluated on NeuroCom EquiTest of the Computerized Dynamic Posturography (CPD) machine.

3.3 Hypothesis

- The main study hypothesize is that there will be a significant positive effect on the composite outcome between the measurements of the joint mobilization intervention group from the control group, leading to overall improvement in the static and dynamic balance
- A significant difference outcome of the ankle and foot mobilization on the measurement of the Sensory Organization Test regarding the Somatosensory, visual, and vestibular conditions.
- A significant difference outcome on static stability by COG control outcome measurement of the Limit of Stability test POST Ankle and Foot mobilizations.
- A significant difference outcome on the COG's latency to restore the center position measured on Motor Control Test POST Ankle and Foot mobilizations.

4 Methodology

The experimental study is to evaluate the effect of one-time ankle and foot joints mobilization according to Lewit on stability. The material used to assess the stability is the Computerized Dynamic Posturography (CDP). NeuroCom (Natus Medical Incorporate, Clackamas, Oregon USA). On CPD, 3 protocol measurements are done Sensory Organization Test (SOT) for visual, vestibular and somatosensory system; Motor Control Test (MCT); and The Limit of Stability test for Center of gravity (COG) stability. The experiment procedure was approved by The Ethics Committee of Faculty of Physical Education and Sport, Charles University in Prague. (In Appendix, the Application of Ethics Committee Approval).

4.1 Setting

The experiment analysis tests on CPD, were conducted in Laboratory of Kinesiology of Physiotherapy Department at The Faculty of Physical Education and Sport, Charles University in Prague.

The intervention of Ankle and Foot mobilization was done on the treatment table at the same Laboratory for the NeuroCom machine of Physiotherapy Department at The Faculty of Physical Education and Sport, Charles University in Prague.

4.2 Subjects

The study included deliberate choice of healthy young students. There were 46 probands who were randomly divided into two groups. Experimental consisted of 26 subjects out of which six subjects were excluded as they did not fit the criteria for the intervention group having joint restriction in the ankle and foot area. The other 20 subjects belong to control group finally 40 subjects were included in the study, 20 experimental subjects and 20 control subjects, refer Table 3

The control group included 20 participants (8 males; 12 female) aged between 20 to 28 years of age (Mean 23.55 years; SD 1.63 years). They range in height from 157 to 190 cm (Mean 171.30 cm; SD 10.31 cm). They range in weight from 50 kg to 79kg (Mean 63.45 kg; SD 9.60 kg).

The final intervention experimental group included 20 participants (12 males; 8 female) aged between 20 to 28 years of age (Mean 23.80 years; SD 2.27 years). They range in height from 160 cm to 190 cm (Mean 168.70 cm; SD 7.92 cm). They range in weight from 43 kg to 80kg (Mean 61.30 kg; SD 9.72kg).

The subjects were volunteers from college students at The Faculty of Physical Education and Sport, Charles University in Prague. The subjects signed informed consents forms for the experiment. (In Appendix, Consent Form).

	Control Group	**Intervention group**
Number of Subjects	20	20
Age	23.55 (1.63)	23.80 (2.27)
Height (cm)	171.30 (10.31)	168.70 (7.92)
Weight (kg)	63.45 (9.60)	61.30 (9.72)
BMI kg/m^2	21.47(1.07)	20.44 (5.06)

Table 3 Subjects Demography

4.3 Inclusion criteria

- Healthy Young Adults
- Age 20 to 30 years
- Both genders male and female.

4.4 Exclusion criteria

- Neurological disorders
- Motor system disorders
- Head & spinal cord injuries
- Sensory deficits
- Visual deficits
- Vestibular disorders
- Vasovagal syncope
- Recent (6 months) lower extremity injury / or any other kind of injury.
- On medication that influences postural stability or balance.
- Cardiac diseases
- Pulmonary diseases
- Middle and inner ear problems
- Metabolic syndromes
- Following athletic lifestyle.

4.5 Procedure

All the 40 participants, prior to the experiment were informed about the consent form and their signatures were taken for their participation in this study (In Appendix, Consent Form). The 40 participants were well informed about the procedure of the experiment and they were randomly divided into either control or intervention Experimental group, each group had 20 participants.

Demographic details of the subjects were collected (age, gender, height, weight and date of birth) and were entered in to the NeuroCom system.

The procedure consists of PRE-testing and POST- testing measurements of the Dynamic and static stability of each individual, for SOT, MCT and LOS; regardless of what group they belonged to, all 40 participants followed the PRE- and POST- testing protocol on Neurocom. Preparatory to the measurements for the Dynamic and static stability assessment on Neurocom, the subjects were given safety harness as shown in Figure 14, to proper fit wear, which were available in size small, medium and large and it was strapped to the overhead bar in NeuroCom machine in order to prevent any fall in case of losing stability or being unstable. NeuroCom Safety Harness Following, the subjects were asked to be barefoot without any socks and shoes to stand on the platform, arms at the sides, looking forward at the eye level to face visual display on the screen. This monitor will be switched off during the SOT and MCT assessment, but will be switched on for the LOS examination. Standard foot placement is required on the force platform.

Centering the subject's feet on the force plate, the medial malleolus of each foot should be centered directly over the enter horizontal 30 wide line on the force plate as shown in the Figure 15. The positioning of the lateral calcaneus is to S, M, or T line according to the height of the subject as instructed on the preparation screen as to the Table 4. If subjects move foot from the recommended position of the foot on the force plate, the trail is stopped, discarded and repeated after they are repositioned correctly again.

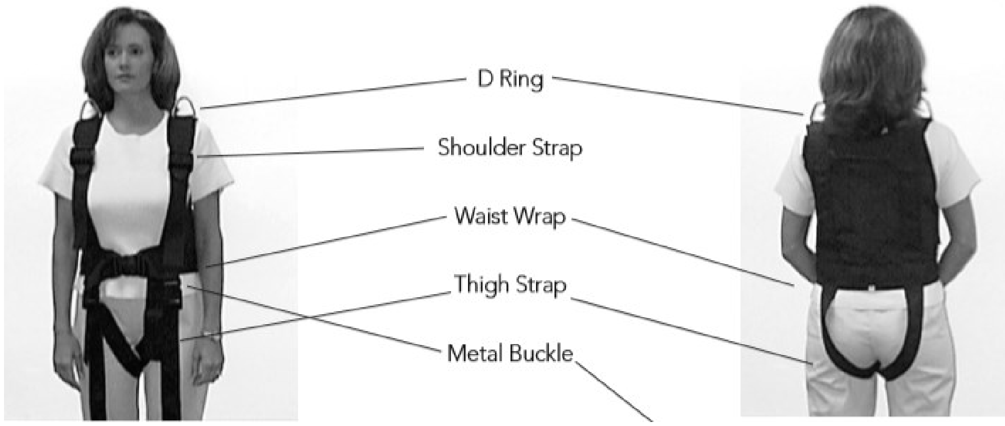


Figure 14 CDP Harness [17]

Table 4 According the the height placement of the foot on the Force Plate [17]

(S) Short	30-55 inches/76-140 cm
(M) Medium	56-65 inches/141-165 cm
(T) Tall	66-80 inches/166-203 cm

Figure 15 Force Plate [17]

Firstly, SOT assessment is done, all 6 conditions with three trials are done (18 in total), refer Table 1 The sensory ratios of different sensory systems involved during the SOT test are present in Table 5.

Second, the MCT assessment is done, two main conditions are evaluated with force platform translation movements, backwards and forward. Three level of magnitudes small, medium and large are done in the two conditions. Eyes are open and subject tries to keep stable posture without moving the feet.

Thirdly, the LOS assessment is followed, where the screen monitor is switched on. The subject is instructed to reach the given place and hold on to the position for 8 seconds, and then return to the starting position. Targets are highlighted clockwise during the measurements [6]. The eight directions are: forward (FW), backward (BW), right (R-T), left (L-T), forward-right (FWRT), forward-left (FWLT), backward-right (BWRT), and backward-left (BWLT) Figure 5.

All the three protocols were performed by all the 40 participants twice. After the pre- testing of Dynamic postural stability of SOT, MCT and LOS; the procedure of the study was continued according to the group the individual belonged.

The control group was tested again for the Dynamic and static postural stability after the 30 minutes' break.

In the experimental group after the initial testing, the individuals were set for joint play examination and mobilization. Then in 30 minutes they were again assessed for the Dynamic and static postural stability, on NeuroCom.

Table 5 Ratio of SOT Conditions [17]

Ratio	Comparison	Functional Relevance
Somatosensory (SOM)	Condition 2 Condition 1	Subjects ability to use input from the somatosensory systems to maintain stability .
Visual (VIS)	Condition 4 Condition 1	Subject's ability to use input from the visual system to maintain stability .
Vestibular (VEST)	Condition 5 Condition 1	Subject's ability to use input from the vestibular system to maintain stability.
Preference (PREF)	Condition 3+6 Condition 2+5	The degree to which a subject relies on the visual information to maintain stability even when the information is incorrect.

5 Results

5.1 Data Analysis

The evaluation of the PRE testing and POST testing of both the control group and the experiment group were recorded and calculated by the SMART Balance Master System (NeuroCom). All the outcome measures of each conditions trails were scored; for SOT condition Somatosensory (SOM), Visual (VIS), Vestibular (VEST); for MCT condition the Composite value; for LOS condition RT (Reaction time), MVL (Movement Velocity), DCL (Directional Control), EPE (Endpoint Excursion), MXE (Max Excursion); for each participant in Control and Experiment group. Descriptive statistics (standard deviations and mean) of demographic data and all the 3 conditions LOS, MCT, SOT outcomes were calculated using the Microsoft Excel.

5.2 Statistical Analysis

The effective evaluation of the experimental group from the PRE and POST value testing, as well same for the control group were statistically analyzed. The results of the Control group were then compared with the Experiment group to evaluate whether a significantly improvement was seen in the manipulated group or not. The P-values of each were calculated using the two sample t-test on the software RStudio. A p-value <0.05 considered as statistical significant.

5.3 Demographic data

All the 40 participants were healthy adults from the age 20 to 28 years old; 20 men and 20 women. The mean of the height of the experiment group is 168.70cm and the control group 171.3 cm; the weight mean of experiment group is 61.30kg and the control group 63.5 kg, with overall BMI mean of experiment group 20.44 kg/m^2 and control group is 21.5 kg/m^2 as shown in Table 6.

Table 6 Demography Data

Variables	**Control (n=20)**	**Experimental (n=20)**
Gender (%)		
Female	12 (60.0)	8 (40.0)
Male	8 (40.0)	12 (60.0)
BMI (kg/m^2)	21.47 ± 1.10	20.44 ± 5.06
Age (Years)	23.55 ± 1.67	23.80 ± 2.27

5.4 Sensory Organization Test

The condition Sensory Organization test consists of the following measurements, the somatosensory result (SOM), the visual result (VIS), the vestibular results (VEST), the preference outcome result (PREF) and the composite equilibrium result (COMP). All the six conditions of the SOT for each participant of both groups have three trials and the composite equilibrium is calculated at the end of the graph, as shown in the Figure 17 Condition and composite result.

The green columns show the actual result of each trial of the tested condition; whereas the grey columns show the minimum limit of the normal result; and the red columns show below normal result. The number on the green columns indicate the quality and the result of each measurement from zero to hundred, however, 0 means fall or loss of balance and on the other hand, 100 means optimal balance The Figure 16 Sensory analysis of SOT condition portrays the actual results of the participants in each sensory system, again the green columns shows the normal outcome of results, while the grey columns show the minimum results.

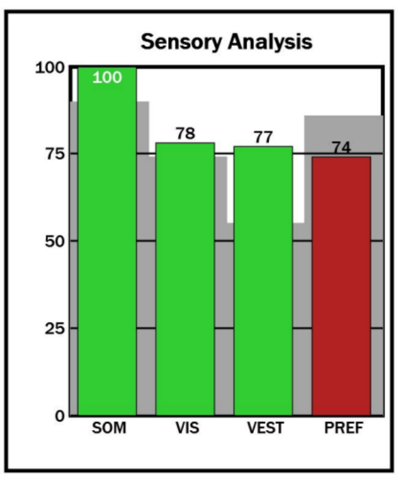


Figure 17 Conditions & Compoiste Graphic illustration example

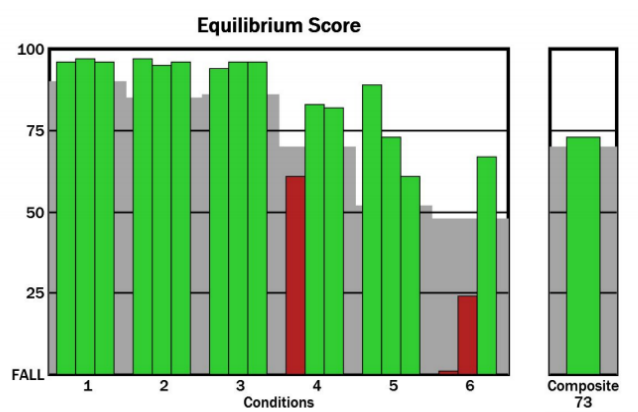


Figure 16 Sensory Analysis of SOT Condition example

5.4.1 Analytic comparing of SOT of PRE and POST values within Control group

The outcome measurement of PRE & POST within the control group showed no significant improvement with p-value > 0.05 in all Dynamic stability of SOT conditions as shown in Table 7 .

Table 7 SOT - Control Group PRE & POST P-values

CONDITIONS	MEAN PRE	MEAN POST	P- VALUE
SOM	0.980	0.982	0.75
VIS	0.926	0.935	0.68
VEST	0.769	0.759	0.70

5.4.2 Analytic comparing of SOT of PRE and POST values within Experimental group:

The outcome measurement of PRE & POST within the Experimental group showed no significant improvement with p-value > 0.05 in all Dynamic stability conditions as shown in Table 8.

Table 8 SOT- Experiment Group PRE & POST P-values

CONDITIONS	MEAN PRE	MEAN POST	P- VALUE
SOM	0.992	0.984	0.38
VIS	0.867	0.856	0.77
VEST	0.744	0.732	0.82

5.4.3 Comparing SOT in Experimental and Control group in PRE-experiment values and POST-experiment values:

The outcome measurement of PRE- experiment values in control and experiment groups, and POST- experiment values in control and experiment groups showed no significant differences in most of the conditions except for the Visual (VIS) condition in both PRE & POST values as shown in Table 9

Table 9 SOT PRE & POST P-values of Experimental Group Comparison with Control Group of SOT

CONDITIONS	Experiment PRE- mean	Control PRE- mean	P- VALUE
SOM	0.992	0.980	0.09
VIS	0.867	0.926	0.03
VEST	0.744	0.769	0.52
	Experiment POST - mean	**Control POST- mean**	**P- VALUE**
SOM	0.984	0.982	0.76
VIS	0.856	0.935	0.02
VEST	0.732	0.759	0.49

5.4.4 Differences between control & experiment group in SOT

The outcome measurement of SOT indicates no significant difference when comparing the difference between the Control and experiment group prior the intervention. Where the $p > 0.05$ in all conditions; visual (VIS), vestibular (VES) and somatosensory (SOM) . As shown in Table 10 .

Table 10 SOT Difference between Control & Experiment Groups.

CONDITIONS	MEAN EXPERIMENT	MEAN CONTROL	P- VALUE
SOM	0.007	0.002	0.31
VIS	0.01	0.009	0.50
VEST	0.01	0.009	0.93

In Figure 18 it shows graphical presentation of individuals from each groups when compared from before and after intervention of an individual. Although there is no significant difference of the experiment group from the control group, the green represent the experiment group is demonstrating a vast diversity in stability measurement done in CPD scattered from the normalized value, indicates that individuals had different reaction.

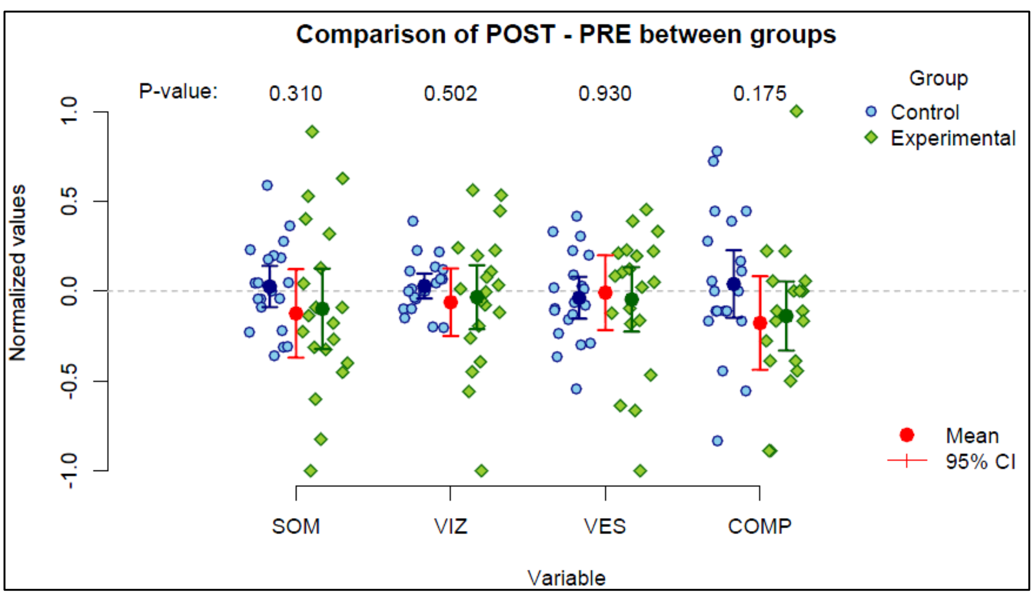
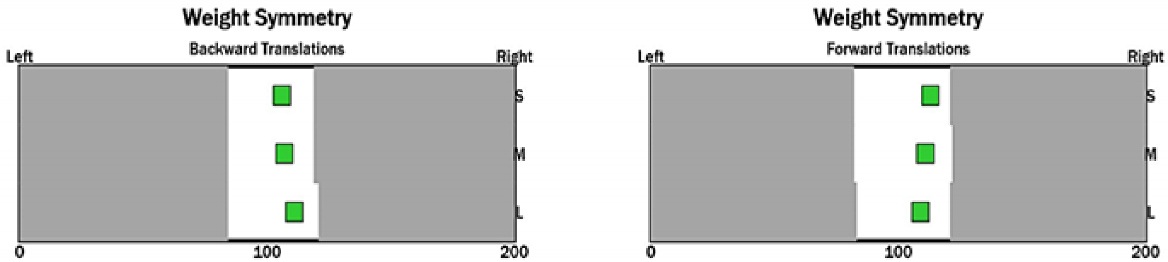


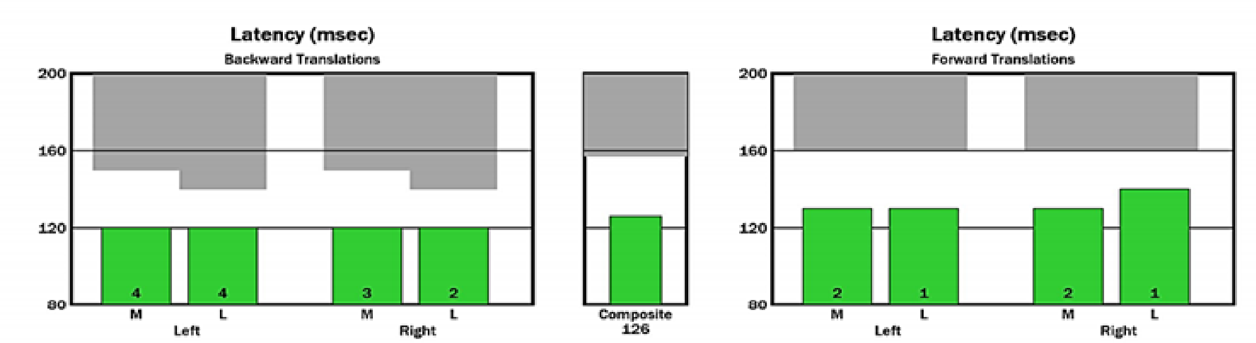
Figure 18 Comparison of SOT Between Experiment & Control Groups

5.5 Motor Control Test

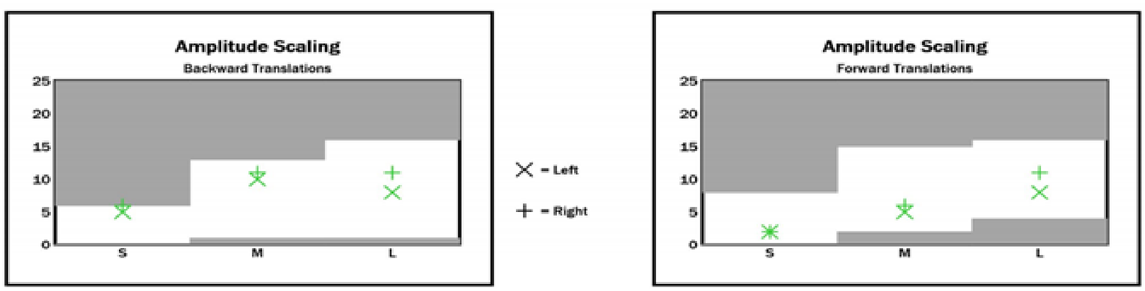
The Motor Control Test parameters measures the Composite (COMP) values according to the Latency period per millisecond, along with the Weight Symmetry, the distribution of weight in both lower extremities of the individual prior to the translation movements backward and forward with the amplitudes ranging from small, medium and large. The placement of feet while standing on the force plate as shown in the Figure 15, is indicated according to the symmetry of weight distribution on both right and left legs of an individual's weight and height. The weight symmetry of the weight distribution, on the force plate of both left and right legs, along with the Latency period prior to backward and forward translation movements of the force plate according to the amplitudes, all illustrated in Figure 19 The data are compared to normative dataset with green indicating the normal stability and grey being below the normal.



A. Weight Symmetry Of MCT, example



B. Latency of MCT, Example



C. Amplitude Scaling of MCT, Example.

Figure 19 CDP representation of the MCT result.

5.5.1 Analytic comparing of MCT of PRE and POST values within Control group:

The outcome measurement of PRE & POST within the control group showed no significant improvement with p-value > 0.05 in the Dynamic stability condition regarding the motor control test (MCT) as shown in Table 11.

Table 11 MCT Control Group PRE & POST P-values.

	MEAN PRE	MEAN POST	P-VALUE
COMP	127.55	128.25	0.85

5.5.2 Analytic comparing of MCT of PRE and POST values within Experimental group:

The outcome measurement of PRE & POST within the experimental group showed no significant improvement with p-value > 0.05 in the Dynamic stability condition regarding the motor control test (MCT) as shown in Table 12.

Table 12 MCT Experiment Group PRE & POST P-values

	MEAN PRE	MEAN POST	P-VALUE
COMP	125.45	122.95	0.60

5.5.3 Comparing MCT in Experimental and Control group in PRE-experiment values and POST-experiment values:

The outcome measurement of PRE- experiment values in control and experiment groups, and POST- experiment values in control and experiment groups showed no significant differences in the COMP as shown in Table 13.

Table 13 MCT P-values of the PRE & POST Comparison of the Experiment and Control Group

	Experiment PRE- mean	**Control PRE- mean**	**P-VALUE**
COMP	125.45	127.55	0.62
	Experiment POST - mean	**Control POST -mean**	**P-VALUE**
COMP	122.95	128.25	0.23

5.5.4 Difference between the Experiment & Control of MCT

The two sample t test with <0.05 p-value was done to calculate the difference between the control and experiment group composite (COMP) values based on the latency reaction in milliseconds.

There is no significant difference of the COMP value based on the Latency period of the difference between the Control and Experiment Group as shown in Table 14 and Figure 20 MCT COMP P-value Difference Between Control & Experiment Group where the p-value is > 0.05.

	Mean experiment	Mean control	P-value
COMP	2.50	0.70	0.17

Table 14 MCT P-value Difference between the Experiment & Control Groups

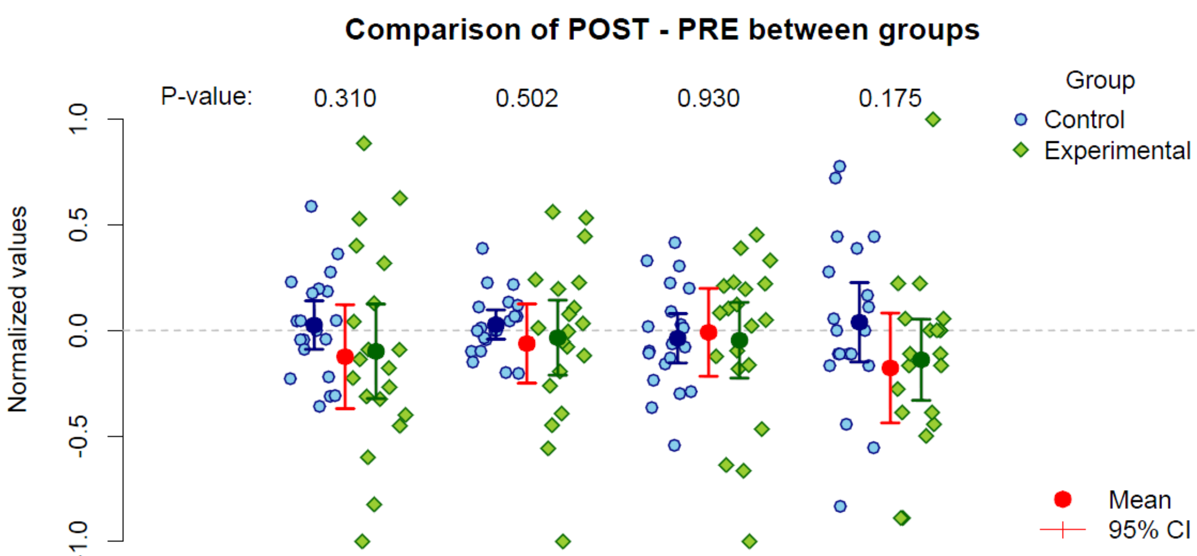


Figure 20 MCT COMP P-value Difference Between Control & Experiment Group

5.6 Limit of stability

The LOS condition measures the RT (Reaction time) in seconds, MVL (Movement Velocity), DCL (Directional Control), EPE (Endpoint Excursion), MXE (Max Excursion), of an individual movement in the following eight directions, forward, diagonally right forward, right, diagonally to left, backwards, diagonally left backwards, left, diagonally left forward and the overall average weight on the force plate as shown on the Figure 12. The Figure 21 shows the resulting representation of an individual's transition form during the LOS testing. Figure 22, graphic representation of the LOS conditions outcome; the green columns show the actual result of each trial of the tested condition; whereas the grey columns show the minimum limit of the normal result; and the red columns shows below normal result.

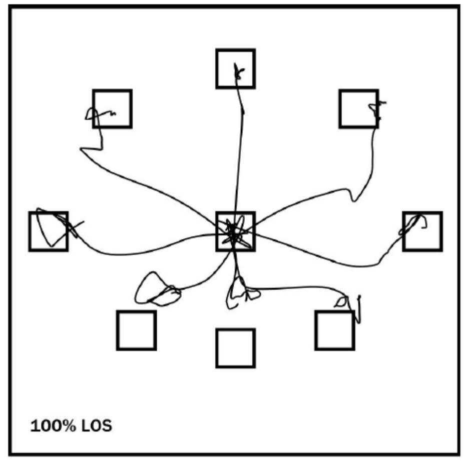


Figure 21 Limit of Stability Transition Representation

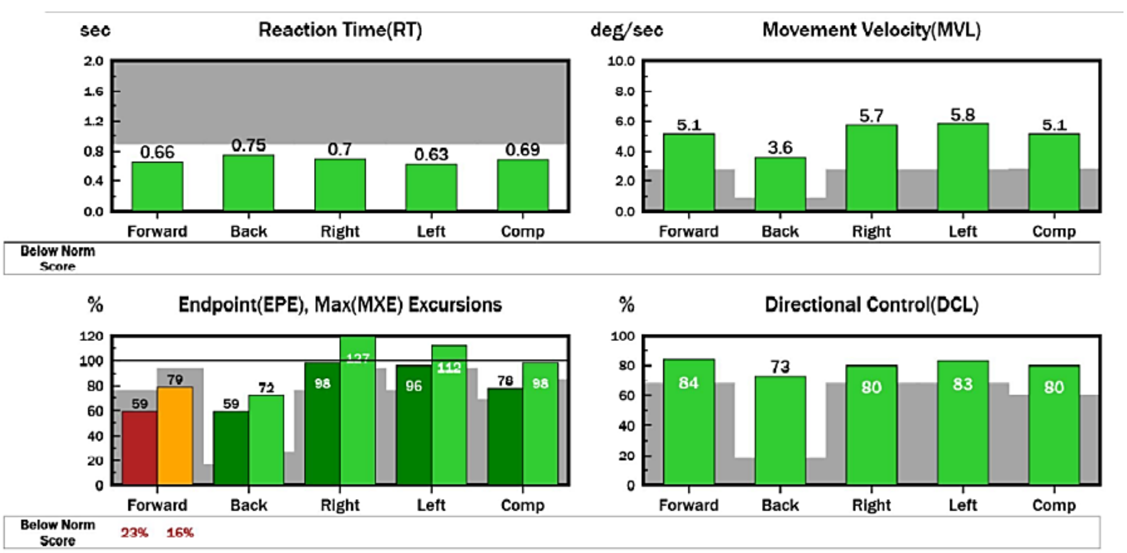


Figure 22 LOS Conditions example

5.6.1 Analytic comparing of LOS of PRE and POST values within Control group:

The outcome measurement of PRE & POST within the control group showed no significant improvement with p-value > 0.05 in all the Static stability conditions regarding the limit of stability test (LOS) as shown in Table 15.

Table 15 LOS Control group PRE & POST values

Mean P-value of control group PRE & POST				
RT	**MVL**	**DCL**	**EPE**	**MXE**
0.40	0.26	0.89	0.20	0.53

5.6.2 Analytic comparing of LOS of PRE and POST values within Experimental group:

The outcome measurement of PRE & POST within the experimental group showed no significant difference with p-value > 0.05 in all the Static stability conditions, except for the end point excursion which showed significant difference as shown in Table 16.

Table 16 LOS Experimental group PRE & POST values

Mean P-value of Experimental group PRE & POST				
RT	**MVL**	**DCL**	**EPE**	**MXE**
0.46	0.80	0.62	0.001	0.06

5.6.3 Comparing LOS in Experimental and Control group in PRE-experiment values and POST-experiment values:

The outcome measurement shows significant difference of the movement directional control (DCL) in both the PRE & POST- experiment values in control and experiment groups, as shown in Table 17.

Table 17 Comparing Experimental and Control group in PRE-experiment and POST- experiment values in LOS

Mean P-value of Experimental and Control group in PRE-experiment values				
RT	**MVL**	**DCL**	**EPE**	**MXE**
0.39	0.71	0.02	0.06	0.19
Mean P-value of Experimental and Control group in POST-experiment values				
RT	**MVL**	**DCL**	**EPE**	**MXE**
0.50	0.39	0.006	0.41	0.72

5.6.4 Difference between Control & Experiment Group of LOS

The two sample t-test of significant P-value defines to be <0.05 is set for evaluation. Table 18 displays the LOS conditions comparisons between the Experiment group and the Control group. Reliable significant difference of P-value has been aggregated at the Reaction Time of 0.03, and for End Point Excursion 0.01 P-value. However, the Directional Control, Movement Velocity and Maximum Excursion have no significant P-value. However, the positive end-results of P-value of the LOS conditions RT and EPE, surmises that the Joint Mobilization intervention of the foot and ankle, has affected the individuals to surpass towards stabilizing their stability by focusing on the COG's reaction of the movement's swiftness to the end reach of the intent. In Figure 23 a graphical representation of the p-value comparison between experimental and control group

Table 18 P-values of differences between experiment and control group

LOS	RT	P-value	MVL	P-value	DCL	P-value	EPE	P-value	MXE	P-value
Mean experiment	0.05	0.03	0.13	0.08	1.50	0.57	9.90	0.01	4.26	0.85
Mean control	0.04		0.38		0.21		2.99		0.90	

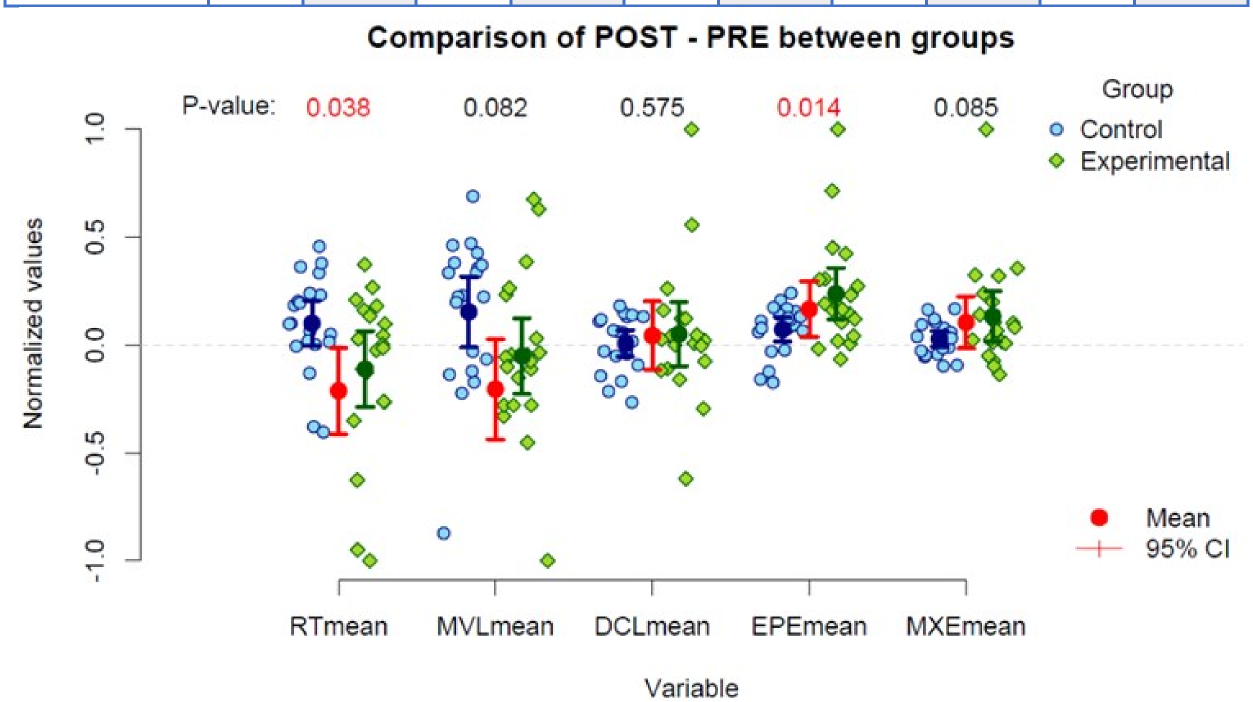


Figure 23 Comparison of difrencess between experiment and control group

6 Discussion

To our knowledge, this is the first dose-response study of Lewit ankle and foot joint mobilization and stability performance in healthy adults. The preliminary study evaluated the effect of one-time ankle and foot mobilization according to Lewit as an intervention model, on the stability of healthy adults with restricted joint play. The ankle joint has a special importance for the stability evaluation, because the ankle was the key joint for the transfer of the body weight to the ground and postural stability and compared those results to control group who hadn't been through any exercise or activity that could influence the stability in the period of conducting the study. When analyzed on the Computerized Dynamic Posturography (CPD) machine evaluation of the NeuroCom EquiTest®. This study found that Joint mobilization of ankle and foot joint mobilization according to Lewit significantly improved the stability on certain condition.

For this study, our clinical experience and analysis of previous studies led us to propose and intermediate dose of one-time intervention, the participants of the experiment group had to undergo and approximately 30 minutes of examination and treatment of restricted joint play following PRE measurement on the CDP, unlike the control group who had only 30 minutes break without any intervention. The reason why the subjects had 30 minutes' break is because in proprioception, fatigue plays an important role. As believed by Dr. Janda, fatigue impedes feedback from the muscle spindle, thus affecting proprioception and posture. After fatigue muscle mechanoreceptors are responsible for decreased proprioception [32]. Different studies claimed that muscle fatigue affects proprioception in the shoulder and the trunk extensors [72], others have shown that little effect of the fatigue on proprioception in the knee and ankle [5, 46].

Furthermore, when the experiment group is generally compared with control, and the main finding was one- time joint mobilization of ankle and foot has an effect on stability. There has been significant difference in the LOS at the reaction time (RT) and the end point excursion (EPE).

That concludes there has been significant difference in LOS test. That can't be said for the two other tests conducted in the study (MCT) and (SOT) where there was no significant difference between the control and experiment.

In previous studies, evaluated the importance of ankle mobility in stability and locomotion performance and mechanical effects. Stability improvement and effectiveness is linked to the improved ankle ROM [60]. Other studies investigated the connection between ankle ROM with Dynamic static stability [25, 69].

Based on these reports, we assumed that functional stability might be affected by increased and physiological joint play, and our present result suggest that optimal joint play appears to be an important factor affecting stability in selected measures. Variety of elements that has direct impact on Dynamic and static stability such as sensory information, feedback or feed-forward, personal experience (memory) and afferent inputs from the muscles and joints, and the ankle and foot contribute on the granting the segmental adjustment by stimulating the proprioceptors. many strategies to improve stability dysfunction, a major risk factor for falls, have included specific stability training strategies, strength training, walking, Tai Chi, and multidimensional exercises. Few interventions, however, have showed consistent positive outcomes in stability [31, 38, 56].

Indeed, it is necessary to consider that, first, the foot pathology associated with aging are common. Second, that stability impairment increase with age and can lead to serious consequences. And third, that the association between these factors has been established not only experimentally [37], but also with theories that elaborate the influence of ankle strategies on postural control, and the importance of foot proprioception and sensomotor functioning in stability, as well as the need of physiological arthokinematics of the foot as the base of support of the human body.

This study has limitations that need to be acknowledged. First, there was no specific tool or device used to assess the restriction of joint play or ROM of ankle and foot joint, the evaluation of joint play whether there was restriction or not was according to the physiotherapist sensation and experience.

Second, the participants were examined after the PRE examination on the CDP, because there might be an influence of joint play during the examination. Third the study was conducted in healthy individuals without a history of recent injury or any pathology or impairment that could have direct influence in stability, regardless the participant's history of exposing to stability – challenging activities in the past, such as certain type of sport or if the participants used the tram or how many steps he or she took on the day of the experiment. Fourth, there was five different segment where the joint play treatment was done and it cannot be realized which joint exactly had the most positive effect.

The experimental study of the joint mobilization intervention comprehends that most of the participant had limited joint play in the first distal metatarsophalangeal joint. 20 participants out of 26 were found to have restricted joint play on at least one joint in the ankle or foot (the remaining six were excluded).

Similar study can be done on specific diagnosis affecting the visual or the vestibular system as a recommendation in clinical practice in management of risk falls, cerebral palsy and many other diagnoses affecting the Dynamic or Static stability. As this study has positive effect on healthy individuals it is expected to have positive results on individuals with specific pathology regarding stability.

Most of studies related to ankle joint and foot are linked or focused on the lateral ankle sprain with marginalization of the reason why the lateral sprain could happen.

Nevertheless, the one-time session of joint mobilization did not show substantial improvement on stability. Therefore, combined joint mobilization with other stability exercises and kinesiological and medical assessment in multi- sessions is suggested for preferable results of visual, proprioceptive and vestibular components to maintain postural stability.

The study had hypothetical questions set to relate regarding the objectivity of this experimental study, which is to evaluated whether one-time Joint mobilization of ankle and foot effects the stability of healthy young individuals.

To begin with, the main study hypothesis is that there will be a significant positive effect on the composite outcome between the measurement of the joint mobilization intervention group from the control group, leading to overall improvement in the static and dynamic stability of the individuals after the interventions. The hypothesis is accepted. A similar study supports the criteria of the hypothesis, where ankle and foot mobilization helps in improving the functional balance. The study was conducted on thirty-three healthy elderly adults who were randomly divided into two groups; the mobilization and control groups, the intervention used in with the mobilization group was traction, anterior and posterior gliding of the talocrural joint, whereas no intervention was mad in the control group, the tests used in the study were One Leg Balance test, Timed Up and Go and Lateral reach tests, which both tests showed significant difference concluding that mobilization of the ankle joint of elderly adults improves the functional balance [14].

Another hypothesis of the study is a significant difference outcome on the COG's latency to restore the center position measured on Motor Control Test POST Ankle and Foot mobilizations. Due to the statistical results of MCT, of COG recovery latency measure, which showed no significant difference when comparing the experimental and control group PRE and POST the intervention of ankle and foot joints mobilization on dynamic stability. It is suggested that there is almost no direct effect of one-time intervention of ankle and foot joint mobilization on the motor response of COG latency recovery, in these subjects. Therefore, the hypothesis is rejected. Further, studies focused on the muscles latency and stability and utilized specific exercise program. One of the studies investigated the effects of a 4-week wobble board training program on the onset of muscle activity and stability. The study involved 19 male subjects with functional ankle instability who were assigned to two groups control and experiment. The study resulted that the experimental group showed significant decrease in muscle onset latency, and a significant improvement in perception of their functional stability. That suggests muscle onset latency contribute on stability and the recovery time to the optimal COG in milliseconds. Additional studies are needed to investigate the linkage between the joint restrictions, muscle activity and COG recovery time to verify which variable is most effective in stability improvement [16].

Further, third hypothesis of the study is A significant difference outcome of the ankle and foot mobilization on the measurement of the Sensory Organization Test regarding the Somatosensory, visual, and vestibular conditions. The hypothesis is accepted regarding to parameter VIS of SOT.

In the outcome measure results of the SOT, there was significant difference in the (VIS) when comparing the POST of experiment mean values in both groups. That suggests that there is a positive effect of ankle and foot joint mobilization in the visual component of the test. In other studies, it is suggested that repetitive administrations of the sensory organization test have a learning affect in healthy young adults using the SMART Equitest 5 times over 2-week period, which showed significant increase in the composite and equilibrium scores [75].

The final hypothesis of this study is a significant difference outcome on static stability by COG control outcome measurement of the Limit of Stability test POST Ankle and Foot mobilizations. The result of one-time intervention of ankle and foot joint mobilization indicates that there is a positive significant difference regarding LOS test in the RT with P- value = 0.03 and EPE with P- value = 0.01, when comparing the difference between the experimental and control group. The hypothesis is accepted in this study regarding the parameter RT and EPE of the LOS. Further studies where forty students in good health participated in a study that measures the immediate effect of ankle joint mobilization with movement according to Mulligan on postural control which resulted in significant improvement in LOS measures. Statistical analyses showed that Mulligan's MWM provided significant improvement in the LOS in forward–right direction concluded that the application of Mulligan's MWM on ankle joint might be beneficial to improve postural control in forward right direction in individuals with healthy ankles [67].

7 Conclusion

To conclude, a one-time passive joint mobilization of ankle and foot according to Lewit intervention resulted in significant improvement on the static stability in the limit of stability test in reaction time and end point excursion in healthy adults measured by CDP NeuroCom. The result supports the efficacy of these selected techniques in demonstrating short term improvement in static stability specifically and stability in general on young healthy subjects. on the other hand, the dynamic stability tests did not show a significant improvement as in the SOT test which showed positive results within the both groups separately which is believed to be due to the repetitive learning as mentioned in previous studies [75]. The Dynamic stability test in MCT did not show significant improvement due to several factors, one-time intervention is believed to be one of them, comparable studies focused in the dynamic stability and concluded that A progressive single-leg dynamic balance exercise program can improve dynamic stability very rapidly [51], and other studies concluded that core stability exercises in addition to conventional therapy improves trunk control, dynamic sitting balance [9].

Another mobilization technique had been used to improve the balance in different diagnosis [30] evaluated the effect of Mulligan's mobilization technique on balance in patient with stroke; the study resulted in significant improvement in the static balance measures. It concludes that mobilizations associated with ankle joint has positive effect on the static stability.

It was a substantial learning experience to where i was able to apply my knowledge I gained through the years at the faculty and demonstrated it in this work, examining and treating multiple different individuals certainly expand my understanding of different end feels and joint play restrictions as well as having the opportunity to sense the difference between each individual.

Further studies with more patients with medical diagnosis that has a direct effect on balance and Dynamic or static stability are needed in order to verify the results and to clarify the approach intensions.

8 Reference

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9 Appendix

9.1 Application Approval by the FTVS UK Ethics Committee

CHARLES UNIVERSITY
FACULTY OF PHYSICAL EDUCATION AND SPORT
José Martího 31, 162 52 Prague 6-Veleslavín

Application for Approval by UK FTVS Ethics Committee

of a research project, thesis, dissertation or seminar work involving human subjects

The title of a project: Effect of Ankle and Foot joints mobilization on balance improvement, analyzed by Computerized Dynamic Posturography
Project form: Master thesis
Period of realization of the project: June 2019 to November 2019
Applicant: Bc. Salem Baqhoum, UK FTVS – Physiotherapy
Main researcher: : Bc. Salem Baqhoum, UK FTVS – Physiotherapy
Workplace: Fakulta tělesné výchovy a sportu Univerzity Karlovy - Kineziologická laboratoř
Supervisor: : PhDr. Tereza Nováková, Ph.D

Project description: Effect of Ankle and Foot joints mobilization on balance improvement, analyzed by Computerized Dynamic Posturography. The aim of the study is find out if joint mobilization of ankle and foot joints will improve the balance using the by Computerized Dynamic Posturography (neurocom) as measurement tool . The methods that are used from the research are based on the knowledge which was obtained during the study of physiotherapy program at UK FTVS

Characteristics of participants in the research: All the participants are between the ages of 20 to 30 years, with no specific diagnose. All the ~~46~~ participants will be divide into 2 groups. The control group and the experimental group, each group will have their balance tested twice on the CPD (neurocom). The control group will be measured first, and after 20 minutes they will measured again without any examination or therapeutic intervention . The experimental group will be measured twice, first before the examination of joint play and the therapy, then the examination of joint play will be done and any restricted joints will be noted and treated, later participants will be measured again for possible improvement. Joint play examination and therapy will take about 20 minutes. Balance analyses will take about 20 minutes. The project will not include persons with severe lower extremity injuries (eg, fractures, recurrent deformation last year), persons with sensory disabilities, people with cerebral palsy, acute illness or injury and convalescence after illness or injury affecting research results

Ensuring safety within the research: No invasive methods will be used as none are required. Risks of the research will not be higher than the commonly anticipated risks for this type of research.
The research will be conducted under adequate conditions for treatment and examination under the supervision of a physiotherapist and under the guidance of a physiotherapist and also the head of the thesis PhDr. Tereza Nováková Ph.D. at the Department of Physiotherapy UK FTVS.

Ethical aspects of the research: All the data used collected will be used only for my thesis and will not be published anywhere else other than the university premises. The gained data will be processed and safely retained in an anonymised form and published in a Master thesis, possibly also in journals, monographs, and presented at conferences, possibly also used in further research at UK FTVS. After the anonymization the personal data will be deleted. Anonymisation of persons on the photographs will be done by blurring their faces or parts of the body or characteristics that could lead to identification of the person. Non-anonymised photographs will be deleted after the end of the research. I shall ensure to the maximum extent possible that the research data will not be misused.

Informed Consent: attached

It is the duty of **all participants of the research team** to protect life, health, dignity, integrity, the right to self-determination, privacy and protection of the personal data of all research subjects, and to undertake all possible precautions. Responsibility for the protection of all research subjects lies on the researcher(s) and not on the research subjects themselves, even if they gave their consent to participation in the research. All participants of the research team must take into consideration ethical, legal and regulative norms and standards of research involving human subjects applicable not only in the Czech Republic but also internationally.
I confirm that this project description corresponds to the plan of the project and, in case of any change, especially of the methods used in the project, I will inform the UK FTVS Ethics Committee, which may require a re-submission of the application form.

In Prague, 12.6.2019 Applicant's signature: [signature]

Approval of UK FTVS Ethics Committee

The Committee: Chair: doc. PhDr. Irena Parry Martínková, Ph.D.
Members: prof. PhDr. Pavel Slepička, DrSc.
doc. MUDr. Jan Heller, CSc.
PhDr. Pavel Hráský, Ph.D.
Mgr. Eva Prokešová, Ph.D.
MUDr. Simona Majorová

The research project was approved by UK FTVS Ethics Committee under the registration number: 153/2019
Date of approval: 13.6.2019

UK FTVS Ethics Committee reviewed the submitted research project and **found no contradictions** with valid principles, regulations and international guidelines for carrying out research involving human subjects.

The applicant has met the necessary requirements for receiving approval of UK FTVS Ethics Committee.

UNIVERZITA KARLOVA
Fakulta tělesné výchovy a sportu
José Martího 31, 162 52, Praha 6
– 20 –
Stamp of UK FTVS

[signature]
Signature of the Chair of UK FTVS Ethics Committee

9.2 Consent Form

INFORMOVANÝ SOUHLAS

Vážený pane, vážená paní,
v souladu se Všeobecnou deklarací lidských práv, zákonem č. 101/2000 Sb., o ochraně osobních údajů a o změně některých zákonů, ve znění pozdějších předpisů 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 v rámci diplomové práce s názvem Vliv aplikace jedné terapeutické metody tzv. Kloubního mobilizačního účinku na posturální rovnováhu měřené na Neurocom SMART Equitest prováděném na Katedře fyzioterapie UK FTVS.

Cílem práce je zpracovat teoretické informace o posturální stabilitě, metodách jejího měření a možnostech ovlivnění posturální stability z pohledu fyzioterapeuta, především prostřednictvím mobilizace kloubů dolních končetin.
Kontroly před léčbou a po léčbě budou prováděny neinvazivně během přibližně půl hodiny za použití standardu Neurocom SMART Equitest. Samotná terapie se bude skládat z jednorázové individuální půlhodinové terapie poskytované fyzioterapeutem (**Bc. Salem Baqhoum**). Cvičení zahrnuje pasivní terapii, tj. Lewitt společnou mobilizační techniku. Žádná z použitých metod by neměla způsobit bolest; osoby se sníženou stabilitou mohou být vystaveny zvýšenému riziku pádu při používání labilních zařízení. Fyzioterapeut však povede terapeutickou jednotku, aby se vyhnul nehodám. Nebudou použity žádné invazivní metody. Budu používat pouze postupy, které jsem se naučil během svých fyzioterapeutických studií. Výzkum bude probíhat za adekvátních podmínek pro léčbu a vyšetření pod dohledem fyzioterapeuta a pod vedením fyzioterapeuta a také vedoucí diplomové práce **PhDr. Tereza Nováková, Ph.D**. na katedře fyzioterapie UK FTVS. Budete měřeni neinvazivní metodou na Neurocom SMART Equitest a experimentální skupina bude také podrobena neinvazivní terapeutické společné mobilizační jednotce. Léčebná jednotka bude probíhat individuálně pod mým vedením a její přesný obsah bude konzultován a schválen školitelem. Projekt nebude zahrnovat osoby se závažným poraněním dolních končetin (např. Zlomeniny, rekurentní deformace v loňském roce), osoby se smyslovým postižením, osoby s dětskou mozkovou obrnou, akutním onemocněním nebo poraněním a v rekonvalescence po nemoci nebo zranění ovlivňující výsledky výzkumu. Vaše zařazení do projektu na základě kontraindikace bude projednáno se školitelem **PhDr. Tereza Nováková Ph.D**. Rizika prováděného výzkumu nebudou vyšší než obvykle očekávaná testovací rizika tohoto typu výzkumu. Vaše účast v projektu je dobrovolná a nebude finančně ohodnocená.
Získaná data budou zpracovávána a bezpečně uchována v anonymní podobě a publikována v diplomové práci, případně v odborných časopisech, monografiích a prezentována na konferencích, případně budou využita při další výzkumné práci na UK FTVS. Po anonymizaci budou osobní data smazána.
Anonymizace osob na fotografiích bude provedena začerněním/rozmazáním obličejů či částí těla, znaků, které by mohly vést k identifikaci jedince. Neanonymizované fotografie budou bezpečně uchovány na heslem zajištěném počítači a po ukončení výzkumu budou smazány.
V maximální možné míře zabezpečím, aby získaná data nebyla zneužita.

Jméno a příjmení předkladatele projektu a hlavního řešitele **Bc. Salem Baqhoum** Podpis:
Jméno a příjmení osoby, která provedla poučení .... Podpis:........................

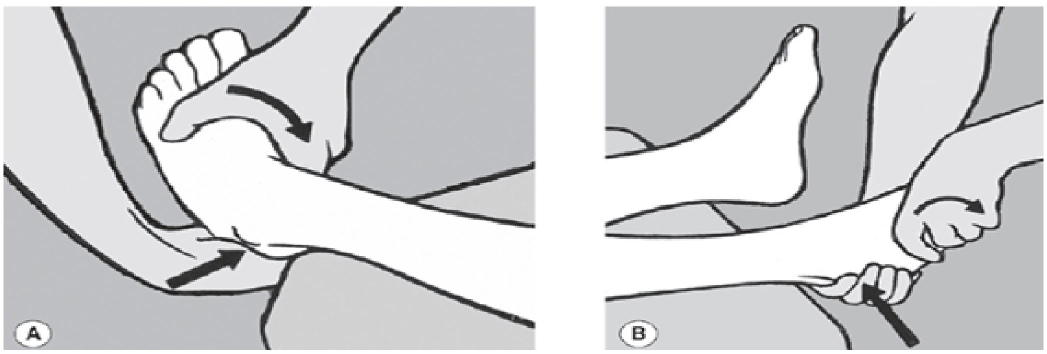
Prohlašuji a svým níže uvedeným vlastnoručním podpisem potvrzuji, že dobrovolně souhlasím se svojí účastí ve výše uvedeném projektu a že jsem měl(a) možnost si řádně a v dostatečném čase zvážit všechny relevantní informace o výzkumu, zeptat se na vše podstatné týkající se mé účasti ve výzkumu a že jsem dostal(a) jasné a srozumitelné odpovědi na své dotazy. 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.

Místo, datum ....
Jméno a příjmení účastníka .... Podpis: ....

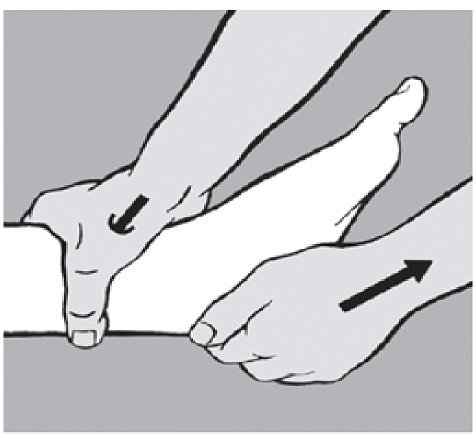
9.3 Joint mobilization illustration according to Lewit

1.Fan-wise spreading of metatarsal

2.Mobilization of Lisfranc's and Chopart's joints by moving the distal arculating bones dorsally



3.Mobilisation oc calcanus against the talus and navicular by applying traction
(A) Medially (B) Laterally



4.Gapping the subtalar joint by pulling the heel

5.Mobilization of the talocrural joint by springing the lower leg against the stablized foot

Figure 24 Ankle & foot mobilization according to Lewit [59]

9.4 Abbreviation

AP - Anterior Posterior

CDP- Computerized Dynamic Posturography

COG- Center of gravity

COMP – Composite

DCL - Directional Control

EPE – End Point Excursion

FTVS UK - Fakulta tělesné výchovy a sportu Univerzita Karlova

Kg – Kilogram

LOS- Limits of Stability

ms- milleseconds

MVL - Movement Velocity

MWM – Mobilization with Movement

MXE - Max Excursion

PREF- Preference

ROM – Range of Motion

RT - Reaction time

SOM- Somatosensory

SOT- Sensory Organization Test

VEST-Vestibular

VIS –Visual

9.5 Figure Content

9.6 Table Content