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Ankle Kinematic Differences During Static Single Limb Stance: Using Two Levels of Isokinetic Balance Board With and Without a Mulligan Mobilization Belt

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ANKLE KINEMATIC DIFFERENCES DURING STATIC SINGLE LIMB STANCE: USING TWO LEVELS OF ISOKINETIC BALANCE BOARD WITH AND WITHOUT A MULLIGAN MOBILIZATION BELT

BY

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A Thesis submitted to the
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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Alahmari, Sami titled "Ankle Kinematic Differences during Static Single Limb Stance: Using Two Levels of Isokinetic Balance Board with and without a Mulligan Mobilization Belt." I have examined the final copy of this thesis for form and content and recommend that it be accepted in fulfillment of the requirements for the degree of Master of Science with a major in Movement Science with a specialization in Sport Injury and Biomechanics.

Dr. Claire Egret, Thesis Committee Chair

We, members of the thesis committee, have examined this thesis and recommend its acceptance:

Accepted:

Chair, Department of Sport and Exercise Sciences

Accepted:

Dean, School of Human Performance and

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Barry University

ABSTRACT

Ankle Kinematic Differences during Static Single Limb Stance: Using Two Levels of Isokinetic Balance Board with and without a Mulligan Mobilization Belt

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Thesis Committee Chair: Dr. Claire Egret

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The ankle complex comprises three articulations or joints (talocrural, subtalar, and distal tibiofibular joints) work in concert to allow coordinated rear-foot motion. The talocrural joint receives ligamentous support from a joint capsule and four ligaments. Injuries to the lateral ligaments of the ankle complex are common incurred by athletes, leading to ankle joint instability. Balance training programs and modalities, such as balance boards, are recommended to maintain stable ankles. This study was designed to identify whether balance board level and holding Mulligan mobilization belt present differential indicator for individuals with healthy ankles during single limb stance (SLS) in order to examine the effectiveness of introducing the belt in any balance training progression. Forty (40) healthy male and female adults (age M= 28.2500; SD= 6.79649) were recruited from in and out Barry University. The balance board that was used is Isokinetic Balance Board (IKBB) with two levels. The object that was held is Mulligan mobilization belt. A seven-camera 3D motion analysis system VICON, using a lower body marker system recorded the kinematic SLS trials for analysis. The participants performed a total of 18 randomized

SLS trials for all conditions. A two-way repeated measures MANOVA was calculated to understand if there was an interaction between the two factors (SLS condition & level) on the dependent variables with a significance level of $p \leq 0.05$. Significant main effect was found (Lambda (4, 36) = .012; $p \leq 0.05$) between subjects in SLS condition (no belt & belt). Also, significant main effect was found (Lambda (8, 150) = .001; $p \leq 0.05$) within subjects in SLS level (normal, level one IKBB, and level two IKBB). Significant interaction effect was found (Lambda (8, 150) = .003; $p \leq 0.05$) within subjects in both dorsiflexion and abduction between SLS condition (no belt & belt/belt) and level (level normal & level one IKBB/level normal & level two IKBB). These findings suggest that researchers can conclude that the SLS level and introduction of the belt had an effective impact in the process of balance training or rehabilitating progression. Beginner IKBB users could use this training device for balance practice under close supervision but should not expect to see increase ankle joint stability or proprioception benefits until the IKBB can be used independently or with the introduction of the belt. Further investigation is needed to determine if experience level or a different form of balance exercise will affect lower body kinematic deviations on an IKBB.

CHAPTER 1

INTRODUCTION

The ankle joint and foot make up a complex anatomical structure consisting of 26 irregularly shaped bones, 30 synovial joints, more than 100 ligaments, and 30 muscles acting on the segments. All of these joints must interact harmoniously and in combination to achieve a smooth motion (Oatis, 2009). The ankle complex comprises three articulations: the talocrural joint, the subtalar joint, and the distal tibiofibular syndesmosis. These three joints work in concert to allow coordinated movement of the rear foot (Hertel, 2002; Oatis, 2009). Rear foot motion is often defined as occurring in the cardinal planes as follows: sagittal-plane motion (plantar flexion-dorsiflexion), frontal-plane motion (inversion-eversion), and transverse-plane motion (internal rotation-external rotation) (Freeman, 1965; Hertel, 2002).

Moreover, both ankle and foot support the weight of the body in both standing and locomotion (Oatis, 2009). When the ankle complex is fully loaded, the articular

Surfaces are the primary stabilizers against excessive talar rotation and translation (Hertel, 2002; Renstrom & Konradsen, 1997). In the closed kinetic chain, pronation consists of plantar flexion, eversion, and external rotation, while supination consists of dorsiflexion, inversion, and internal rotation. Closed kinetic chain dorsiflexion occurs when the tibia moves anteriorly on the fixed talus during weight bearing (Hertel, 2002). The three major contributors to stability of the ankle joints are (a) the congruity of the articular surfaces when the joints are loaded, (b) the static ligamentous restraints, and (c) the musculotendinous units, which allow for dynamic stabilization of the joints (Freeman, Dean & Hanham, 1965; Hertel, 2002). The contribution of the ligaments to talocrural joint stability is crucial. The talocrural joint receives ligamentous support from a joint capsule and several ligaments, including the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL), and deltoid ligament. The ATFL, PTFL, and CFL support the lateral aspect of the ankle, while the deltoid ligament provides medial support (Renstrom & Konradsen, 1997).

Single Limb Stance (SLS) is a functional balance activity, and one of the primary tasks of that activity is to regain stability and coordination of the body (Rozzi, Lephart, Sterner & Kuligowski, 1999). Despite the involvement of SLS in daily life balance activities, scientific studies are still limited, particularly in the field of biomechanics (Weirich, 2010). In addition, the presence of balance boards added an important value in any functional balance activity (Weirich, 2010).

Using an Isokinetic Balance Board (IKBB) to ameliorate stability has not been tested from a biomechanical perspective. According to Weirich (2010), balance boards or wobble boards, such as the IKBB can be used to develop reflexes for athletic training, physical therapy, recreation and more. IKBB is composed of two levels of difficulty (see figure 6, chapter 2). An optional base cone fits over the existing center cone, raising the surface and providing a greater degree of instability for a more challenging workout. Moreover, it is used for proprioceptive and rehabilitation exercise to improve balance and coordination (Beynnon et al., 2000; Weirich, 20 I 0). Despite the benefits of this balance board, most weight bearing balance activities played substantial influence in improving the functional balance (Alkjaer, Henriksen & Dyhre-Poulsen, 2009; Hrysomallis, 2007).

In order to properly regain the functional outcome of practicing any sport, performing balance activities for effective rehabilitation of the athlete must be staged with clear intent and goals for each stage of recovery (Alkjaer, Henriksen & Dyhre-Poulsen, 2009; Hrysomallis, 2007). Moreover, further knowledge in the topic of balance training and exercises, based on previous studies, is crucial in order to capture essence of the present study.

According to Hu & Woollacott (1994), balance exercises were mostly designed for an objective of ameliorating equilibrium and stability for many individuals despite their gender, age or physical abilities. Single-limb stance balance activity is considered one of the closed kinetic chain (CKC) exercises (Blackbum & Morrissey, 1998). Also, CKC exercises represent an integral part of rehabilitation programs after lower extremity injuries. For example, reliable research noted that progressive single-leg dynamic balance exercise programs have improved dynamic stability very quickly for subjects who were involved in sport activities, such as pre-season training (Rasool & George, 2007). In addition, it has been indicated that the most prevalent musculoskeletal injuries that occur in athletes were ankle sprains. Also, balance-training programs are tremendously substantial in eliminating the risk of ankle sprains in high school soccer and for basketball players (McGuine & Keene, 2006). Another study indicated that balance and coordination exercises are recommended for patients in need of reduction or elimination in the implications of proprioceptive deficit incidence and the symptom of "giving way" due to ligamentous injuries at the foot and ankle (Freeman, Dean & Hanham, 1965).

In addition, in patients with non-impaired, but unstable ankles, a conclusive study demonstrated that balance training activities have improved the joint proprioception and enhanced single-leg stance (Rozzi, Lephart, Sterner & Kuligowski, 1999). As a matter of fact, using proprioceptive balance board training program has an impact in the limitation of ankle sprain recurrences (Beynnon et al., 2000; Verhagen, Van Der, Twisk, Bouter, Bahr & Van Mechelen, 2004). Nonetheless, it intervened in the occurrence of overuse knee injuries (Verhagen et al., 2004). Another related study about balance board influence in training situations, maintained that the rate of significance (injuries), in the lower extremities, was greater than not using balance boards during training (Soderman, Werner, Pietila, Engstrom & Alfredson, 2000). Moreover, functional ankle instability is one of the leading factors for using balance boards while training to regain functionality (Tropp, Odenrick & Gillquist, 1985). Both balance training and balance boards played vital role in both balance improvement and functional rehabilitation (Alkjaer, Henriksen & Dyhre-Poulsen, 2009)

Alkjaer et al., (2009) stated that some specified balance activities have been presented as a common group of activities among athletes for training as well as for popular rehabilitation tasks of exercise. Factors of postural instability are many, yet body weight is one of the major indicators of postural instability (Greve, Alonso, Bordini, & Camanho, 2007). In fact, unregulated body sway oscillations were substantially observed in heavier weight individuals or in greater body mass index (BMI) due to lower balance control sensitivity (Greve, Alonso, Bordini, & Camanho, 2007; Hue et al., 2007).

Therefore, Individuals with weight higher than 250 Pounds (113 Kilograms) were not included or involved in the study.

On a final note, limited published studies were presented in terms of using two heights of IKBB difficulty. The degree of difficulty was based on the height of the balance-board base; that is, the 1st level of difficulty is ten degrees angle, while the 2nd level of difficulty is fifteen degrees angle. In addition, holding or grasping Mulligan mobilization belt will provide valuable feedback on balance training for stability improvement.

Statement of the Problem

According to the literature review, despite the extensive use of balance boards, there were few published studies about the IKBB. Many scientific and trustworthy studies have showed the significant outcomes of using balance boards in preventing and rehabilitating ankle joint instability (Verhagen et al., 2004). Balance is the process of maintaining the position of the body's center of gravity vertically over the base of support and relies on rapid, continuous feedback from visual, vestibular and somatosensory structures and then executing smooth and coordinated neuromuscular actions (DiStefano, Clark, & Padua, 2009; Hrysomallis, 2011; Nashner, 1993). Bateni, Zecevic, Mcllroy & Maki (2004) indicated that holding an object can have a deep effect on the control of upper-limb balance reactions. They concluded that there is an extraordinary tendency for the CNS to persist in the ongoing task of holding an object, and to give priority to this task over the execution of upper-limb balancing reactions. Participants persisted in holding the object even when it provided no benefit, and no consequence or cost associated with dropping it. Therefore, it was imperative to identify whether IKBB level and holding an object (Mulligan Mobilization Belt) presents differential indicator (joint angle changes) for healthy individuals with healthy ankles during SLS.

Purpose of the Study

The purpose of the study was to quantify the kinematic differences (mean values) at the ankle joint (sagittal-plane motion & frontal-plane motion) during static single-limb stance (SLS) without holding an object and with holding an object (Mulligan Mobilization Belt). As a result, kinematic differences had provided feedback on balance training, or rehabilitation programs in terms of introducing the Mulligan blue belt in the process of ankle joint balance progression. Two levels of balance board were used.

Research Hypothesis

In order to determine differences in the ankle joint kinematics (sagittal & frontal plane), the following hypothesis was investigated: Holding an object (belt) during performing SLS without and with IKBB (two levels) presented a decrease in the mean maximum kinematics of the ankle (sagittal & frontal) compared to not holding an object.

Operational Definitions

1. Single Leg Stance (SLS): Functional balance and closed kinetic chain exercise; to put it differently, standing on one leg, abducting both shoulders, extending both elbows, placing both forearm in neutral position, and legs do not touch each other.
2. Isokinetic Balance Board (IBB): An adjustable balance board into two degrees of height or difficulty: 10 degree angle without adapter, 15 degree with adapter, and

it is used to improve the following: core strengthening and stability, ankle range of motion (ROM) and flexibility, ankle and knee injury prevention and strengthening, and most importantly, ameliorate balance and proprioceptive training for lower and upper extremity.

3. Closed Kinetic Chain (CKC) Exercises: Exercises performed where the foot or hand do not move during the exercise (foot/hand remains in constant contact with a surface).
4. Healthy Individuals: medically fit individuals.
5. Functional Ankle Instability: Ankle joint instability due to strength deficits, impaired postural control, impaired neuromuscular control or impaired proprioception (Hertal 2002).
6. Mechanical Ankle Instability: Ankle joint instability due to arthrokinematic restrictions, pathologic laxity, degenerative changes and synovial changes (Hertal 2002).
7. Chronic ankle instability (CAI) denotes the occurrence of repetitive traumas of lateral ankle instability, resulting in numerous ankle sprains (Hertel, 2002).
8. Wobble Balance Board: A training device made of a round, solid plastic platform with a hard, plastic semi-circle attached to the bottom (adjustable) (Weirich, 2010).

Assumptions

The present study was performed under the following assumptions:

1. All of the participations fully understood what was required of them during their participation for this research study.
2. All of the participants performed the best of their ability. Each individual performed static single-leg balance activity based on the examiner's instructions before and after using the isokinetic balance board (IKBB), considering the exercise difficulty (balance level).
3. All of the participants were truthful and honest in providing accurate information (demographic and experience questionnaire — appendix D) pertaining to personal information and experience level during their participation.

Limitations

The following limitations may apply to the present study and were considered:

1. Participants may drop out of the study at any time.
2. Time constraint was expected based on how many trials were needed for complete self-maintaining balance, especially during performing the static SLS on the second level of balance board difficulty.
3. All of the Participants were limited to intact and healthy ankle tissues, excluding participants with (a) ankle injuries and pathologies and (b) ankle surgeries within the past six months.
4. All testing trials were performed in a laboratory setting.
5. All of the participants used the same isokinetic balance board and belt.

Delimitations

The following delimitations were made in the present study:

1. Participants were over the age of 18 years old.
2. This study included both males and females.
3. Participants were completely voluntary and recruitment was open to include individuals from Barry University.
4. All of the participants were free from injury for the past six weeks and do not have any balance issues, such as inner ear problems up to the time of the experiment.
5. All of the participants performed the SLS without and with IKBB by using only the left leg; yet, most of the participants were right side dominance.

Variables

The following variables were identified or determined in the present study:

1. Control variable was the population (healthy participants).

2. Independent variables were two. First independent variable was performing SLS without and with grasping an object (Mulligan Mobilization Belt). Second independent variable was performing static SLS without and with IKBB.

3. Dependent variables were maximum ankle joint angles (sagittal-plane motion & frontal-plane motion). In other words, the dependent variables were four (maximum ankle dorsiflexion, plantar flexion, abduction and adduction).

Significance of the study

The study has provided the following information: (a) kinematic changes during SLS off and on IKBB, without and with grasping Mulligan mobilization belt for healthy participants in order to provide feedback on balance training or rehabilitation programs in terms of introducing the Mulligan blue belt in the process of ankle joint balance progression over stable and unstable (IKBB) surfaces.

CHAPTER 2

LITERATURE REVIEW

In order to have a comprehensive review of the literature on this topic, the following subtopics were discussed: (a) Ankle anatomy and pathomechanics, and (b) Neuromuscular training.

Ankle Anatomy and Pathomechanics

The ankle joint and foot make up a complex anatomical structure consisting of 26 irregularly shaped bones, 30 synovial joints, more than 100 ligaments, and 30 muscles acting on the segments. All of these joints must interact harmoniously and in combination to achieve a smooth motion. Most of the foot motion occurs at three of the synovial joints: the talocrural, the subtalar, and the midtarsal joints. The foot moves in three planes, with most of the motion occurring in the rear foot. Moreover, the foot supports the weight of the body in both standing and locomotion. The foot must be a loose adapter to uneven surfaces at contact. Upon contact with the ground, it serves as a shock absorber, attenuating the large forces resulting from ground contact. Late in the support phase, it must be a rigid lever for effective propulsion. Finally, when the foot is fixed during stance, it must absorb the rotation of the lower extremity.

These functions of the foot all occur during a closed kinetic chain, as it is receiving frictional and reaction forces from the ground or another surface. The foot can be divided into three regions: the rear-foot (talus and calcaneus), the mid-foot (navicular, cuneiforms, and the cuboid), and the forefoot (metatarsals and phalanges) (Hamill, Knutzen, & Derrick, 2015). Interestingly, two-dimensional analysis reveals that translation of the tibia produces a change in the Instant Center of Rotation (ICR) of the ankle joint, so that the ICR moves posteriorly with plantar flexion, anteriorly with dorsiflexion, medially with inversion, and laterally with eversion (Oatis, 2009)**.**

The range of motion (ROM) at the ankle joint varies with the application of loads to the joint. The ROM in dorsiflexion (20 degrees) and plantar flexion (50 degrees) is limited (bony, capsular, ligamentous, and muscular restriction). When performing a full squat with Body Weight (BW), dorsiflexion may reach 40 degrees (Hamill, Knutzen, & Derrick, 2015). Ankle arthritis decreases the passive dorsiflexion and increases the active dorsiflexion (the ROM increases in dorsiflexion because of the reduced flexibility in the gastrocnemius or weakness in the soleus). Nevertheless, ankle arthritis in plantar flexion ROM is less for both active and passive measurements. In the rear-foot, subtalar or calcaneal eversion and inversion can be measured by the angle formed between the leg and the calcaneus. In the closed-chain weight bearing movement, the talus moves on the calcaneus (Hamill, Knutzen, & Derrick, 2015). In addition, in an in vivo study of loaded ankles in the closed kinetic chain, 30 degrees of physiologic plantar flexion (actual motion) from the neutral position was composed of 28 degrees sagittal-plane movement (plantar flexion), 1 degree transverse-plane movement (internal rotation), and 4 degrees frontal-plane movement (inversion) (Lundberg, Goldie, Kalin & Selvik, 1989). Comparatively, 30 degrees of physiologic dorsiflexion (actual motion) in the closed kinetic chain was composed of 23 degrees sagittal-plane motion (dorsiflexion), 9 degrees transverse-plane movement (external rotation), and 2 degrees frontal-plane movement (eversion) (Lundberg, Goldie, Kalin & Selvik, 1989).

The powerful movement at the ankle is plantar flexion because of muscular mass component; furthermore, the plantar flexors are used more to work against gravity and maintain an upright posture, control lowering to the ground, and add to propulsion. During standing, the plantar flexors, particularly the soleus, contract to control dorsiflexion in the standing posture. Plantar flexion strength is greater from a position of slight dorsiflexion. A starting dorsiflexion angle of I 05 degrees, increases plantar flexion strength by 16% from the neutral 90 degrees position. Also, plantar flexion strength can be increased if the knee is maintained extended (gastrocnemius muscle length advantage). On the other hand, dorsiflexion is incapable of generating a large force because of its decreased muscle mass and minimal usage in daily activities, so the dorsiflexors strength constitute 25% of the plantar flexors (Hamill, Knutzen, & Derrick, 2015).

Hertel (2002) stated that lateral ankle instability refers to the existence of an unstable ankle due to lateral ligamentous damage caused by excessive supination or inversion of the rear foot. This term does not differentiate whether the instability is acute or chronic (Brand, Black & Cox, 1977; Hertel, 2002). Traditionally, chronic ankle instability (CAI) has been attributed to two potential causes: mechanical instability and functional instability. Mechanical instability of the ankle complex occurs as a result of anatomic changes after initial ankle sprain, which lead to insufficiencies that predispose the ankle to further episodes of instability, while functional instability refers to injury in the lateral ligaments of the ankle results in adverse changes to the neuromuscular system that provides dynamic support to the ankle (Bosien, Staples & Russell, 1955; Hertel, 2002; Tropp, Odenrick & Gillquist, 1985). The concept of functional ankle instability was described in a study, as attributed impaired balance in individuals with lateral ankle sprains to damaged articular mechanoreceptors in the lateral ankle ligaments, which resulted in proprioceptive deficits (Freeman, I 965; Hertel, 2002; Renstrom & Konradsen, 1997; Tropp, Odenrick & Gillquist, 1985). Functional ankle instability can also be related to a number of factors, including peroneal tendon weakness, rotational talar instability, subtalar instability, tibio-fibular instability, or hind foot misalignment (Hamill, Knutzen, & Derrick, 2015). See figures 1, 2, 3 and 4. Furthermore, functional ankle instability has been reported to impact the maintenance of equilibrium (Tropp, Odenrick & Gillquist, 1985). Ankle instability is a condition whereby the restraining lateral ligaments of the ankle become stretched. This can lead to a sense of instability in the ankle and predispose the patient to frequent ankle sprains (Caulfield, 2000). Interestingly research concluded that mechanical ankle instability was not a factor in maintaining balance (Tropp, Odenrick & Gillquist, 1985). Also, participants or patients with functional ankle instability revealed a reliance on the hip motion in order to maintain equilibrium (Tropp & Odenrick, 1988). In a systematic study, Hertal (2002) indicated two potential causes of chronic ankle instability. These causes might be due to mechanical ankle insufficiencies or functional ankle insufficiencies. Both ankle insufficiencies have led to recurrent ankle sprain (Caulfield, 2000).

Injuries to the foot and ankle account for a large portion of the potential injuries in the lower extremity. Injuries to the hind-foot usually occur as a result of vertical compression, injuries to the midfoot occur with excessive lateral movement or range of motion in the foot. Injuries to the forefoot occur similarly to injuries in long bones elsewhere in the body. Both compressive and tensile forces create the injury in the forefoot. In addition, foot and ankle injuries are associated with anatomical factors; a greater incidence of injury is seen in individuals who over-pronate and in those with cavus alignment in the lower extremity (Hamill, Knutzen, & Derrick, 2015).

The most prevalent injury to the foot is ankle sprain. The injury mechanism is a movement of the tibia laterally, posteriorly, anteriorly, or rotating while the foot is firmly fixed on the surface. For example, ankle sprain can occur when someone lose balance in high heels. Disability from ankle sprains in athletes can be severe, with 40% of patients having dysfunction that persists for as long as six months after the injury. In fact, this dysfunction includes a reduction in proprioception after acute ankle sprains. In addition, athletes with multiple ankle sprains have significantly decreased kinesthetic awareness and proprioception. This loss in proprioception is a potential risk factor for re-injury (Trojian & McKeag, 2006). The factors associated with ankle sprain differ between men and women. Men with increased talar tilt and women with increased tibial varum and calcaneal eversion range of motion are more susceptible to ankle ligament injury. Mainly, the ankle and foot are subjected to significant compressive and shear forces in both walking and running (Hamill, Knutzen, & Derrick, 2015). Finally, the single leg balance test can be used in a pre-participation setting to identify athletes with an increased risk of ankle sprains (Trojian & McKeag, 2006).

When calculating the absolute ankle angle, adding 90 degrees makes the angle oscillate about 0 degree. Subsequently, a positive angle represents dorsiflexion, and a negative angle represents plantar flexion (Hamill, Knutzen, & Derrick, 2015).

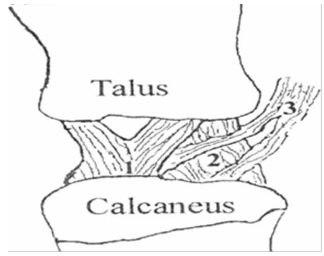


Figure 1: *The intrinsic subtalar ligaments: (I) interosseous ligament, (2) cervical ligament, and (3) deep fibers of the extensor retinaculum (Hertel, 2002).*

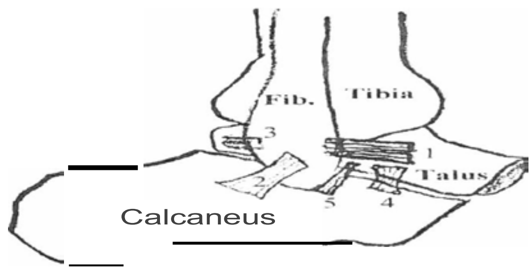


Figure 2: *The lateral ligaments of the ankle: (I) anterior talofibular ligament, (2) calcaneofibular ligament, (3) posterior talofibular ligament, (4) cervical ligament, and (5) lateral talocalcaneal ligament (Hertel, 2002).*

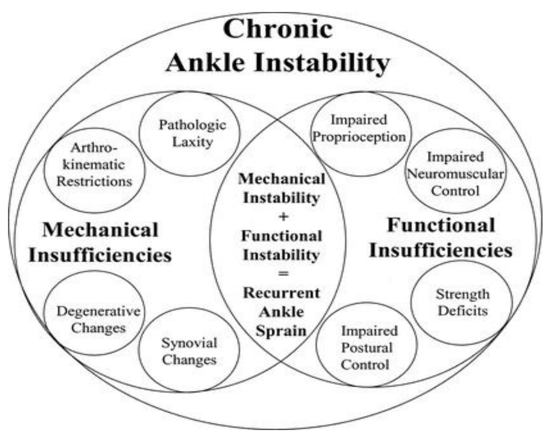


Figure 3: *Paradigm of mechanical and functional insufficiencies that contribute to chronic ankle instability (Hertel, 2002).*

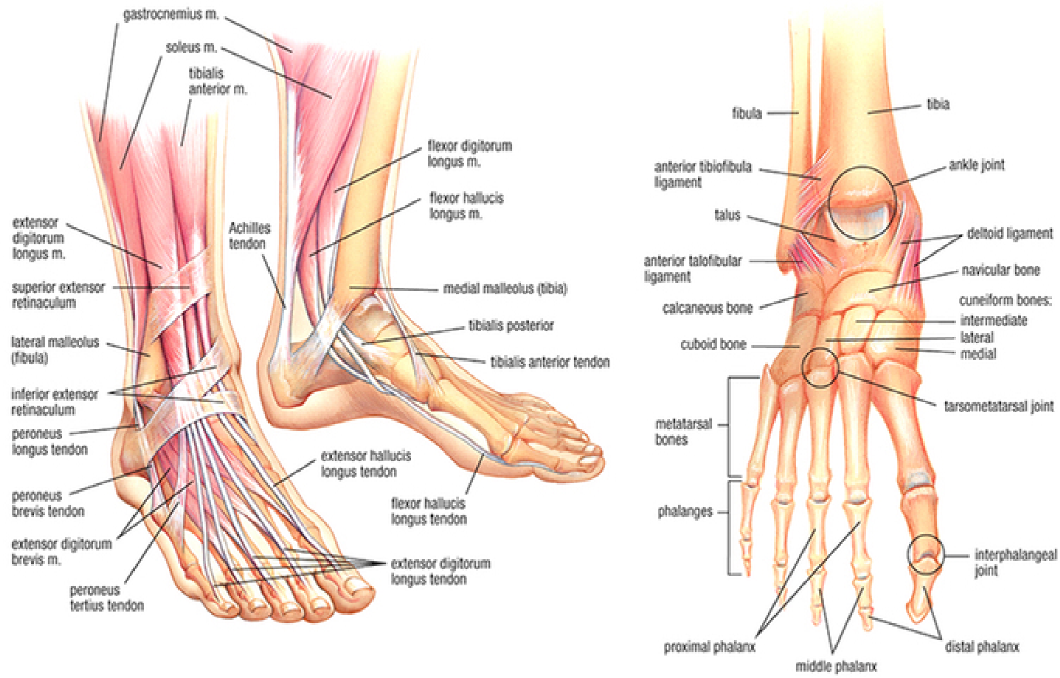


Figure 4: *Ankle/Foot anatomy (Mark A. Wolgin, MD, Orthopaedic Surgeon)*

Neuromuscular Training

According to Weirich (2010), there are many different types of balance training devices. Consumers assume these devices have the same outcomes for strength, balance, and stability improvements. The usage concepts are comparable between devices, yet the outcomes vary. The basic notion for neuromuscular development is to generate an unstable environment, which promotes increased neuromuscular activation, and strengthens proprioception. The level of instability in different planes of motion is one of the mechanical reasons of variability between devices. Some devices have instability in only one plane (front to back or side to side) where as others have instability in all planes.

Some devices show instability factor with the level of height, such as the isokinetic balance-board (IKBB) (see figure 5).

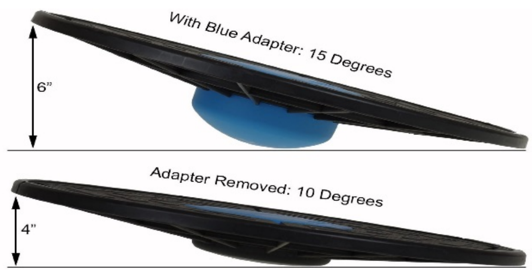


Figure 5: *Isokinetic balance board without and with adapter (Isokinetic Inc., retrieved April 22, 2015).*

In addition, Weirich (20 I 0) maintained that balance boards, such as the IKBB could be used to develop reflexes for athletic training, physical therapy, recreation and more. These boards are built with a wide assortment of shapes, sizes and settings for a comfortable, safe and challenging exercise experience. IKBB is composed of two levels of difficulty (see figure 6). An optional base cone fits over the existing center cone, raising the surface and providing a greater degree of instability for a more challenging workout. Moreover, it is used for proprioceptive and rehabilitation exercise to improve balance and coordination (Beynnon et al., 2000; Weirich, 2010).

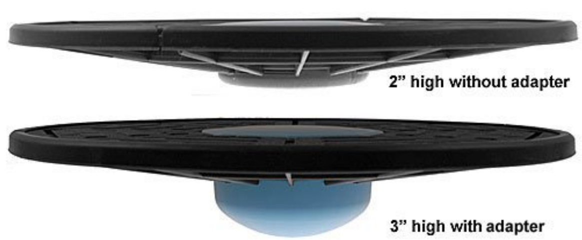


Figure 6: *lsokinetic balance board with 2” high without base cone, 3” high with base cone (lsokinetics Inc., retrieved April 22, 2015).*

Physiological differences between demographics, such as physical fitness and age, can account for the variability of balance devices (Weirich, 2010). Neuromuscular training can be beneficial for people of any age, yet the results will vary. Balance has an inverse relationship with age (Bohannon, Larkin, Cook, Gear, & Singer, 1984). 184 subjects between the ages 20 to 79 performed eight balance tasks to examine the relationship between test performance and age. Performance seemed to decline for healthy adults over 39 years old (Bohannon et al., 1984). Reaction time for balance recovery increases with increasing age as well (Luchies et al., 2002). These measures were taken from healthy, exercising adults; so balance recovery time could be even greater for the sedentary adult population (Bohannon et al., 1984; Luchies et al., 2002). Balance training can help reduce the effects of aging through increased proprioception and strength (Anderson & Behm, 2005; Schilling et al., 2009; Mattacola & Lloyd, 1997).

Balance is simply define as the ability to maintain the body's center of gravity within its base of support (DiStefano, Clark, & Padua, 2009). In other words, balance is the process of maintaining the position of the body's center of gravity vertically over the base of support and relies on rapid, continuous feedback from visual, vestibular and somatosensory structures and then executing smooth and coordinated neuromuscular actions (Hrysomallis, 201 l; Nashner, 1993).

Traditionally, balance training has been used as part of the rehabilitation program for ankle injuries. More recently, balance training has been adopted to try and prevent injuries to the ankle and knee joints during sport (Hrysomallis, 2007). Alkjaer, Henriksen & Dyhre-Poulsen (2009), stated that some specified balance activities have presented, as a common group of activities among athletes for training as well as a popular rehabilitation tasks of exercise.

Balance and postural stability are crucial to everyone for performance enhancement and injury prevention (Weirich, 2010). Static and dynamic proprioceptive training through the use of balance training devices can significantly reduce sport-related injuries among healthy adolescents (DiStefano et al., 2009; Emery, Cassidy, Klassen, Rosychuck, & Rowe, 2005; McGuine & Keene, 2006; Mcleod, Armstrong, Miller & Sauers, 2009). The term proprioceptor has been restricted to receptors consistent with conscious sensations, such as the senses of limb position and movement, the sense of tension or force, the sense of effort, and the sense of balance (Proske & Gandevia, 2012).

Hrysomallis (2011), mentioned that prospective studies have shown that the addition of a balance training component to the activities of recreationally active subjects or physical education students has resulted in improvements in vertical jump, agility, shuttle run and downhill slalom skiing. Based on the available data from cross-sectional studies, gymnasts tended to have the best balance ability, followed by soccer players, swimmers, active control subjects and then basketball players (Hrysomallis, 2011).

A conclusive study was applied upon participants with non-impaired, but unstable ankles, demonstrated that balance training activities improved the joint proprioception, and enhanced the ability of single-leg stance (Rozzi, Lephart, Sterner & Kuligowski, 1999). As a matter of fact, using proprioceptive balance board training program has a substantial impact in the limitation of ankle sprain recurrences. Nonetheless, it has an essential intervention in the occurrence of overuse knee injuries (Verhagen, Van Der Beek, Twisk, Bouter, Bahr & Van Mechelen, 2004).

As a single intervention, balance training without balance board devices has been shown to significantly reduce the recurrence of ankle ligament injuries in soccer, volleyball and recreational athletes; nonetheless, it did not clearly show any reduction of ankle injuries in athletes without a prior ankle injury (Verhagen, Van Der Beek, Twisk, Bouter, Bahr & Van Mechelen, 2004). When the balance training programs are adequately effective, the overall postural balance and stability is maintained (Beynnon, et al., 2000; Hrysomallis, 2007).

Postural stability is the ability to achieve a state of equilibrium by maintaining the body's center of gravity (CoG) over the body's base of support (Beynnon, et al., 2000; Hrysomallis, 2007). Stationary balance represents the center of gravity over the base of support when a body is not moving (Harrison, Duenke, Dunlop, & Russell, 1994). The control of balance involves a continuous feedback system of processing visual, vestibular and somatosensory inputs and executing neuromuscular actions. A component of the somatosensory system is proprioception (i.e. afferent information on position and movement from internal receptors in joints, muscles and tendons) (Beynnon, et al., 2000; Hrysomallis, 2007).

Leg dominance seems to be function of the type of activity a subject is required to perform. When the task is manipulative in nature, most participants will use the right leg, yet when the task involves stabilization such as standing on one leg, more that 50% of the participants in the study use the left leg to perform the task. Any researcher should select the appropriate leg dominance test depending on the task being investigated (Velotta, Weyer, Ramirez, Winstead, & Bahamonde, 2011). It is important to mention that no differences were found in postural sway during single-leg standing between dominant and non-dominant legs (Harrison, Duenke, Dunlop, & Russell, 1994). Also, it is essential to note that the ability to reach and "grasp" (grip or touch) structures for support in reaction to instability has an impact or effect for the stability range of the body's posture. Nevertheless, it is uncertain, how the central nervous system (CNS) (see figure 7) resolves the potential conflict between holding an object and the need to release the held object and grasp alternative support, particularly if the held object is perceived to be relevant to the task of stabilizing the body, e.g. an assistive device (Bateni, Zecevic, Mcllroy & Maki, 2004). The results of the research indicated that holding an object can have a deep effect on the control of upper-limb balance reactions. Most noteworthy was the finding that the influence of holding an object was not critically dependent on the task- or context-relevance of the object being held. Inhibition of grasping reactions was observed to occur whether the held object was relevant to the task of stabilizing the body or not. The study concluded that there is an extraordinary tendency for the CNS to persist in the ongoing task of holding an object, and to give priority to this task over the execution of upper-limb balancing reactions. Subjects commonly persisted in holding the object even when it provided no benefit, there was no consequence or cost associated with dropping it, and the concern was to fall against a safety harness or padded barriers (Bateni, Zecevic, Mcllroy & Maki, 2004). In the present study, each participant performed the static SLS functional balance task off and on the IKBB, and grasped Mulligan mobilization belt (see figure 8) with both hands.

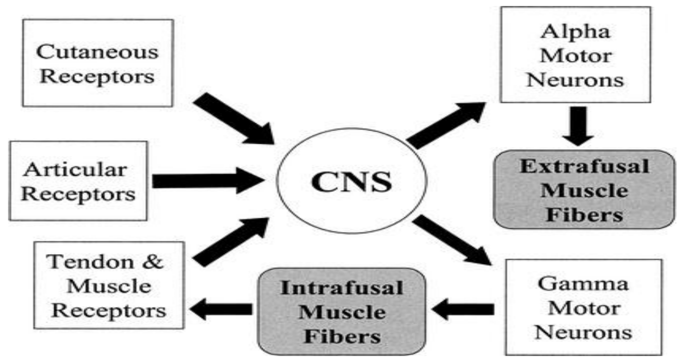


Figure 7: *Paradigm of proprioception and neuromuscular control. CNS indicates central nervous system (Hertel, 2002).*

Figure 8: *Mulligan Mobilization Belt (Mulligan Mobilisation Belt™, retrieved April 22, 2015).*

The complex integration of the visual and vestibular systems with somatosensory function results in the ability for a person to carry out physical activities effectively and safely. Reduced sensation, lower-extremity muscle weakness, and damage to receptors can affect standing balance (Harrison, Duenke, Dunlop, & Russell, 1994). As a consequence, it is important to consider some neuromuscular training programs.

Some training programs incorporate a balance training device to engage the core muscles and try to improve the proprioceptive response. As a matter of fact, these devices train its user the proper distribution of body weight to achieve a constant equilibrium. An interruption or deficit in any part of the sensorimotor system can result in a loss of balance, which can result in injury (DiStefano et al., 2009). A sensorimotor deficit causes proprioception problems, such as a lack in ability to reposition a joint to a predetermined position or a lack of coordination during single limb or whole body movements. This is predominantly seen in people with functional ankle instability (FAI), mechanical ankle instability (MAI), and chronic ankle instability (CAI) (Arnold, Motte, Linens, & Ross, 2009; Docherty, McLeod. & Shultz, 2006; Hiller, Refshauge, & Beard, 2004; Riemann, 2002). Both static and dynamic balance require effective integration of visual, vestibular, and proprioceptive inputs to produce an efferent response to control the body within its base of support (Guskiewicz & Perrin, 1996; Irrgang, Whitney, & Cox, 1994).

In addition, despite the fact that functional ankle instability has been reported to impact the maintenance of equilibrium, an interesting research concluded that mechanical ankle instability was not a factor in maintaining balance (Tropp, Odenrick & Gillquist, 1985). Also, participants or patients with functional ankle instability revealed the reliance on the hip motion in order to maintain equilibrium (Tropp & Odenrick, 1988). In 2002, a systematic study indicated two potential causes of chronic ankle instability. These causes might be due to mechanical ankle insufficiencies or functional ankle insufficiencies. Both ankle insufficiencies have led to recurrent ankle sprain (Hertal, 2002).

Furthermore, the relationship between balance ability and sport injury risk has been established in many cases, yet the relationship between balance ability and athletic performance is less clear (Hrysomallis, 2007; Hrysomalli s, 2011). When examining the relationship between balance ability and athletic performance, researchers have used a number of different tests to assess static and dynamic balance. A simple field test for static balance is the timed unipedal stance — single limb stance (Aalto, Pyykk6, Ilmarinen, Kahkonen, & Starck, 1990; Hrysomallis, 2011; Kioumourtzoglou, Derri, Mertzanidou, & Tzetzis, 1997).

The consideration of including unstable and stable support surfaces has been used as part of balance training programs. Balance assessment has been conducted on an unstable surface. This makes the balance test dynamic and possibly more applicable to the sporting context (Hrysomallis, 2007). Unstable surfaces, such as wobble, adjustable with different heights or tilt boards, can also be used to assess balance ability (Hrysomallis, 2007). The side of the balance boards can incorporate contact switches to detect the time when a subject is out of balance while attempting to maintain single limb balance for a specified period of time (Tyler, McHugh, Mirabella, Mullaney, & Nicholas, 2006).

When a balance exercise was performed with an unstable rather than a stable base, a number of studies have reported increased electromyography (EMG) activity (Anderson & Behm, 2005b; Wahl & Behm, 2008). During squatting, there was more EMG activity in the soleus on the wobble board than in a stable surface (Wahl & Behm, 2008). Similar to previously published research, the greater instability of the wobble board did result in greater muscle activation than found on a stable surface (Wahl & Behm, 2008). The study showed statistical significance (M= 0.41; $p= 0.30 < .05$) in the peak muscle (soleus) activation during squatting with the wobble board; nonetheless, the study did not show statistical significance (M= 0.13; $p= 0.08 < .05$) in the peak muscle activation during squatting on stable flat surface (Wahl & Behm, 2008). The increase in muscle activity as seen in the previous study is due to co-contraction of muscles on either side of the joint to maintain support and balance (Gantchev & Dimitrova, 1996). Another interesting study, the purpose was to compare differences in mean peak EMO activity in five lower body muscles, including gastrocnemius, during dynamic squats on and off an indo balance board for each condition: a) baseline, b) cushion, and c) roller. The investigator found the following mean peak muscle (gastrocnemius) activation values: a) baseline (M= 1.33; SD= .67), b) cushion (M= 1.78; SD= .76), and c) roller (M= 1.8; SD= 1.22) (Weirich, 2010). The results of the previous study were as follows: a) no significant effect was found (p= .333 > .01), the gastrocnemius was not significantly affected by the squat condition, b) no significant differences were found (p= .634 > .01), gender had no significant effect on peak neuromuscular activation of the gastrocnemius. The study concluded that performing squats on an Indo board has no greater effect on lower body neuromuscular activation than doing squats on a flat, stable surface. However, there was a noticeable fear factor contributing to the participants' insecurities on the Indo board, which means the participants were more concerned about not falling off the balance board than performing a fluid dynamic squat (Weirich, 2010). Not all studies have found an increase in neuromuscular activation during unstable condition. A related study found that instability resulted in a significant decrease in activity of the agonist muscles and no significant change in antagonist or synergist muscles; therefore, the noted benefit of increased muscle activation with instability seems to be unfound as well (Behm, Anderson & Curnew, 2002). In short, most functional balance performances represented reliable and valid measures of balance disability and suggested for research or clinical use (Tyson & Desouza, 2004). Alkjaer, Henriksen, Dyhre-Poulsen & Simonsen (2009) stated that most of the functional balance tests are reliable and recommended to represent the biomechanical variables. Consequently, it was logical to justify the validity that functional balance performances present a plausible measure and respectable indicator for balance training.

CHAPTER 3

METHODS

Participants

Forty (40) healthy adults (aged 21-53 years/M= 28.25; SD= 6.79) were recruited from in and out Barry University to participate in this study. Thirty six (36) male and four (4) female adults constitute the total participants. All of the participants were recruited via recruitment flyers (Appendix A) and word of mouth. The participants filled out a demographic and experience questionnaire (Appendix C). Participants were limited to healthy ankles, excluding the following participants who indicate they have: a) ankle injuries and pathologies such as pathologic laxity, arthrokinematic impairments, or synovial and degenerative changes or b) ankle surgeries within the past six months. Furthermore, participants were limited to healthy individuals, excluding the following participants who indicate they have: a) viral or bacterial infections, b) head injury within the past three months, c) vestibular or brain traumas, or d) under specific medications, such as tranquilizers, analgesics, sedatives, and alcohol or tobacco products. All of the participants were instructed to refrain from alcohol and drug use at least more than 24 hours before and the day of the balance board training and testing. The participants signed an informed consent (Appendix B), and they were informed of their right to stop their participation in this study at any time. Benefits and risks of this study were made clear to the participants before signing the informed consent. There were no known risks associated with the participation in this study.

Instrumentation

For the present experimental study, IKBB with two levels of difficulty (level one is 10 degrees angle without adapter. Level two is 15 degrees with adapter) was used (see figure 6). The IKBB is made of durable Polyethylene. Also, Mulligan Mobilization Belt (8 foot, blue nylon belt, used to mobilize the patient while movement occurs, and belt can be adjusted with one hand and has a side release plastic buckle) was used (see figure 8).

By using Vicon Nexus 1.8.5 program, 3D movements of the lower extremity segments were tracked by a 7-camera (MX-3+) with 8.5 mm lenses, collecting at 240 Hz. A static trials SLS were collected. The lower body anatomical coordinate system was then constructed for each participant based on the static trial, through using the Vicon Plug-In Gait standard lower body marker set (see figure 9). Data were analyzed with Vicon Polygon (Centennial, CO) software new version 4.1.

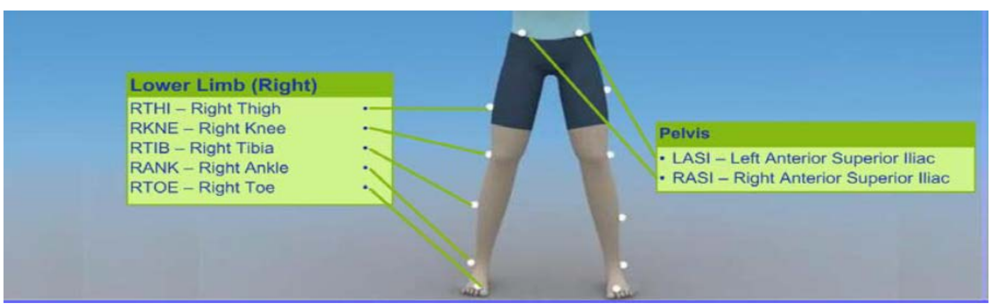


Figure 9: *Lower Body Marker System Frontal View (not pictured the LPSI: left posterior superior iliac, RPSI: right posterior superior iliac, LCAL: left calcaneus, RCAL: right calcaneus).*

Participant Preparation

The participants were instructed prior to their arrival to wear athletic clothing (non-reflective firm fitting spandex shorts and T-shirt) during SLS trials to eliminate marker errors. Then the participant's measurements were taken by the investigator and recorded in millimeters, such as leg length, knee width and ankle width. Sixteen reflective surface markers were placed over the skin using double-sided tape. According to the VICON Nexus manual, markers were positioned on both lower limbs over specific areas. Those areas were as follow: the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), lateral mid-thigh, lateral femoral condyle, lateral mid-calf, lateral malleolus, medial malleolus, posterior calcaneus, and head of the second metatarsal. Table 1 presented the descriptive statistics of general body measurements.

Table 1: *Descriptive statistics of general body measurements*

	Participant N	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Age	40	21.00	53.00	28.2500	6.79649
Body Mass (kg)	40	55.00	107.00	75.8000	12.55797
Height (cm)	40	147.60	191.10	173.1925	11.22032
Shoulder Length (cm	40	40.00	53.00	45.7250	2.81012

Note. Kg: Kilogram; Cm: Centimeters

Procedures

Cameras were calibrated according to VICON manual. Next, a static capture of the participant was taken to create a local coordinate system. The application of modalities (test conditions) were randomized and the order unknown to the participant who performed the SLS balance activity trials under the following testing conditions: a) normal SLS (no IKBB modality), b) 1st level of IKBB, c) 2nd level of IKBB, d) normal SLS with belt, e) 1st level of IKBB with belt, and f) 2nd level of IKBB with belt. SLS balance activity was performed on left leg only. Belt length was twice shoulder length. The belt was fitted for each participant.

The participants were introduced to the IKBB and the controlled balancing space to familiarize them to the area, which the SLS trials were captured without and with the use of two levels of IKBB & the belt. Safety procedure was maintained to all of the participants, including the use of protective lab mats.

After all reflective markers were positioned on the skin, the participant was asked to perform SLS normally at self-selected pace, in the designated balancing space over one of the two force plates. Three trials of each testing condition were recorded and analyzed. Prior to SLS balance performance, the investigator verbally demonstrated how to get on and off the IKBB.

Experimental procedure was carefully explained for each degree of balance board difficulty. For each testing condition with no use of belt, each participant was informed to perform SLS without and with IKBB and try to stabilize the total body at self-selected pace, abducted arms 90 degrees and pronated forearms. For each testing condition with use of belt, each participant was verbally informed to perform SLS without and with IKBB modality and try to stabilize the total body at self-selected pace, abducted arms 45 degrees, flexed elbows 90 degrees, and forearms in natural position; moreover, both hands grasp the belt of two times shoulder length (see figure 10). All of the participants had to perform the SLS over the balancing space for three successful trials for each condition. Each participant performed a total of 18 trials.

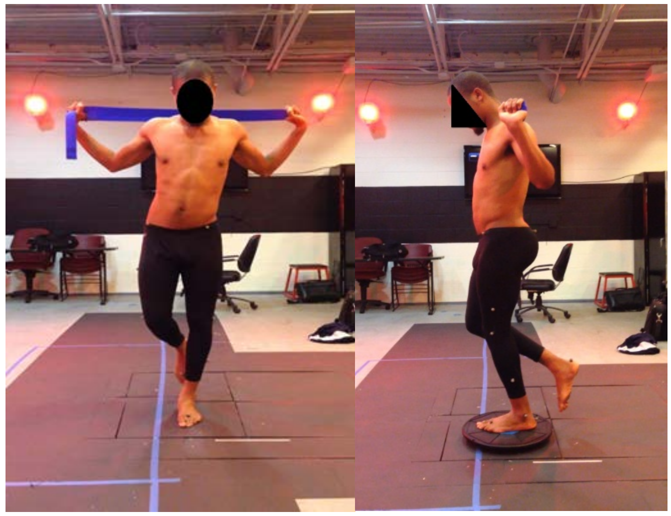


Figure 10: *Single Limb/Leg Stance (SLS) and handling Mulligan Mobilization Belt in two planes (frontal & sagittal).*

During data collection, at least three successful trials (consisting of 3 consecutive SLS) were collected for each participant during each condition. Immediately after a trial was completed, the participant was allowed to rest for five seconds, and the SLS trial was performed during five seconds. Immediately after a condition was completed, the participant was allowed to rest five seconds and continued the rest of the other conditions.

For each participant, experimental testing (data collection) was performed in one day for at least one hour and 30 minutes for each participant. The procedure consisted of the following: a) IKBB, Mulligan belt introduction and explaining safety procedures (25 minutes) and b) lower limb marker set preparation (30 minutes). Total preparation time was 55 minutes.

Randomized data collection of each participant during single limb stance without and with use of belt was taken, and three successful trials for each condition were considered. Repetitions were reach up to three times, and the resting time needed between each repetition was five seconds (total resting time was one minutes and 30 seconds for each participant). The total time needed for experimental data collection was 20 minutes for each participant. The residual time (15 minutes) was divided between filling out the demographic and experience questionnaire (10 minutes), and reading and signing the informed consent (5 minutes).

Data Analysis

All of the participants (N = 40) passed successfully during the experimental day. Despite the fact that most participants showed right side dominance, all of them performed the balance task on the left leg, and they showed minimal struggle in maintaining stability, especially in the second height of IKBB.

The kinematic dependent variables that were analyzed during SLS balance trials of all testing conditions include:

a) Maximum ankle dorsiflexion & plantar flexion on full weight bearing limb.
b) Maximum ankle abduction & adduction on full weight bearing limb.

The independent variables that analyzed were based on two factors (SLS condition and level). The overall testing conditions were as follows:

No belt is held

a) Normal SLS (no IKBB modality)

b) The application of the 1^{st} level of IKBB

c) The application of the 2^{nd} level of IKBB

Belt is held

a) Normal SLS (no IKBB modality)

b) The application of the 1^{st} level of IKBB (10 degrees)

c) The application of the 2^{nd} level of IKBB (15 degrees)

Statistical Analysis

Polygon 4.1 new version software was used to analyze the kinematic data collected by the VICON infrared 3D cameras. A two-way repeated measures MANOVA was performed to understand if there was an interaction between these two factors (SLS condition & level) on the dependent variables, and to examine the significance (set at $p \leq 0.05$). When alpha (p) is set at 0.05, the number of participants was 40 (range 35-45) in order to have a meaningful effect size (Thomas & Nelson, 2011). All statistical tests were analyzed by Statistical Package for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA).

CHAPTER 4

RESULTS

The purpose of the study was to quantify and compare differences in mean peak ankle kinematic (sagittal & frontal) during static SLS off and on IKBB. The main goal was to identify whether IKBB level and holding an object (Mulligan mobilization belt) present differential indicator for individuals with healthy ankles in order to provide feedback on balance training or rehabilitation programs in terms of introducing the belt in the process of ankle joint balance progression. Ankle joint kinematic values were successfully collected and processed in order to meet the prior purpose of the study. The dependent variables wear peak ankle joint kinematic values of the dorsiflexion, plantar flexion, abduction, and adduction. The hypothesis stated that mean ankle joint kinematic (sagittal & frontal) values during holding an object (belt) would not be greater during performing SLS without and with IKBB compared to not holding the belt.

Forty participants were recruited from in and out Barry University. Thirty-six male and four female participants volunteered to participate in this study. Age range of all participants was between 21 and 53 years old. All participants had once a month or no isokinetic balance board experience. The results are presented as follows: a) normality and descriptive analysis, b) Mauchly's sphericity test, c) multivariate tests and c) pairwise comparisons of SLS condition and SLS level.

Normality and Descriptive Analysis

The raw ankle joint kinematic peak values were transformed into useable data and then averaging the peak values of the three trials for each SLS condition. Table 2 showed the descriptive statistics for the two dependent variables (ankle joint dorsiflexion and plantar flexion).

Table 2: *Mean and standard deviation of the variables (as measured by degree) dorsiflexion and plantar flexion for each SLS level and condition*

Ankle Joint	SLS Level	SLS Condition	Mean	Std. Deviation	N
Dorsiflexion	Normal	No Belt	1.7350	.54985	40
		Belt	2.6850	.69855	40
		Total	2.2100	.78653	80
	Level One IKBB	No Belt	3.3450	.65943	40
		Belt	1.4375	.74479	40
		Total	2.3912	1.18729	80
	Level Two IKBB	No Belt	8.6975	.74918	40
		Belt	7.1175	.80380	40
		Total	7.9075	1.10817	80
Plantar Flexion	Normal	No Belt	2.7525	.78642	40
		Belt	2.7825	.84091	40
		Total	2.7675	.80909	80
	Level One IKBB	No Belt	8.1400	.87700	40
		Belt	6.3550	.92069	40
		Total	7.2475	1.26681	80
	Level Two IKBB	No Belt	23.0725	2.03734	40
		Belt	12.7650	1.40339	40
		Total	17.9188	5.46980	80

Table 3 showed the descriptive statistics for the other two dependent variables (ankle joint abduction and adduction). The initial values showed no missing values, no significant outliers, and were normally distributed.

Table 3: *Mean and standard deviation of the variables (as measured by degree) abduction and adduction for each SLS level and condition*

Ankle Joint	SLS Level	SLS Condition	Mean	Std. Deviation	N
Abduction	Normal	No Belt	6.3600	1.01774	40
		Belt	7.3100	.88746	40
		Total	6.8350	1.06237	80
	Level One IKBB	No Belt	8.7550	.68909	40
		Belt	8.4975	.82539	40
		Total	8.6262	.76651	80
	Level Two IKBB	No Belt	20.8050	1.46899	40
		Belt	7.1925	1.14855	40
		Total	13.9988	6.97338	80
Adduction	Normal	No Belt	3.4450	.81805	40
		Belt	1.5925	.66309	40
		Total	2.5187	1.19005	80
	Level One IKBB	No Belt	10.2700	.94766	40
		Belt	5.3175	.87086	40
		Total	7.7938	2.65088	80
	Level Two IKBB	No Belt	21.6325	1.78489	40
		Belt	11.0425	1.19998	40
		Total	16.3375	5.53855	80

Mauchly's sphericity test

Sphericity is an important assumption of a repeated-measures analysis. Mauchly's sphericity test is used to validate a repeated-measures analysis that was calculated. Table 4 showed the Mauchly's sphericity test within-subjects effect. Significant (statistical difference) interaction effect was found in dorsiflexion measure (Greenhouse-Geisser (.863) = .038; $p \leq 0.05$).

Table 4: *Mauchly's sphericity test within-subjects effect*

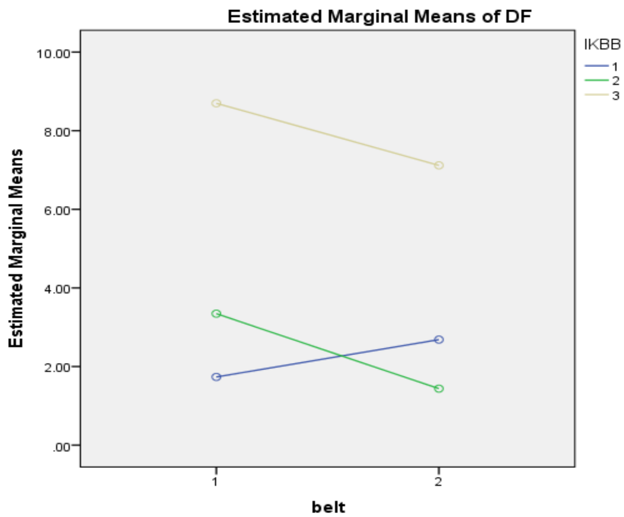
Within-Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser
SLS level * SLS condition	Dorsiflexion	.842	6.540	2	.038	.863
	Plantar Flexion	.585	20.404	2	.000	.706
	Abduction	.874	5.118	2	.077	.888
	Adduction	.616	18.385	2	.000	.723

Note. Statistical difference is significant at $p \leq 0.05$.

Multivariate Tests

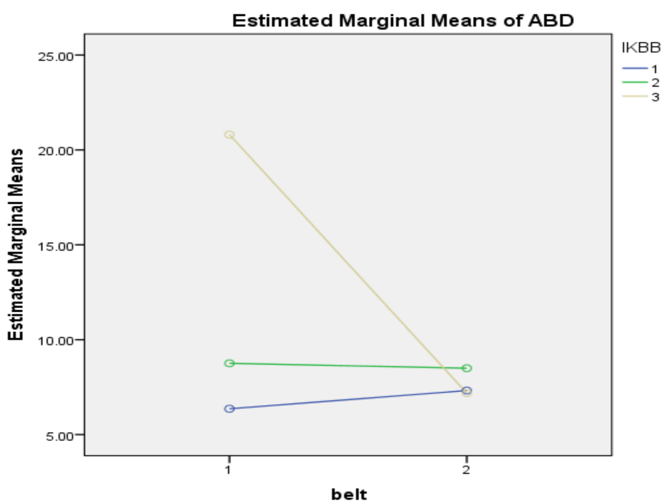
A two-way repeated measures MANOVA was calculated to examine the dependent variables at all conditions and levels of the independent variables. Table 5 showed the results of the multivariate tests (tests of within-subjects effects). Significant main effect was found (Lambda (4, 36) = .012; $p \leq 0.05$) between subjects in SLS condition (no belt & belt). Also, significant main effect was found (Lambda (8, 150) = .001; $p \leq 0.05$) within subjects in SLS level (normal, level one IKBB, and level two IKBB). Significant interaction effect was found (Lambda (8, 150) = .003; $p \leq 0.05$) within subjects in both SLS level and condition. Figure 11 (profile plot) showed that an interaction effect was found in dorsiflexion between normal SLS (no IKBB) and level one IKBB. Also, figure 12 (profile plot) showed that an interaction effect was found in abduction between normal SLS and level two IKBB during SLS condition (belt). All of the dependent variables (ankle joint angles) were significantly affected by the SLS condition and level.

Figure 11: *Dorsiflexion profile plot*



Note. DF: Dorsiflexion; 1(belt): no belt; 2(belt): belt; 1(IKBB): normal SLS (no IKBB); 2(IKBB): SLS level one IKBB; 3(IKBB): SLS level two IKBB.

Figure 12: *Abduction profile plot*



Note. ABD: Abduction; 1(belt): no belt; 2(belt): belt; 1(IKBB): normal SLS (no IKBB); 2(IKBB): SLS level one IKBB; 3(IKBB): SLS level two IKBB.

Table 5: *Results of multivariate tests of the independent variables (SLS condition & level)*

Effect			Value	F	Hypothesis df	Error df	Sig	Power
Between Subjects	Intercept	Wilks' Lambda	.004	2010.760	4.000	36.000	.000	1.000
Within Subjects	SLS condition	Wilks' Lambda	.012	750.329	4.000	36.000	.000	1.000
	SLS level	Wilks' Lambda	.001	789.859	8.000	150.000	.000	1.000
	SLS level * SLS condition	Wilks' Lambda	.003	304.750	8.000	150.000	.000	1.000

Note. Statistical difference is significant at $p \leq 0.05$.

Pairwise Comparisons

Repeated measures analysis was calculated to examine the dependent variables at all conditions of the independent variable. Table 6 presented the results of the pairwise comparisons (SLS condition). Significant mean differences (I-J) were found in dorsiflexion, plantar flexion, abduction, and adduction.

Table 6: *Results of the pairwise comparisons (SLS condition)*

Measure	SLS Condition (I)	SLS Condition (J)	Mean Difference (I-J)	Std. Error	Sig
Dorsiflexion	No Belt	Belt	.846	.065	.000
	Belt	No Belt	-.846	.065	.000
Plantar Flexion	No Belt	Belt	4.021	.151	.000
	Belt	No Belt	-4.021	.151	.000
Abduction	No Belt	Belt	4.307	.099	.000
	Belt	No Belt	-4.307	.099	.000
Adduction	No Belt	Belt	5.798	.151	.000
	Belt	No Belt	-5.798	.151	.000

Note. Mean difference is significant at $p \leq 0.05$.

Table 7 presented the results of the pairwise comparisons (SLS level). Significant mean differences (I-J) were found in dorsiflexion, plantar flexion, abduction, and adduction except in one SLS level of dorsiflexion. This SLS level was Normal to level one IKBB (m= ±.181; $p \leq 0.05$).

Table 7: *Results of the pairwise comparisons (SLS level)*

Measure	SLS Level (I)	SLS Level (J)	Mean Difference (I-J)	Std. Error	Sig
Dorsiflexion	Normal	Level One IKBB	-.181	.097	.209
		Level Two IKBB	-5.697	.092	.000
	Level One IKBB	Normal	.181	.097	.209
		Level Two IKBB	-5.516	.079	.000
	Level Two IKBB	Normal	5.697	.092	.000
		Level One IKBB	5.516	.079	.000
Plantar Flexion	Normal	Level One IKBB	-4.480	.130	.000
		Level Two IKBB	-15.151	.192	.000
	Level One IKBB	Normal	4.480	.130	.000
		Level Two IKBB	-10.671	.171	.000
	Level Two IKBB	Normal	15.151	.192	.000
		Level One IKBB	10.671	.171	.000
Abduction	Normal	Level One IKBB	-1.791	.093	.000
		Level Two IKBB	-7.164	.174	.000
	Level One IKBB	Normal	1.791	.093	.000
		Level Two IKBB	-5.372	.120	.000
	Level Two IKBB	Normal	7.164	.174	.000
		Level One IKBB	5.372	.120	.000
Adduction	Normal	Level One IKBB	-5.275	.114	.000
		Level Two IKBB	-13.819	.158	.000
	Level One IKBB	Normal	5.275	.114	.000
		Level Two IKBB	-8.544	.132	.000
	Level Two IKBB	Normal	13.819	.158	.000
		Level One IKBB	8.544	.132	.000

Note. Mean difference is significant at $p \leq 0.05$.

CHAPTER 5

DISCUSSION

The purpose of the study was to identify whether SLS level (no IKBB/IKBB [two levels) and SLS condition (no belt/belt) present differential indicator for individuals with healthy ankles during performing static SLS. The main goal was to provide feedback on balance training or rehabilitation programs in terms of introducing the belt in the process of ankle joint balance progression. The dependent variables wear peak ankle joint kinematic values of the dorsiflexion, plantar flexion, abduction, and adduction. The hypothesis researched was that mean ankle joint angles (sagittal & frontal) values during holding the belt would not be greater during performing SLS without and with IKBB compared to not holding the belt. A scientific study stated that that holding an object provided no benefit, no consequence and no cost associated with dropping it (Bateni, Zecevic, Mcllroy & Maki, 2004). Any main effects, interactions, unexpected findings, and importance of results between both factors (SLS condition & level) were discussed in more detail.

The hypothesis stated that mean ankle joint kinematic values during holding the Mulligan mobilization belt would not be greater during performing SLS without and with IKBB compared to not holding the belt. The statistics showed there were significant differences and clear trends between both factors (SLS condition & level). When looking at the total mean in dorsiflexion, plantar flexion, abduction, and adduction during each SLS level and condition. 100% of the participants showed increased total mean values in all dorsiflexion, plantar flexion, abduction, and adduction based on the SLS three levels

(Table 2 & 3). In dorsiflexion, the total mean of SLS level normal (M= 2.21; SD= .786) was lower than SLS level one IKBB (M= 2.39; SD= 1.187), and SLS level two IKBB (M= 7.90; SD= 1.108). Despite the fact that total mean of SLS level one was lower than SLS level two IKBB, It was important to notice that the standard deviation of SLS level two IKBB was lower than SLS level one IKBB. Also, it was important to restate that SLS level normal was performed on stable surface compared to the two levels of IKBB (unstable surface). In addition, the mean value of SLS condition with no belt during SLS level normal (stable surface) was lower than SLS condition with no belt during SLS level one IKBB (unstable surface); nonetheless, the mean value of SLS condition with belt during SLS level one IKBB was lower than SLS condition with no belt during SLS level normal. The mean value of SLS condition with no belt during SLS level two IKBB (M= 8.69; SD= .749) was greater than SLS condition with no belt during SLS level one IKBB (M= 3.345; SD= .659). It was interesting to notice that the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 7.11; SD= .803) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 8.69; SD= .749) compared to the SLS condition with no belt during SLS level one IKBB (M= 3.345; SD= .659).

In plantar flexion, the total mean of SLS level normal (M= 2.79; SD= .809) was lower than SLS level one IKBB (M= 7.247; SD= 1.266), and SLS level two IKBB (M= 17.918; SD= 5.469). Moreover, the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 12.765; SD= 1.403) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 23.07; SD= 2.03) compared to the SLS condition with no belt during SLS level one IKBB (M= 8.14; SD=

.877). The total mean plantar flexion was higher during performing SLS without holding the belt compared to holding a belt (M= 5.66 > 3.650).

In abduction, the total mean of SLS level normal (M= 6.835; SD= 1.062) was lower than SLS level one IKBB (M= 8.626; SD= .766), and SLS level two IKBB (M= 13.998; SD= 6.973). It was important to notice that the standard deviation of SLS level one IKBB was lower than SLS level normal. Also, the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 7.192; SD= 1.148) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 20.805; SD= 1.468); in fact, it was lower compared to the SLS condition with no belt during SLS level one IKBB (M= 8.755; SD= .689). The total mean ankle abduction was higher during performing SLS without holding a belt compared to holding a belt (M= 5.986 > 3.83).

In adduction, the total mean of SLS level normal (M= 2.518; SD= 1.190) was lower than SLS level one IKBB (M= 7.793; SD= 2.650), and SLS level two IKBB (M= 16.337; SD= 5.538). Moreover, the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 11.04; SD= 1.199) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 21.63; SD= 1.784) compared to the SLS condition with no belt during SLS level one IKBB (M= 10.27; SD= .947). Also, the total mean ankle adduction was higher during performing SLS without holding a belt compared to holding the belt (M= 5.89 > 2.99).

This meant that all of the participants who held the belt showed lower angle alterations in ankle joint plantar flexion and adduction within the SLS conditions compared to not holding the belt. Also, all of the participants showed angle alterations in ankle joint dorsiflexion, plantar flexion, abduction, and adduction within the SLS levels compared to not holding the belt. Significant statistical differences were found among most participants in ankle joint dorsiflexion, plantar flexion, abduction, and adduction during performing SLS conditions. According to table 5, significant main effect was found in SLS condition (no belt/ belt). Significant main effect was found in SLS level (normal normal/level one IKBB/level two IKBB). Significant interaction effect was found in both dorsiflexion and abduction between SLS condition (no belt & belt/belt) and level (level normal & level one IKBB/level normal & level two IKBB).

Performing the SLS on stable and unstable surface (SLS level factor) was factor in angle differences from both sagittal and frontal planes. Also, Performing the SLS without/with the belt (SLS condition factor) was factor in angle differences from both sagittal and frontal planes. Both SLS level and condition were factors in angle differences. Fatigue could not have been a factor in these results due to the randomized selection of SLS condition order. Bateni, Zecevic, Mcllroy & Maki (2004) indicated that holding an object can have a deep effect on the control of upper-limb balance reactions. The nature of the held object and direction of the loss of balance did have some influence, in that there was a tendency to firmly grasp the belt in an effort to recover balance when falling forward.

Muscle strength and activation could have been a factor in these results due to the static SLS balance activity, the IKBB challenge, and due to the randomized selection of SLS condition order. In studies that found no significant increase in neuromuscular activation during movements on an unstable surface compared to a stable surface, researchers have concluded that a percentage of force had been diverted to joint stabilization (Anderson & Behm, 2005). There were a couple studies that did find increase in EMG activity of muscles controlling joints while unstable or perturbed (Gantchev & Dimitrova, 1996). This discrepancy may be attributed to the muscles examined. These two studies evaluated stabilizer muscles instead of prime movers. Their response to instability may differ from primarily stabilizing muscles (Anderson & Behm, 2005). Stabilizer muscles are usually not directly involved in a movement but work to maintain steadiness, so the primary movers can do their job. An example of ankle joint stabilizer muscles could include: peroneal, calf, and posterior tibialis muscles.

Another possibility for discrepancy could be the difference in experience level. The past studies had participants with experience on that particular balance training device, whereas, the current study had all beginner Isokinetic Balance Board (IKBB) users; therefore, these participants should not be expected to have the same results as those more experienced on the IKBB or other balance training devices. This meant that stability assistance was needed (SLS level one & two IKBB) to successfully perform SLS without the IKBB touching the ground or the participant falling off. Maybe the participants were provided with too much stability and did not have true angle differences during the SLS. Some participants needed more stability assistance than others, so there should have been a way to quantify or differentiate between balance abilities among participants. Balance assessment values result from input originating from not only the peripheral somatosensory system but also from both the visual and vestibular systems (DiStefano, Clark & Padua, 2009; Hrysomallis, 2011; Nashner, 1993). The ability to grasp structures for support in reaction to instability has an effect for the stability range of the body's posture; nonetheless, it is uncertain, how CNS resolves the potential conflict between holding an object and the need to release the held object and grasp an alternative support, especially if the held object is perceived to be relevant to the task of stabilizing the body (Bateni, Zecevic, Mcllroy & Maki, 2004).

Conclusions

According to the results of this study, performing SLS with the belt over stable (level normal) and unstable (level one & two IKBB) surfaces has an effect on ankle joint angles, especially ankle plantar flexion and adduction, compared to performing SLS without the belt over stable and unstable surfaces. There was a noticeable fear factor contributing to the participants' insecurities on the IKBB (level two IKBB), which meant the participants were more concerned about not falling off the IKBB than actually performing a static SLS. Since the participants were facing difficulty to perform on the IKBB independently, especially on the second level, researcher, physical therapists, and trainers should expect to see a decrease in ankle joint angle alterations after introducing the belt during performing the static SLS over stable and unstable surfaces. Possible reason for ankle angle differences could be due to the muscles that are not recruiting fully on their own to control balance, which could be identified via the use of EMG. Through examining the results of this study, researchers can conclude that the SLS level and introduction of the belt had an effective impact in the process of balance training or rehabilitating progression. Beginner IKBB users can use this training device for balance practice under close supervision but should not expect to see increase ankle joint stability or proprioception benefits until the IKBB can be used independently or with the introduction of the belt.

Practical Application and Use of Knowledge

Results of the current study showed that the SLS level, including the IKBB device, and SLS condition (belt) does have an interaction effect on ankle joint dorsiflexion, plantar flexion, abduction, and adduction during static SLS. Both factors had considered an effective training device and technique in the process of balance training or rehabilitating progression. Also, the IKBB device could provide variety in an exercise or therapeutic routine with the added benefits of proprioception training once stability is achieved or improved on their own, or with the gradual introduction of the belt. According to previous studies, static and dynamic proprioceptive training through the use of a wobble board (IKBB) and other balance training devices can significantly reduce sport-related injuries among healthy adolescents (DiStefano et al., 2009; Emery, Cassidy, Klassen, Rosychuk & Rowe, 2005; McGuine & Keene, 2006; McLeod, Armstrong, Miller & Sauers, 2009). The inclusion of balance training in a program is thought to improve co-activation of the muscles surrounding joints, increasing joint stiffness and active joint stability; also, it may alters biomechanical injury risk factors (Myer, Ford, McClean & Hewett, 2006). Moreover, the need for greater stabilizing responsibilities of the limb musculature may mimic more closely the typical requirements of daily activities or sport (Anderson & Behm, 2005). In order to gain the benefits of proprioception and increased muscle activity from performing exercise on a balance training device, expertise is needed. Balance training devices are only useful after an individual can perform on them independently without any form of stability assistance. The level of instability in different planes of motion is one of the mechanical reasons of variability between devices. Some devices have instability in only one plane where as others have instability in all planes, such as the IKBB that shows instability factor with the level of height (Weirich, 2010). Most beginners on balance training devices can benefit from closely supervised practice on the balance board device. It is known that training under unstable conditions provides a greater stress to the overall musculature compared to training under stable conditions (Anderson & Behm, 2005). Anderson & Behm (2005) mentioned that, according to Selye's adaptation curve, stress is substantial in forcing the body to adapt to new stimuli. Healthy adolescents who complete a balance training program using tilt boards can effectively increase their balance time on an unstable surface (Emery et al., 2005). Emery et al. (2005) demonstrated that improvements in static and dynamic balance were observed in the experimental group but not in the control group. Another similar study made weekly progressions in the difficulty of the exercises and increased the number of repetitions, which may have assisted in ameliorating neuromuscular control (McLeod et al., 2009).

Limitations

A major limitation in this study was the EMG troubleshooting and technical issues during testing the activity of both prime muscles (gastrocnemius and anterior tibialis); furthermore, male participants were the majority, and all of them showed reluctance or refusal of hair removal from the site of electrode placement. Therefore, EMG was excluded from this study. All Participants had once a month or no IKBB experience, so the researcher could not examine if experience level was related to peak ankle joint kinematic differences on the training device. All participants were healthy at the time of the study, so results may not be the same for individuals using the IKBB device for rehabilitation purposes. Also, the results were limited to only ankle joint in two planes (sagittal & frontal).

Future Recommended Research

There are many opportunities for further research surrounding the findings of the study including yet not limited to:

a) A study similar to the current study but including the lower extremity joints, in the pelvic and hip region.
b) A study similar to the current study but including the in-shoe plantar pressure analysis (F-Scan) that can provide the plantar pressure distribution.
c) A study similar to the current study but including joint internal and external rotation.
d) Investigate kinematic differences of various exercises on the IKBB
e) A study examining neuromuscular activity differences, including the prime movers, stabilizers, and core muscles.
f) A study examining neuromuscular differences between experienced and amateur IKBB users.
g) Examine neuromuscular differences and training effects of multiple training devices, such as Indo board and rocker boards.

h) Investigate neuromuscular differences of various exercises on the IKBB, such as squat.

i) Analyze kinetic and kinematic differences of various exercises, such as SLS and squat, with grasping objects in the upper extremity.

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APPENDIX

APPENDIX A

Barry University

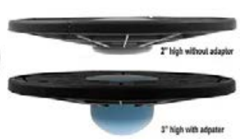
Recruitment Flyer

Be part of an important study in biomechanics

The Motion Analysis Center Lab (MAC-LAB) is recruiting individuals for participation in a research project titled biomechanical feedback on balance training for ankle stability: using two levels of isokinetic balance board (IKBB). The purpose of this research is to identify whether IKBB level and holding an object (Mulligan mobilization belt) present a differential indicator in ankle kinematics and muscle activity of two muscles (tibialis anterior & gastrocnemius) for individuals with healthy ankles during single limb stance (SLS) in order to provide feedback training for future balance programs.

Requirements:

- Ages 18 and older.
- Healthy individuals (no injuries or balance problems)
- Ability to perform SLS without and with IKBB

Eligible participants will attend training and testing session with one data collection period that will involve participants to perform SLS at self-selected pace. Time commitment for participation will be between 60 to 90 minutes of your time. Participants will be rewarded with a biomechanical evaluation in the end of the study.

There is minimal risk of feeling a degree of postural instability associated with participation with the study. However, protective floor mats will be used to minimize this risk. Any further precautions will be firmly maintained prior to the beginning of the study. If you have any concerns or questions regarding the study you may contact investigator, Sami Alahmari, at sami.alahmari@mymail.barry.edu or (215)869-3804, or Dr. Claire Egret at cegret@barry.edu, (305) 899-3064, or the Institutional Review Board point of contact, Barbara Cook, at bcook@barry.edu, (305)-899-3020. This research is being conducted at Barry University Campus. Your participation and time are greatly appreciated.

MAC-Lab

Barry University Biomechanics Master's Program

11300 NE 2nd Avenue

Miami Shores, FL 33161

APPENDIX B

Barry University

Informed Consent Form

Your participation in a research project is requested. The title of the study is biomechanical feedback on balance training for ankle stability: using two levels of isokinetic balance board (IKBB). The research is being conducted by Sami Alahmari, a student in the Human Performance and Leisure Sciences department at Barry University, and is seeking information that will be useful in the field of physical therapy, athletic training, and rehabilitation. The aims of the research is to identify whether IKBB level and holding an object (Mulligan blue belt) presents a differential indicator in ankle kinematic and muscle activity of two muscles (tibialis anterior & gastrocnemius) for individuals with healthy ankles during single limb stance (SLS) in order to provide a biofeedback training for future balance programs. In accordance with these aims, the following procedures will be used: A seven-camera 3D motion analysis system VICON, using a lower body marker system will record the ankle kinematics. Moreover, a Delsys electromyography (Bagnoli EMG system) will record the muscle activity. We anticipate the number of participants to be 40.

If you decide to participate in this research, you will be asked to do the following: be present to perform the SLS balance activity, and time commitment for participation will be between 60 to 90 minutes of your time.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects associated.

The risks of involvement in this study are minimal and include feeling a degree of postural instability. The following procedure will be used to minimize these risks: Protective floor mats. Although there are no direct benefits to you, your participation in this study may help our understanding of balance training programs in physical therapy and rehabilitation.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file in the researcher's office. All video data will be stored in the MAC-Lab files. Video tape will only show the lower extremities. Your signed consent form will be kept separate from the data.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me at, sami.alahmari@mymail.barry.edu or (215) 869-3804, my advisor, Dr. Claire Egret, at cegret@barry.edu, (305) 899-3064, or the Institutional Review Board point of contact, Barbara Cook, at bcook@barry.edu, (305)899-3020. If you are satisfied with the information provided and are willing to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Sami Alahmari and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to participate in this experiment.

______________________ __________

Signature of Participant Date

______________________ __________

Researcher Date

APPENDIX C

Barry University

Demographic and Experience Questionnaire

Name: …………………………………………..

Age: ……………….. Sex: ………………..

Weight: ……………. Height: …………….

Email address: …………………………………….

1. Describe any previous or recent experience with an Isokinetic Balance Board (frequency of use, etc.)?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

2. Describe any previous or recent experience with single limb/leg stance (recreational or professional functional exercise, etc.)?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

3. Do you have inner ear or pathologic balance problems?

Yes [ ] or No [ ]

4. Do you have any current injuries?

Yes [ ] or No [ ]

5. Have you had a head injury within the past 6 weeks?

Yes [ ] or No [ ]

6. Do you have chronic ankle instability?

Yes [ ] or No [ ]

7. Are you taking any medications or supplements?

Yes [ ] or No [ ]

If yes, please list what medications or supplements you are taking?
………………………………………………………………………………………………
………………………………………………………………………………………………

APPENDIX D

JOURNAL MANUSCRIPT

Abstract

The ankle complex comprises three articulations or joints (talocrural, subtalar, and distal tibiofibular joints) work in concert to allow coordinated rear-foot motion. The talocrural joint receives ligamentous support from a joint capsule and four ligaments. Injuries to the lateral ligaments of the ankle complex are common incurred by athletes, leading to ankle joint instability. Balance training programs and modalities, such as balance boards, are recommended to maintain stable ankles. This study was designed to identify whether balance board level and holding Mulligan mobilization belt present differential indicator for individuals with healthy ankles during single limb stance (SLS) in order to examine the effectiveness of introducing the belt in any balance training progression. Forty (40) healthy male and female adults (age M= 28.2500; SD= 6.79649) were recruited from in and out Barry University. The balance board that was used is Isokinetic Balance Board (IKBB) with two levels. The object that was held is Mulligan mobilization belt. A seven-camera 3D motion analysis system VICON, using a lower body marker system recorded the kinematic SLS trials for analysis. The participants performed a total of 18 randomized SLS trials for all conditions. A two-way repeated measures MANOVA was calculated to understand if there was an interaction between the two factors (SLS condition & level) on the dependent variables with a significance level of $p \leq 0.05$. Significant main effect was found (Lambda (4, 36) = .012; $p \leq 0.05$) between subjects in SLS condition (no belt & belt). Also, significant main effect was found (Lambda (8, 150) = .001; $p \leq 0.05$) within subjects in SLS level (normal, level one IKBB, and level two IKBB). Significant interaction effect was found (Lambda (8, 150) = .003; $p \leq 0.05$) within subjects in both dorsiflexion and abduction between SLS condition (no belt & belt/belt) and level (level normal & level one IKBB/level normal & level two IKBB). These findings suggest that researchers can conclude that the SLS level and introduction of the belt had an effective impact in the process of balance training or rehabilitating progression. Beginner IKBB users can use this training device for balance practice under close supervision but should not expect to see increase ankle joint stability or proprioception benefits until the IKBB can be used independently or with the introduction of the belt. Further investigation is needed to determine if experience level or a different form of balance exercise will affect lower body kinematic deviations on an IKBB.

Introduction

The ankle joint and foot make up a complex anatomical structure consisting of 26 irregularly shaped bones, 30 synovial joints, more than 100 ligaments, and 30 muscles acting on the segments. All of these joints must interact harmoniously and in combination to achieve a smooth motion [21]. The ankle complex comprises three articulations: the talocrural joint, the subtalar joint, and the distal tibiofibular syndesmosis. These three joints work in concert to allow coordinated movement of the rear foot [12, 21]. Rear foot motion is often defined as occurring in the cardinal planes as follows: sagittal-plane motion (plantar flexion-dorsiflexion), frontal- plane motion (inversion-eversion), and transverse-plane motion (internal rotation-external rotation) [9, 12]. Moreover, both ankle and foot support the weight of the body in both standing and locomotion [21].When the ankle complex is fully loaded, the articular surfaces are the primary stabilizers against excessive talar rotation and translation [12, 23]. In the closed kinetic chain, pronation consists of plantar flexion, eversion, and external rotation, while supination consists of dorsiflexion, inversion, and internal rotation. Closed kinetic chain dorsiflexion occurs when the tibia moves anteriorly on the fixed talus during weight bearing [12]. The three major contributors to stability of the ankle joints are (a) the congruity of the articular surfaces when the joints are loaded, (b) the static ligamentous restraints, and (c) the musculotendinous units, which allow for dynamic stabilization of the joints [8, 12]. The contribution of the ligaments to talocrural joint stability is crucial. The talocrural joint receives ligamentous support from a joint capsule and several ligaments, including the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL), and deltoid ligament. The ATFL, PTFL, and CFL support the lateral aspect of the ankle, while the deltoid ligament provides medial support [23]. Single Limb Stance (SLS) is a functional balance activity, and one of the primary tasks of that activity is to regain stability and coordination of the body [24]. Despite the involvement of SLS in daily life balance activities, scientific studies are still limited, particularly in the field of biomechanics [28]. In addition, the presence of balance boards added an important value in any functional balance activity [28]. Using an Isokinetic Balance Board (IKBB) to ameliorate stability has not been tested from a biomechanical perspective. Balance boards or wobble boards, such as the IKBB can be used to develop reflexes for athletic training, physical therapy, recreation and more [28]. IKBB is composed of two levels of difficulty. Moreover, it is used for proprioceptive and rehabilitation exercise to improve balance and coordination [4, 28]. Despite the benefits of this balance board, most weight bearing balance activities played substantial influence in improving the functional balance [1, 14]. In order to properly regain the functional outcome of practicing any sport, performing balance activities for effective rehabilitation of the athlete must be staged with clear intent and goals for each stage of recovery [1, 14]. Further knowledge in the topic of balance training and exercises, based on previous studies, was crucial in order to capture the essence of the present study. Balance exercises were mostly designed for an objective of ameliorating equilibrium and stability for many individuals despite their gender, age or physical abilities [15, 16]. Single-limb stance balance activity is considered one of the closed kinetic chain (CKC) exercises [5]. CKC exercises represent an integral part of rehabilitation programs after lower extremity injuries. For example, reliable research noted that progressive single-leg dynamic balance exercise programs have improved dynamic stability very quickly for subjects who were involved in sport activities, such as pre-season training [22]. In addition, it has been indicated that the most prevalent musculoskeletal injuries that occur in athletes were ankle sprains. Also, balance-training programs are tremendously substantial in eliminating the risk of ankle sprains in high school soccer and for basketball players [17]. Another study indicated that balance and coordination exercises are recommended for patients in need of reduction or elimination in the implications of proprioceptive deficit incidence and the symptom of “giving way” due to ligamentous injuries at the foot and ankle [8]. In addition, in patients with non-impaired, but unstable ankles, a conclusive study demonstrated that balance training activities have improved the joint proprioception and enhanced single-leg stance [24]. Using proprioceptive balance board training program has an impact in the limitation of ankle sprain recurrences [4, 27]. Nonetheless, it intervened in the occurrence of overuse knee injuries [27]. Another related study about balance board influence in training situations, maintained that the rate of significance, in the lower extremities, was greater than not using balance boards during training [25]. Functional ankle instability is one of the leading factors for using balance boards while training to regain functionality [26]. Both balance training and balance boards played vital role in both balance improvement and functional rehabilitation [1]. Some balance activities have been presented as a common group of activities among athletes for training as well as for popular rehabilitation tasks of exercise [1]. Factors of postural instability are many, yet body weight is one of the major indicators of postural instability [11]. Unregulated body sway oscillations were substantially observed in heavier weight individuals due to lower balance control sensitivity [11, 16]. In the present study, not too many published studies are presented in using two different heights of IKBB. The purpose of the study was to quantify the kinematic differences (mean values) at the ankle joint (sagittal-plane motion & frontal-plane motion) during static single-limb stance (SLS) without/with holding an object (Mulligan Mobilization Belt). As a result, kinematic differences had provided feedback on balance training or rehabilitating in terms of introducing the belt in the process of ankle joint balance progression. Two levels of balance board were used. The following hypothesis was investigated: Holding the belt during performing SLS without and with IKBB (two levels) presented a decrease in the mean maximum kinematics of the ankle (sagittal & frontal) compared to not holding the belt.

Methods

Forty (40) healthy male (36) and female (4) adults (age M= 28.2500; SD= 6.79649) were recruited from in and out Barry University to participate in the study. Participants were limited to healthy ankles and individuals. All participants were healthy and physically able to perform physical activity. After a review of the experimental and safety protocol, the participants signed an informed consent document approved by the Barry University Institutional Review Board, filled out a short demographic and experience questionnaire, and they were informed of their right to stop their participation in the study at any time. Benefits and risks of this study were made clear to the participants before signing the informed consent. There were no known risks associated with their participation.

Instrumentation

IKBB with two levels of difficulty (Adjustable for 2 degrees of difficulty: 10 degrees without adapter, and 15 degrees with adapter) was used. Also, Mulligan Mobilization Belt (8 foot, blue nylon belt, used to mobilize the patient while movement occurs, and belt can be adjusted with one hand and has a side release plastic buckle) was used. By using Vicon Nexus 1.8.5 program, 3D movements of the lower extremity segments were tracked by a 7-camera (MX-3+) with 8.5 mm lenses, collecting at 240 Hz. A static trials SLS were collected. The lower body anatomical coordinate system was then constructed for each participant based on the static trial, through using the Vicon Plug-In Gait standard lower body marker set (see figure 9). Data were analyzed with Vicon Polygon (Centennial, CO) software new version 4.1.

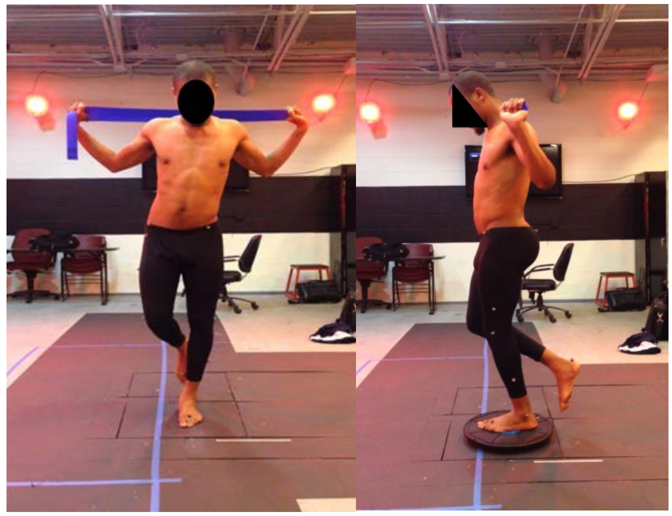
Procedures

The participants were instructed prior to their arrival to wear non-reflective firm fitting spandex shorts during SLS trials to eliminate marker errors. Then the participant's measurements were taken, by the investigator (shoulder length, leg length, knee width and ankle width). Sixteen reflective surface markers were placed over the skin. According to the VICON Nexus manual (Table 1), markers were positioned on both lower limbs over specific areas. Those areas were as follow: the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), lateral mid-thigh, lateral femoral condyle, lateral mid-calf, lateral malleolus, medial malleolus, posterior calcaneus, and head of the second metatarsal.

Cameras were calibrated according to VICON manual. A static capture of the participant was taken to create a local coordinate system. The application of modalities (test conditions) were randomized. Testing conditions were as follow: a) normal SLS (no IKBB modality), b) 1st level of IKBB, c) 2nd level of IKBB, d) normal SLS with belt, e) 1st level of IKBB with belt, and f) 2nd level of IKBB with belt. SLS balance activity was performed on left leg only. Belt length was twice shoulder length. The participants were introduced to the IKBB. Safety procedure was maintained to all of the participants, including the use of protective lab mats. Each participant was asked to perform SLS at self-selected pace, in the designated balancing space. Three trials of each testing condition were recorded and analyzed.

Experimental procedure was explained for each degree of balance board difficulty. For each testing condition with no use of belt, each participant was informed to perform SLS without and with IKBB and try to stabilize the total body at self-selected pace, abducted arms 90 degrees and pronated forearms. For each testing condition with use of belt, each participant was verbally informed to perform SLS without and with IKBB modality and try to stabilize the total body at self-selected pace, abducted arms 45 degrees, flexed elbows 90 degrees, and forearms in natural position; moreover, both hands grasp a belt of two times shoulder length (see figure 1). Each participant performed a total of 18 trials. During data collection, at least three successful trials was collected for each participant during each condition.

Figure 1: *Single Limb/Leg Stance (SLS) and handling Mulligan Mobilization Belt in two planes (frontal & sagittal).*



For each participant, experimental testing (data collection) were performed in one day for at least one hour and 30 minutes for each participant. The procedure consisted of the following: a) IKBB, Mulligan belt and safety introduction for 25 minutes, and b) lower limb marker set preparation for 30 minutes. Total preparation and training time is 55 minutes. Randomized data collection of each participant during single limb stance without and with use of belt was taken, and three successful trials for each condition were considered. Repetitions were reach up to three times, and the resting time needed between each repetition was five seconds. The total time needed for experimental data collection was 20 minutes for each participant. The residual time (15 minutes) was divided between filling out the demographic and experience questionnaire (10 minutes), and reading and signing the informed consent (5 minutes).

Design and Analysis

Polygon 4.1 new version software was used to analyze the kinematic data collected by the VICON infrared 3D cameras. A two-way repeated measures MANOVA was performed to understand if there was an interaction between these two factors (SLS condition & level) on the dependent variables, and to examine the significance (set at $p \leq 0.05$). When alpha (p) is set at 0.05, the number of participants was 40 (range 35-45) in order to have a meaningful effect size (Thomas & Nelson, 2011). All statistical tests were analyzed by Statistical Package for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA).

Results

Normality and Descriptive Analysis

The raw ankle joint kinematic peak values were transformed into useable data and then averaging the peak values of the three trials for each SLS condition. Table 1 showed the descriptive statistics for the two dependent variables (ankle joint dorsiflexion and plantar flexion).

Table 1: *Mean and standard deviation of the variables (as measured by degree) dorsiflexion and plantarflexion for each SLS level and condition*

Ankle Joint	SLS Level	SLS Condition	Mean	Std. Deviation	N
Dorsiflexion	Normal	No Belt	1.7350	.54985	40
		Belt	2.6850	.69855	40
		Total	2.2100	.78653	80
	Level One IKBB	No Belt	3.3450	.65943	40
		Belt	1.4375	.74479	40
		Total	2.3912	1.18729	80
	Level Two IKBB	No Belt	8.6975	.74918	40
		Belt	7.1175	.80380	40
		Total	7.9075	1.10817	80
Plantar Flexion	Normal	No Belt	2.7525	.78642	40
		Belt	2.7825	.84091	40
		Total	2.7675	.80909	80
	Level One IKBB	No Belt	8.1400	.87700	40
		Belt	6.3550	.92069	40
		Total	7.2475	1.26681	80
	Level Two IKBB	No Belt	23.0725	2.03734	40
		Belt	12.7650	1.40339	40
		Total	17.9188	5.46980	80

Table 2 showed the descriptive statistics for the other two dependent variables (abduction and adduction). The initial values showed no missing values, no significant outliers, and were normally distributed.

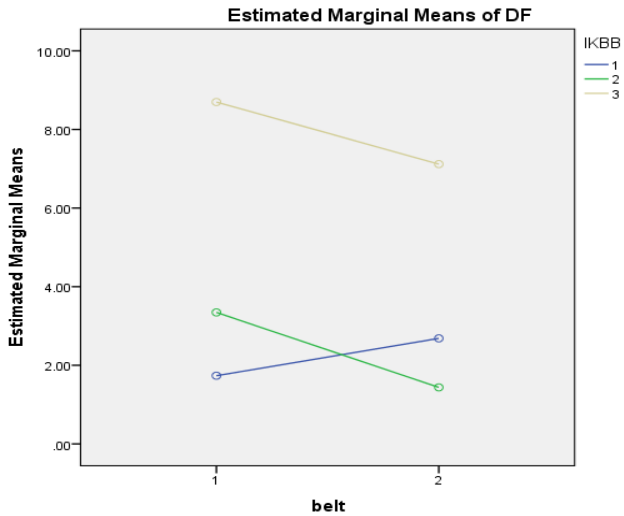
Table 2: *Mean and standard deviation of the variables (as measured by degree) abduction and adduction for each SLS level and condition*

Ankle Joint	SLS Level	SLS Condition	Mean	Std. Deviation	N
Abduction	Normal	No Belt	6.3600	1.01774	40
		Belt	7.3100	.88746	40
		Total	6.8350	1.06237	80
	Level One IKBB	No Belt	8.7550	.68909	40
		Belt	8.4975	.82539	40
		Total	8.6262	.76651	80
	Level Two IKBB	No Belt	20.8050	1.46899	40
		Belt	7.1925	1.14855	40
		Total	13.9988	6.97338	80
Adduction	Normal	No Belt	3.4450	.81805	40
		Belt	1.5925	.66309	40
		Total	2.5187	1.19005	80
	Level One IKBB	No Belt	10.2700	.94766	40
		Belt	5.3175	.87086	40
		Total	7.7938	2.65088	80
	Level Two IKBB	No Belt	21.6325	1.78489	40
		Belt	11.0425	1.19998	40
		Total	16.3375	5.53855	80

Multivariate Analysis

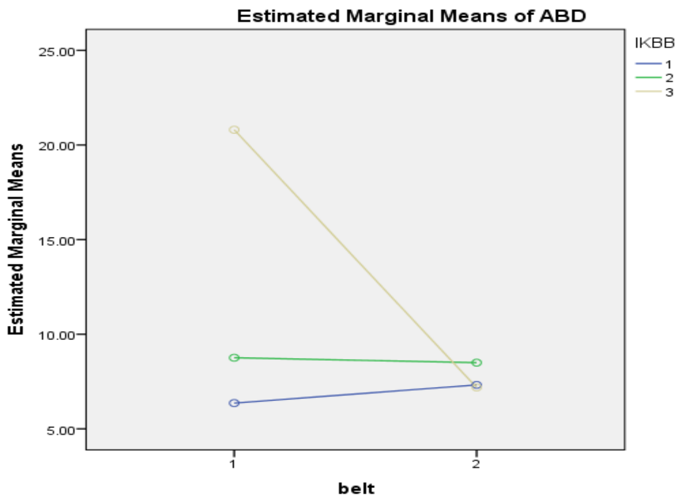
A two-way repeated measures MANOVA was calculated to examine the dependent variables at all conditions and levels of the independent variables. Table 3 showed the results of the multivariate tests (tests of within-subjects effects). Significant main effect was found (Lambda (4, 36) = .012; $p \leq 0.05$) between subjects in SLS condition (no belt & belt). Also, significant main effect was found (Lambda (8, 150) = .001; $p \leq 0.05$) within subjects in SLS level (normal, level one IKBB, and level two IKBB). Significant interaction effect was found (Lambda (8, 150) = .003; $p \leq 0.05$) within subjects in both SLS level and condition. Figure 1 (profile plot) showed that an interaction effect was found in dorsiflexion between normal SLS (no IKBB) and level one IKBB. Also, figure 2 (profile plot) showed that an interaction effect was found in abduction between normal SLS and level two IKBB during SLS condition (belt). All of the dependent variables (ankle joint angles) were significantly affected by the SLS condition and level.

Figure 1: *Dorsiflexion profile plot*



Note. DF: Dorsiflexion; 1(belt): no belt; 2(belt): belt; 1(IKBB): normal SLS (no IKBB); 2(IKBB): SLS level one IKBB; 3(IKBB): SLS level two IKBB.

Figure 2: *Abduction profile plot*



Note. ABD: Abduction; 1(belt): no belt; 2(belt): belt; 1(IKBB): normal SLS (no IKBB); 2(IKBB): SLS level one IKBB; 3(IKBB): SLS level two IKBB.

Table 3: *Results of multivariate tests of the independent variables (SLS condition & level)*

Effect			Value	F	Hypothesis df	Error df	Sig	Power
Between Subjects	Intercept	Wilks' Lambda	.004	2010.760	4.000	36.000	.000	1.000
Within Subjects	SLS condition	Wilks' Lambda	.012	750.329	4.000	36.000	.000	1.000
	SLS level	Wilks' Lambda	.001	789.859	8.000	150.000	.000	1.000
	SLS level * SLS condition	Wilks' Lambda	.003	304.750	8.000	150.000	.000	1.000

Note. Statistical difference is significant at $p \leq 0.05$.

Discussion

The hypothesis researched was that mean ankle joint angles (sagittal & frontal) values during holding the belt would not be greater during performing SLS without and with IKBB compared to not holding the belt. A scientific study stated that that holding an object provided no benefit, no consequence and no cost associated with dropping it [3]. Any main effects, interactions, unexpected findings, and importance of results between both factors (SLS condition & level) were discussed in more detail.

The hypothesis stated that mean ankle joint kinematic values during holding the Mulligan mobilization belt would not be greater during performing SLS without and with IKBB compared to not holding the belt. The statistics showed significant differences and clear trends between both factors (SLS condition & level). When looking at the total mean in dorsiflexion, plantar flexion, abduction, and adduction during each SLS level and condition. 100% of the participants showed increased total mean values in all dorsiflexion, plantar flexion, abduction, and adduction based on the SLS three levels (Table 1 & 2). In dorsiflexion, the total mean of SLS level normal (M= 2.21; SD= .786) was lower than SLS level one IKBB (M= 2.39; SD= 1.187), and SLS level two IKBB (M= 7.90; SD= 1.108). Despite the fact that total mean of SLS level one was lower than SLS level two IKBB, It was important to notice that the standard deviation of SLS level two IKBB was lower than SLS level one IKBB. The mean value of SLS condition with no belt during SLS level normal (stable surface) was lower than SLS condition with no belt during SLS level one IKBB (unstable surface); nonetheless, the mean value of SLS condition with belt during SLS level one IKBB was lower than SLS condition with no belt during SLS level normal. The mean value of SLS condition with no belt during SLS level two IKBB (M= 8.69; SD= .749) was greater than SLS condition with no belt during SLS level one IKBB (M= 3.345; SD= .659). It was interesting to notice that the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 7.11; SD= .803) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 8.69; SD= .749) compared to the SLS condition with no belt during SLS level one IKBB (M= 3.345; SD= .659).

In plantar flexion, the total mean of SLS level normal (M= 2.79; SD= .809) was lower than SLS level one IKBB (M= 7.247; SD= 1.266), and SLS level two IKBB (M=

17.918; SD= 5.469). Moreover, the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 12.765; SD= 1.403) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 23.07; SD= 2.03) compared to the SLS condition with no belt during SLS level one IKBB (M= 8.14; SD= .877). The total mean plantar flexion was higher during performing SLS without holding the belt compared to holding a belt (M= 5.66 > 3.650).

In abduction, the total mean of SLS level normal (M= 6.835; SD= 1.062) was lower than SLS level one IKBB (M= 8.626; SD= .766), and SLS level two IKBB (M= 13.998; SD= 6.973). Standard deviation of SLS level one IKBB was lower than SLS level normal. The mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 7.192; SD= 1.148) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 20.805; SD= 1.468); in fact, it was lower compared to the SLS condition with no belt during SLS level one IKBB (M= 8.755; SD= .689). The total mean ankle abduction was higher during performing SLS without holding a belt compared to holding a belt (M= 5.986 > 3.83).

In adduction, the total mean of SLS level normal (M= 2.518; SD= 1.190) was lower than SLS level one IKBB (M= 7.793; SD= 2.650), and SLS level two IKBB (M= 16.337; SD= 5.538). Moreover, the mean value of angle alteration of SLS condition with belt during SLS level two IKBB (M= 11.04; SD= 1.199) was not greater as the mean value of SLS condition with no belt during SLS level two IKBB (M= 21.63; SD= 1.784) compared to the SLS condition with no belt during SLS level one IKBB (M= 10.27; SD= .947). Also, the total mean ankle adduction was higher during performing SLS without holding a belt compared to holding the belt (M= 5.89 > 2.99).

This meant that all of the participants who held the belt showed lower angle alterations in ankle joint plantar flexion and adduction within the SLS conditions compared to not holding the belt. Also, all of the participants showed angle changes in ankle joint dorsiflexion, plantar flexion, abduction, and adduction within the SLS levels compared to not holding the belt. Significant statistical differences were found among most participants in ankle joint dorsiflexion, plantar flexion, abduction, and adduction during performing SLS conditions. According to table 5, significant main effect was found in SLS condition (no belt/ belt). Significant main effect was found in SLS level (normal normal/level one IKBB/level two IKBB). Significant interaction effect was found in both dorsiflexion and abduction between SLS condition (no belt & belt/belt) and level (level normal & level one IKBB/level normal & level two IKBB).

Performing the SLS on stable and unstable surface (SLS level factor) was factor in angle differences from both sagittal and frontal planes. Also, Performing the SLS without/with the belt (SLS condition factor) was factor in angle differences from both sagittal and frontal planes. Both SLS level and condition were factors in angle differences. Performing the SLS on stable and unstable surface was factor in the values of mean ankle angles from both sagittal and frontal planes with and without holding belt. Fatigue could not have been a factor in these results due to the randomized selection of SLS condition order. Holding an object can have a deep effect on the control of upper-limb balance reactions [3]. The nature of the held object and direction of the loss of balance did have some influence, in that there was a tendency to firmly grasp the belt in an effort to recover balance when falling forward. In studies that found no significant increase in neuromuscular activation during movements on an unstable surface compared to a stable surface, researchers have concluded that a percentage of force had been diverted to joint stabilization [2]. There were a couple studies that did find increases in EMG activity of muscles controlling joints while unstable or perturbed [10]. This discrepancy may be attributed to the muscles examined. These two studies evaluated stabilizer muscles while the current study did intended to evaluate prime movers. Their response to instability may differ from primarily stabilizing muscles [2]. Stabilizer muscles are usually not directly involved in a movement but work to maintain steadiness, so the primary movers can do their job. Another possibility for discrepancy could be the difference in experience level. The past studies had participants with experience on that particular balance training device, whereas, the current study had all beginner isokinetic balance board users; therefore, these participants should not be expected to have the same results as those more experienced on the IKBB or other balance training device. This meant that stability assistance was needed to successfully perform SLS without the IKBB touching the ground or the participant falling off. Maybe the participants were provided with too much stability assistance and did not have true muscle activation during the SLS. Some participants needed more stability assistance than others, so there should have been a way to quantify or differentiate between balance abilities among participants. Balance assessment values result from input originating from not only the peripheral somatosensory system but also from both the visual and vestibular systems [6, 13, 20]. The ability to grasp structures for support in reaction to instability has an effect for the stability range of the body’s posture; nonetheless, it is uncertain, how CNS resolves the potential conflict between holding an object and the need to release the held object and grasp an alternative support, especially if the held object is perceived to be relevant to the task of stabilizing the body [3].

Conclusions

According to the results of this study, performing SLS with the belt over stable (level normal) and unstable (level one & two IKBB) surfaces has an effect on ankle joint angles, especially ankle plantar flexion and adduction, compared to performing SLS without the belt over stable and unstable surfaces. There was a noticeable fear factor contributing to the participants’ insecurities on the IKBB (level two IKBB), which meant the participants were more concerned about not falling off the IKBB than actually performing a static SLS. Since the participants were facing difficulty to perform on the IKBB independently, especially on the second level, researcher, physical therapists, and trainers should expect to see a decrease in ankle joint angle alterations after introducing the belt during performing the static SLS over stable and unstable surfaces. Possible reason for ankle angle differences could be due to the muscles that are not recruiting fully on their own to control balance, which could be identified via the use of EMG. Through examining the results of this study, researchers can conclude that the SLS level and introduction of the belt had an effective impact in the process of balance training progression. Beginner IKBB users can use this training device for balance practice under close supervision but should not expect to see increase ankle joint stability or proprioception benefits until the IKBB can be used independently or with the introduction of the belt. On a final note, the belt introduction provided the practical concept of slow and gradual balance training or rehabilitating progression from stable to unstable surfaces with less ankle angle deviations, and more postural stability compared to no belt introduction.

Practical Application and Use of Knowledge

Results of the current study showed that the SLS level, including the IKBB device, and SLS condition (belt) does have an interaction effect on ankle joint dorsiflexion, plantar flexion, abduction, and adduction during static SLS. Both factors had considered an effective training device and technique in the process of balance training or rehabilitating progression. Also, the IKBB device could provide variety in an exercise or therapeutic routine with the added benefits of proprioception training once stability is achieved or improved on their own, or with the gradual introduction of the belt. According to previous studies, static and dynamic proprioceptive training through the use of a wobble board (IKBB) and other balance training devices can significantly reduce sport-related injuries among healthy adolescents [6, 7, 17, 18]. The inclusion of balance training in a program is thought to improve co-activation of the muscles surrounding joints, increasing joint stiffness and active joint stability; also, it may alters biomechanical injury risk factors [19]. Moreover, the need for greater stabilizing responsibilities of the limb musculature may mimic more closely the typical requirements of daily activities or sport [2]. In order to gain the benefits of proprioception and increased muscle activity from performing exercise on a balance training device, expertise is needed. Balance training devices are only useful after an individual can perform on them independently without any form of stability assistance. The level of instability in different planes of motion is one of the mechanical reasons of variability between devices. Some devices have instability in only one plane where as others have instability in all planes, such as the IKBB that shows instability factor with the level of height [28]. Most beginners on balance training devices can benefit from closely supervised practice on the balance board device. It is known that training under unstable conditions provides a greater stress to the overall musculature compared to training under stable conditions [2]. According to Selye's adaptation curve, stress is substantial in forcing the body to adapt to new stimuli [2]. Healthy adolescents who complete a balance training program using tilt boards can effectively increase their balance time on an unstable surface [7]. Improvements in static and dynamic balance were observed in the experimental group but not in the control group [7]. Another similar study made weekly progressions in the difficulty of the exercises and increased the number of repetitions, which may have assisted in ameliorating neuromuscular control [18].

Limitations

A major limitation in this study was the EMG troubleshooting and technical issues during testing the activity of both prime muscles (gastrocnemius and tibialis anterior); furthermore, male participants were the majority, and all of them showed reluctance or refusal of hair removal from the site of electrode placement. Therefore, EMG was excluded from this study. All Participants had once a month or no IKBB experience, so the researcher could not examine if experience level was related to peak ankle joint kinematic differences on the training device. All participants were healthy at the time of the study, so results may not be the same for individuals using the IKBB device for rehabilitation purposes. Also, the results were limited to only ankle joint in two planes (sagittal & frontal).

Research

There are many opportunities for further research surrounding the findings of the study including yet not limited to:

a) A study similar to the current study but including the lower extremity joints, in the pelvic and hip region.
b) A study similar to the current study but including the in-shoe plantar pressure analysis (F-Scan) that can provide the plantar pressure distribution.
c) A study similar to the current study but including joint internal and external rotation.
d) Investigate kinematic differences of various exercises on the IKBB
e) A study examining neuromuscular activity differences, including the prime movers, stabilizers, and core muscles.
f) A study examining neuromuscular differences between experienced and amateur IKBB users.
g) Examine neuromuscular differences and training effects of multiple training devices, such as Indo board and rocker boards.
h) Investigate neuromuscular differences of various exercises on the IKBB, such as squat.
i) Analyze kinetic and kinematic differences of various exercises, such as SLS and squat, with grasping objects in the upper extremity.

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