ACUTE EFFECTS OF BIOMECHANICAL MUSCLE STIMULATION TO LOWER EXTREMITY USING THE SWISSWING® ON SEBT SCORES IN PERSONS WITH AND WITHOUT CHRONIC ANKLE INSTABILITY

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The objective of this study was to investigate the acute effects of biomechanical muscle stimulation (BMS) on neurological control by evaluating performance on the star excursion balance test (SEBT) among uninjured and chronic ankle instability (CAI) subjects. Forty subjects aged 18 to 26 who participated in physical activity at least two times a week were placed in two groups: CAI or non-CAI group. Subjects performed 4 unscored SEBT practice attempts before completing 3 baseline tests were recorded and averaged. Experimental groups (CAI and Non-CAI) performed a 3 seated BMS intervention for 2 minutes each at 20 Hz: bottom of foot with both feet; heels of both feet; and gastrocnemius belly of both legs. Control group (CAI and Non-CAI) received no intervention and simply sat for 9 minutes. Three posttest SEBTs were recorded and averaged.

A delta score was calculated by finding a change score between pre and post for each of the 8 directions of the SEBT. The MANOVA for SEBT change scores revealed no statistically significant differences between CAI and Non-CAI in both experimental and control groups relative to excursion direction ($p > 0.05$). Further analysis revealed a main effect of group (experimental and control) showing statistical significance ($F \geq 6.317, p \leq 0.017$) when using change scores in all excursion directions. Results suggest that the
BMS intervention can have a positive effect on SEBT performance in a variety of populations.
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CHAPTER I
INTRODUCTION

Ankle injuries are very common in athletics (Brown & Mynark, 2007; Carcia, Martin, & Drouin, 2008; Demeritt, Shultz, Docherty, Gansneder, & Perrin, 2002; Hertel, 2000; Hiller, Kilbreath, & Refshauge, 2011; Olmsted, Carcia, Hertel, & Shultz, 2002). An ankle sprain creates structural damage to the lateral or medial ligamentous, nervous and musculotendinous tissue around the ankle complex causing pain, swelling, laxity, and neuromuscular deficits (Hertel, 2000). These neuromuscular deficits can lead to impaired balance, reduced joint position sense, slowed contraction of the peroneal muscles to inversion perturbation of the ankle, decreased nerve conduction velocity, impaired cutaneous sensation, strength deficits, and decreased dorsiflexion range of motion (Hertel, 2000). Chronic ankle instability (CAI) is identified in individuals experiencing recurrent sprains, unknown long-term consequences to their joint health, and symptoms of instability persisting longer than six months (Brown & Mynark, 2007; de Vries, Kingma, Blankevoort, & van Dijk, 2010). The most common characteristics of CAI include pain, swelling, loss of strength, and instability (Hiller et al., 2011). In addition to the physiological effects, the classic symptom of CAI is a subjectively reported phenomenon of the tendency to “give way” during normal activity (Demeritt et al., 2002). As CAI continues to evolve as a predominant injury in sport, the definition continues to change slightly but maintains the classic symptom of “giving away” as a key factor in diagnosis of this condition. CAI involves both mechanical (excessive inversion laxity of the rear foot or excessive anterior laxity of the talocrural joint) and functional
(experiencing frequent episodes of ankle joint giving way and feelings of ankle joint instability) instability of the ankle joint (O’Driscoll & Delahunt, 2011). Functional instability predisposes individuals to reinjury because neuromuscular deficits result following injury (Hertel, 2000). Continued study of CAI will provide more concise definition of CAI, which may illuminate strategies to integrate into rehabilitation and treatment to ensure maximal functionality to the ankle complex.

Advancements in therapeutic interventions like biomechanical muscle stimulation (BMS) have recently attracted interest in the athletic population as a means to facilitate injury recovery and/or return to play. BMS was developed in Russia at the end of 1970 by Professor Nazarov and is primarily applied in the field of competitive sport (Hansenberger, Wick, & Lenz, 2007). This external stimulation to muscle tissue facilitates a mechanical stretch of the muscle fibers, specifically the muscle spindle leading to a contraction resulting in a tonic vibratory response (Peer, Barkley, & Knapp, 2009). When BMS is applied directly to the area with lower stimulation loads compared to whole body vibration (WBV), a more comfortable intervention is provided to facilitate a therapeutic benefit (Peer et al., 2009). Due to these physiological changes, BMS has been shown to increase range of motion in healthy young and older adults (Ridgel, Peacock, Sanders, Corbett & Peer, 2011). Research has also been performed to determine the effects of BMS on improving strength and power (Luo, McNamara, & Moran, 2005). BMS has been combined with conventional resistance training in an attempt to demonstrate greater gains in neuromuscular performance than from conventional resistance training alone (Luo et al., 2005). BMS has also been shown to
help athletes in their specific sport train more efficiently due to the increases in muscle capability through manipulation of intrinsic feedback. It has been hypothesized that applying vibrations might lead to positive results in the final performance as well as mastering a skill in the same manner (Liebermann et al., 2002). Previous research also examined BMS and found it increased range of motion and flexibility, decreased muscle stiffness, increased recovery from musculoskeletal injury, and decreased pain (Peer et al., 2009). Due to these physiological effects of BMS, it may be a viable therapeutic intervention for CAI. Neuromuscular deficits in CAI can cause impairments to both functional and mechanical at the ankle joint (Hertel, 2000; O’Driscoll & Delahunt, 2011). Functional instability is detected when evaluating neurological control by the star excursion balance test (SEBT) in people with CAI (O’Driscoll & Delahunt, 2011). BMS can facilitate flexibility, increase range of motion, decrease muscle stiffness, increase recovery from musculoskeletal injury, increase strength and power, and decrease pain (Peer et al., 2009). This study investigated if neurological control can be improved by BMS in subjects with CAI.

**Statement of Problem**

CAI creates balance deficits at the ankle joint (Hertel, 2000). The ability to be able to use a full range of motion is inhibited by the injury due to laxity or structural damage, which affects the neurological system (Hertel, 2000). Contemporary interventions for CAI have proven effective to increase specific physiological and functional performance; however, BMS has not yet been investigated as a tool to
facilitate balance in the CAI population (Brown & Mynark, 2007; Demeritt et al., 2002; de Vries et al., 2010; Hertel, 2000; Hiller et al., 2011; O’Driscoll & Delahunt, 2011).

**Purpose**

The purpose of this study is to investigate the acute effects of BMS on neurological control by evaluating performance on the SEBT among uninjured and CAI subjects.

**Research Questions**

1. Does biomechanical muscle stimulation to the lower extremity improve performance on the SEBT in persons with CAI?
2. Does biomechanical muscle stimulation to the lower extremity improve performance on the SEBT in uninjured persons?
3. Is biomechanical muscle stimulation more effective as an intervention on neurological control with CAI or uninjured persons?

**Assumptions**

The researcher assumes that all participants agree to the terms and conditions of the study and voluntarily participate as indicated in their consent to participate. The researcher assumes that all participants are honest in reporting previous injuries and their activity levels. In addition, it is an assumption of the researcher that the participants put forth their maximal efforts when performing the SEBT in order for the researcher to gain the best and most accurate information.
Delimitations

This research did not study the effects of BMS on any other injury besides chronic ankle instability and can only be interpreted as such. Other balance tests besides the SEBT were not selected as measuring tools because of preference of the researcher and the support of previous literature. Therefore, the results can only be utilized to interpret performance on this specific test of functional balance.

Operational Terms

*Biomechanical muscle stimulation:* Mechanical action onto the human body by means of vibration having respectively a specific frequency and a specific amplitude which are selected in accordance with the desired application. The vibrations that resemble the natural vibrations of the body and imitate the same are acting upon the strained or expanded muscles along the muscle fiber. By purposively influencing the vibrational parameters, BMS displays positive effects on the body (Hansenberger et al., 2007).

*Chronic ankle instability:* Two or more ankle sprains happening prior of 6 months. Having recurrent episodes of ankle instability or “giving way” regardless of the existence of neuromuscular deficits or pathologic laxity (Hiller et al., 2011). The number of recent giving-way episodes, both perceived and real, should be noted, mechanical instability tested in at least the anterior-posterior and medial direction, and any activity limitation and participation restriction be measured using instruments such as the Foot and Ankle Ability Measure (Carcia et al., 2008).
Non-chronic ankle instability: One or less ankle sprains with no injury more recent than the prior 6 months, no reported episodes of giving way, or no laxity when testing anterior and posterior drawer, and talar tilt.

Foot and Ankle Ability Measure: A region-specific, non-disease-specific outcome instrument that possesses many of the clinimetric qualities recommended for an outcome instrument (Carcia et al., 2008). This tool helps identify and evaluate instruments to quantify functional disabilities with the ankle and foot (Carcia et al., 2008).

Star Excursion Balance Test: A dynamic test that requires strength, flexibility, and proprioception and has been used to assess physical performance, identify chronic ankle instability, and identify athletes at greater risk for lower extremity injury: When standing on the dominant limb and reaching with the contralateral limb as far as possible in the anterior, anteromedial, anterolateral, medial, lateral, posterior, posteromedial, and posterolateral directions (Plisky et al., 2009).

Summary

Functional stability of the ankle is disturbed in patients with CAI due to an initial ankle inversion or eversion trauma (Hertel, 2000; Hiller et al., 2011). BMS has been proven to have positive functional and physiological effects on other anatomical regions. SEBT can measure the deficits of functional instability in the lower extremity (Luo et al., 2005). This study observed the acute affects of a BMS treatment on people with CAI to determine if BMS is a viable therapeutic intervention to restore functional stability.
CHAPTER II

REVIEW OF LITERATURE

Introduction

Ankle injuries are frequent in sports (Brown & Mynark, 2007; Carcia et al., 2008; Demeritt et al., 2002; Hertel, 2000; Hiller et al., 2011; Olmsted et al., 2002). A common outcome of repeated ankle sprains is CAI (Brown & Mynark, 2007; de Vries et al., 2010; Demeritt et al., 2002; Hiller et al., 2011). CAI causes impediment in nervous and musculotendinuous tissue around the ankle complex caused by pain, swelling, laxity, and neuromuscular deficits from previous ankle sprains (Hertel, 2000). Vibration therapy is being examined in research as a therapeutic intervention. The use of vibration has been used as an exercise intervention to help improve strength, endurance, and power prior, during, and after exercise (Cardinale & Wakeling, 2005; Luo et al., 2005; Mikhael, Orr, Amsen, Greene, & Fiatarone Singh, 2010). Recent research has investigated vibrations to be used as a therapeutic modality to assist after an injury to facilitate the recovery process and restore function (Barnes, Perry, Mundel, & Cochrane, 2012; Peer et al., 2009).

Therefore, the purpose of this review is to look at chronic ankle instability causes and symptoms, the discovery and use of vibration therapy, previous research conducted, and the transition from an exercise intervention to a therapeutic modality for injuries.

Chronic Ankle Instability

Definition

Inversion ankle sprains are one of the most common injuries among athletes (Demeritt et al., 2002; Gribble, Hertel, Denegar, & Buckley, 2004; Olmsted et al., 2002).
At least half the population will experience one ankle sprain during their life (Nyska et al., 2003). After the first ankle sprain occurs the rate of recurrence may be as high as 80% among active individuals (Gribble et al., 2004). In addition, after an ankle sprain 30% will report persistent symptoms of pain, swelling, decreased function, feelings of ankle joint instability, and recurrent sprains (Brown & Mynark, 2007; O’Driscoll, & Delahunt, 2011). Following the injury, damage not only occurs to the structural integrity of the ligaments but also to various mechanoreceptors in the joint capsules, ligaments, and tendons about the ankle complex (Brown & Mynark, 2007; Olmsted et al., 2002). These mechanoreceptors offer feedback regarding joint pressure and tension, ultimately providing a sense of joint movement and position (Olmsted et al., 2002). The damage occurring to the mechanoreceptors contributes to the feelings of instability (Brown & Mynark, 2007). Multiple studies have demonstrated larger deficits in proprioceptive capabilities than to deficits in muscle strength (Demeritt et al., 2002). Increased ligamentous laxity, proprioceptive deficits, and neuromuscular control are impairments in patients with CAI due to the initial ankle sprain (de Vries et al., 2010; Hiller et al., 2011). Joint range of motion is beyond the normal expected for physiological or accessory range of motion (O’Driscoll & Delahunt, 2011), although increased laxity is not present in all patients with recurrent giving away or instability (de Vries et al., 2010). Even though acute symptoms of an ankle sprain may resolve, many people report persistent problems (Hiller et al., 2011).

Conservative treatment of an ankle sprain often leads to a full recovery in the majority of the population, although some people continue to suffer from recurrent
sprains or instability (de Vries et al., 2010). This can be due to the lack of care or the extent of damage present. If this instability persists for longer than six months, this is referred to as CAI (de Vries et al., 2010). CAI is most commonly diagnosed from residual problems of frequent ankle sprains that include a subjectively reported phenomenon defined as “giving way” during normal activity as compared to the same phenomenon occurring in an unstable knee, functional instability, and mechanical instability (Brown & Mynark, 2007; Demeritt et al., 2002; Hiller et al., 2011; Nyska et al., 2003; O’Driscoll & Delahunt, 2011). Both mechanical and functional instability is present when recurrent sprains occur (Hiller et al., 2011).

Functional instability is defined as the tendency of frequent episodes of “giving way” that provides a perceived instability of the ankle joint (Hiller et al., 2011; O’Driscoll & Delahunt, 2011). Functional or perceived instability is when the patients feel their ankle to be unstable, whether or not this perception is associated with physical signs (Hiller et al., 2011). Using the term “perceived instability” would make a clear difference between impairments involved with CAI and any functional or activity limitations that may result or coexist (Hiller et al., 2011). Perceived instability is caused from subtalar instability (Nyska et al., 2003). The decrease in perceived instability diminishes the reliability of static and dynamic support of the joint (Demeritt et al., 2002). This gives the perception that the ankle is less functional when compared bilateral or before the injury occurred (Hiller et al., 2011).

Mechanical instability is the excessive laxity of the rear foot or excessive laxity of the talocrural joint (O’Driscoll & Delahunt, 2011). Mechanical instability is focused on
the anatomical structures of the ankle joint. These anatomic changes of excessive laxity at the ankle joint can expose a patient to further episodes of instability (Hiller et al., 2011). Although laxity could lead to further instability, there may or may not be reinjury to the ankle (Hiller et al., 2011). When perceived and mechanical instability coexist in the ankle, recurrent sprains can arise or can be present separately (Hiller et al., 2011).

CAI is commonly used in research but the definition is consistently changing (Hiller et al., 2011). CAI is assessed clinically by evaluating laxity and radiologically by evaluating radiographs for mechanical instability (de Vries et al., 2010; Nyska et al., 2003). However, there is a low correlation between radiographs and perceived instability based on subjective input (Nyska et al., 2003). The difference between perceived CAI to actual functional performance has received minimal attention (Demeritt et al., 2002). This results in the inconsistencies in terminology, definitions, and impairments that lead to activity limitations and participation restrictions (Hiller et al., 2011). Research is constantly being conducted to eliminate these inconsistencies.

**Foot and Ankle Ability Measurement**

The perceived deficits from CAI can be examined by using a variety of evaluative instruments. At this point in time there is no universally accepted instrument that can be used to evaluate changes in self-reported physical function for individuals with leg, ankle, and foot musculoskeletal disorders (Martin, Irrgang, Burdett, Conti, & Van Swearingen, 2005). Many different evaluation instruments can be used to help distinguish someone with an injury from a healthy individual. The Ankle Instability Instrument, Cumberland Ankle Instability Tool and Foot and Ankle Ability Measure (FAAM) are tools used to
measure an individual’s change in ankle health status over time, thereby assessing the effectiveness and outcome of treatment (Carcia et al., 2008). The FAAM is a reliable, responsive, and valid measure of physical function for individuals with a broad range of musculoskeletal disorders of the lower leg, foot, and ankle with a test retest reliability of 0.89 and 0.87 for the activity of daily living and Sports subscales (Martin et al., 2005). The FAAM is split between two different sections of activities of daily living and sports subscales.

**Star Excursion Balance Test**

Balance is an essential physiological element for athletes and physically active people alike. How athletes and physically active people from different sports perform on balance tests is not well understood (Bressel, Yonker, Kras, & Heath, 2007). The decrease in ability to maintain balance in athletes without recent history of ankle sprains can predict future sprains (de Vries et al., 2010). There are two different types of balance or postural control assessments. Static balance describes attempting to maintain a position with minimal movement while dynamic balance is maintaining a stable base of support while completing a prescribed movement (Robinson & Gribble, 2008). Dynamic balance or postural control is much more physically demanding when compared to static. When maintaining dynamic balance of postural control adds additional demands on proprioception, range of motion and strength (Robinson & Gribble, 2008). The SEBT is a multidirectional test designed to measure dynamic balance that requires strength, flexibility, and proprioception and can provide a more accurate assessment of lower extremity function than tests involving only quiet standing or static balance (Gribble &
Hertel, 2003; Hardy, Huxel, Brucker, & Nesser, 2008; Olmsted et al., 2002; Plisky et al., 2009; Robinson & Gribble, 2008). To perform the SEBT, a subject will be challenged to assume a single leg stance and reach as far as possible in eight directions with the contralateral leg (Gribble et al., 2004; Hardy et al., 2008; Plisky et al., 2009). The reach directions of the SEBT are anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), lateral (L), and anteriolateral (AL; Hardy et al., 2008). The directions are at a 45-degree angle to the next direction in relation to the center of the grid (Hardy et al., 2008). The stance leg or test leg is the leg being tested for dynamic balance whereas the reach leg will be the opposite. The ball of the foot or the plantar aspect of the first metatarsophalangeal of the test leg will be positioned on the intersecting lines at the center of the grid with their reach leg next to them at the start position (Hardy et al., 2008). The subjects should be akimbo and keep the stance leg’s heel on the ground. The subject is then instructed to reach with the contralateral leg to the maximal distance possible and touch the line using the most distal part of their foot, without supporting themselves, while maintaining their stance leg in the center of the grid (Hardy et al., 2008). The reach leg will immediately return to the start position after every reach (Hardy et al., 2008). The reach order is anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anteriolateral (Hardy et al., 2008). If the right leg is being tested, then the medial side will be to his or her left and the lateral to his or her right (Robinson & Gribble, 2008). The test is conducted counter clockwise. If the left leg is being tested then the medial side will be to his or her right and lateral to the left (Robinson, & Gribble, 2008). The test is conducted clockwise.
The recommended SEBT protocol is to perform seven trials consisting of four practice and three test trials for each of the eight directions (Gribble & Hertel, 2003). After the three test trials are performed and measured, an average of the eight directions should be calculated. The average scores should be normalized due to different heights and leg length of subjects (Gribble & Hertel, 2003). Before SEBT is performed, a true leg length measurement should be taken. To normalize the scores, the excursion distance should be divided by the subject’s true leg length and multiplied by a hundred (Gribble & Hertel, 2003).

The SEBT is highly reliable and valid for both research and clinical purposes (Gribble et al., 2004). The intrarater reliability of the SEBT has been reported as moderate to good, 0.67-0.97, and interrater reliability has been reported as poor to good 0.35-0.93 (Plisky et al., 2009; Robinson & Gribble, 2008).

The SEBT can be used for clinical use and screening purposes to find the greatest amount of information in the shortest amount of time to assess physical performance and identify athletes at a greater risk for lower extremity injury (Plisky et al., 2009). This offers a simple, reliable, low cost alternative to other methods that are currently available (Olmsted et al., 2002). The SEBT is sensitive to functional deficits due to musculoskeletal impairments of CAI, anterior cruciate ligament reconstruction, quadriceps strength deficits, and patellofemoral pain syndrome (Gribble & Hertel, 2003; Olmsted et al., 2002; Plisky et al., 2009; Robinson & Gribble, 2008). Distinct muscle recruitment patterns in the stance leg or test leg in each of the eight reaching directions suggest that specific neuromuscular control patterns are required to maintain the base of
support during the SEBT (Gribble et al., 2004). Previous research using the SEBT has demonstrated a decrease in dynamic balance or postural control in those with CAI when compared to healthy subjects (Gribble et al., 2004; Plisky et al., 2009; Robinson & Gribble, 2008). The SEBT has also been used to identify people who are at greater risk for lower extremity injuries (Plisky et al., 2009).

**Vibration**

**Definition**

Vibration from natural occurrences or from those that are manipulated affect the body. Our bodies interact with the environment and experience externally applied forces that induce vibrations and oscillations within the tissues of the body (Cardinale & Wakeling, 2005). An example of such a force is experienced through the leg when the heel strikes the ground during running (Cardinale & Wakeling, 2005). Mechanical vibrations stimulate the muscles causing a tonic vibratory response (Cardinale & Bosco, 2003; Peer et al., 2009). Tonic vibratory response is a reflex that results from the stimulation of the muscle spindle and joint receptors leading to a contraction of the muscle stimulated and cause reciprocal inhibition (Atha, Wheatley, & Wheatley, 1976; Cardinale & Bosco, 2003; Peer et al., 2009). Using vibration as a treatment, inhibition of the monosynaptic reflex causes depression of the antagonist muscle group resulting in facilitation of a muscle stretch (Atha et al., 1976; Cardinale & Bosco, 2003; Peer et al., 2009). When vibrations are produced, the external stimulation to muscle tissue facilitates mechanical stretch of the muscle fibers similar to that of a maximal stretch by simulating biomechanical stressors (Peer et al., 2009). After the muscles or tendons are affected
from the vibration there is a significant change in position and velocity sensing (Liebermann et al., 2002). This can make the muscles or joints affected from the vibration feel as if they are able to move differently in space. These movements may cause undershooting or overshooting limb displacements without the participant being aware of these changes (Liebermann et al., 2002). Vibration stimulation of proprioceptors might also have positive effects in training muscle elasticity in sports (Liebermann et al., 2002).

**Function**

Mechanical vibration is dependent on three factors: amplitude, frequency and magnitude. The extent of the oscillatory motion determines the amplitude or peak to peak displacement, in millimeters, of the vibration. The repetition rate of the cycles of oscillation denotes the frequency of the vibration, measured in hertz (Hz) and the acceleration indicates the magnitude of the vibration (Cardinale & Bosco, 2003; Cardinale & Wakeling, 2005). Although we do not yet know the most effective range of vibration settings that can be applied safely and maintain a beneficial physiological response, recent work has suggested that low amplitude and low frequency mechanical stimulation on the human body is a safe and effective (Cardinale & Wakeling, 2005). Vibration therapy if not properly applied may have negative effects on the body. Prolonged exposure to vibration has been shown to have detrimental effects on the soft tissues, including muscle fatigue, reductions in motor unit firing rates and muscle contraction force, decreases in nerve conduction velocity, and attenuated perception (Cardinale & Wakeling, 2005). Also, there are contraindications with vibration therapy.
of joint prostheses, cardiac pacemakers, diabetic neuropathy, and cardiovascular and circulatory diseases (Peer et al., 2009).

**Whole Body Vibration (WBV)**

WBV are vibrations that are applied indirectly to the muscle being trained (Luo et al., 2005). Vibrations are transmitted from a vibrating source away from the target muscle as the vibrations travel through part of the body to the targeted muscle (Luo et al., 2005). Typically, WBV devices transfer vibrations to the body through a vibrating platform when used therapeutically. This platform delivers vibrations to the whole body through oscillating plates (Luo et al., 2005). It is possible to use many different positions when implementing WBV. A locked knee position is when a person is standing straight up on the platform. A locked knee position will send the vibrations to the entire body as a whole. A semi flexed knee position is when the subject is crouching down in a squat position (Luo et al., 2005). This position will limit the vibrations from passing through the lower limbs to the upper body. Even when using WBV, low amplitude and low frequency stimulation on the human body is safe and effective (Cardinale & Wakeling, 2005).

**Short and Long Term Effects**

WBV exercise has been shown to acutely enhance strength and power capabilities in trained people (Cardinale & Wakeling, 2005). Short treatment sessions for WBV on physically active people has been shown to significantly enhance force and power generating capacity of the lower extremities (Cardinale & Wakeling, 2005). When resistance exercises are performed with WBV, physically active people can improve
vertical jumping ability more than resistance training alone (Cardinale & Wakeling, 2005). Long term use of WBV has a better result in untrained people than with trained people (Cardinale & Wakeling, 2005). However, long-term effects from WBV can have detrimental effects on the spine (Cardinale & Wakeling, 2005). Safety procedures have suggested that WBV should be performed for a short period of time on the vibration plate with knees semiflexed to limit transmission of vibrations to the head and spine to limit the impact on these specific structures (Cardinale & Wakeling, 2005). Further research needs to be conducted to understand how much vibration to the body is necessary and effective WBV protocol (Cardinale & Wakeling, 2005).

**Performance Enhancing Application—Strength and Power**

Vibration as a training modality did not attract attention until the late 1980s (Issurin, 2005). The effects vibration has on strength and power development are dependent upon the perimeters of application, amplitude and frequency and exercise procedures of type of training type, intensity and volume. These results will vary depending on the amount of vibration application. Vibration when combined with resistance training has resulted in superior gains in neuromuscular performance than from resistance training alone (Luo et al., 2005).

WBV research has shown to increase maximal strength but different parameters will result in different outcomes (Luo et al., 2005). In healthy young males, WBV has shown to increase vertical jump height (Mikhael et al., 2010). In addition, WBV has shown a slight decrease or no change in peak force or peak power and no difference on an electromyography (Cormie, Deane, Triplett, & McBride, 2006). WBV parameters were
set at 30 Hz while the subject was in a half-squat position. These results suggest that these specific parameters used where able to increase jump height but have no effect on force, power or muscle activity.

WBV research has also focused on the elderly population. Men and women between the ages of 50 and 80 were recruited to study how vibration therapy impacted muscle function, muscle morphology and physical performance (Mikhael et al., 2010). This study focused on what position performed with WBV would have the most significant results. Flexed knees WBV, locked knees WBV, and sham WBV group were examined (Mikhael et al., 2010). Muscle function was looking at strength, power, and velocity in both the upper body and lower body (Mikhael et al., 2010). Velocity significantly improved in the flexed knees compared to the locked knees group with the upper body and strength increased significantly in both groups in the lower body (Mikhael et al., 2010). These results can be determined by the parameters and time elapsed with WBV. There were no significant results with muscle morphology relative to muscle mass and fat mass and no significant results in physical performance in gait and balance measures (Mikhael et al., 2010).

When using WBV to increase strength and power, the results will likely vary based upon the parameters of the application. Many studies have used constantly changing parameters to determine the most effective way to transmit vibrations to the body and end with the greatest results; however, no consensus relative to the best protocol has yet been validated.
**Therapeutic Vibration Application in Sports Medicine**

The integration of vibration in the athletic setting was introduced relatively recently by Russian scientists who developed specific devices to transmit vibratory waves from distal to proximal links of muscle groups (Cardinale & Wakeling, 2005). Recently there has been an increased interest with these devices. This new interest has sparked research which has been investigating the effects of vibration on muscular function and functional performance (Cronin, Oliver, & McNair, 2004). Many physically active people and fitness centers have used vibrations but the current knowledge and literature is very limited on appropriate safety and effective exercise protocols (Cardinale & Wakeling, 2005).

Efficient recovery after an athletic event has always been of interest in athletic populations. Athletes utilize various recovery modalities in an attempt to accelerate the recovery process to minimize the performance decrements (Barnes et al., 2012). WBV could possibly be used as a post exercise recovery modality to reduce pain and muscle soreness (Barnes et al., 2012). It has been theorized that WBV could increase blood flow to accelerate the recovery process by increasing oxygen delivery, raising muscle temperature, and enhancing waste product removal that inhibit tissue repair (Barnes et al., 2012). After an eccentric exercise, a decrease in functional performance will result after WBV treatment at 26 Hz (Barnes et al., 2012). By using WBV in the first 24 hours after damaging exercise may be detrimental to force production and/or recovery (Barnes et al., 2012). This can suggest that WBV should not be used as a post exercise recovery modality to accelerate the recovery process.
Biomechanical Muscle Stimulation

WBV therapy can positively impact range of motion and muscle stiffness but does have some potential unwanted side effects such as transient numbness (Siegmund, 2011). Due to the negative effects from WBV, the future of vibration therapy needed to change to be more beneficial. BMS was developed in Russia at the end of the 1970 by Professor Nazarov and was primarily applied in the field of competitive sport (Hansenberger et al., 2007). This device was comprised of a padded drum that rotates at predetermined hertz level to provide vibrations to the body tissue (Swiss Therapeutic Training Products, 2000). This design was created to target specific areas of the body with vibrations instead of sending them through the whole body. BMS can be applied directly to the affected area using lower stimulation loads. Having direct application of vibration therapy to smaller areas of body may be just as effective as whole body vibration (Peer et al., 2009). In addition, using lower stimulation loads may be more comfortable for a patient while still providing a therapeutic benefit (Peer et al., 2009). A current BMS device is the Swisswing®. Swisswing® technology is defined by circular movements with positive and negative acceleration to stimulate muscle tissue with amplitudes (1–6 mm) independent of frequency and load (Swiss Therapeutic Training Products, 2000). The goal of the Swisswing® is to create a mechanical imitation of a physiological tremor due with external stimulation causing a vibratory stimulation about the muscles and tendons (Swiss Therapeutic Training Products, 2000). Previous research examining whole body BMS has demonstrated increased range of motion and flexibility, decreased muscle stiffness, increased recovery from musculoskeletal injury, decreased
pain, reduction of fibromyalgia and Parkinson’s disease symptoms, and improvement in respiratory gas exchange in overweight and obese women (Peer et al., 2009). Whole body BMS therapy may impact other physiological functions such as physical strength and power, blood flow and peripheral lymphatic drainage, bone density, muscle activation, neuromuscular recruitment patterns, and body balance (Peer et al., 2009). Unlike WBV, BMS has been shown to be beneficial with no unwanted side effects (Siegmund, 2011).

**Performance Enhancing Application—Flexibility and Joint Mobility**

Joint mobility is limited by bony structures and soft tissues that block movements in the end position by muscles, tendons, ligaments, and capsules (Atha et al., 1976). These structures or soft tissues affect range of motion when no structural damage has occurred. Research investigating the effects of WBV and segmental vibration on flexibility and joint mobility is lacking (Sands, McNeal, Stone, Russell, & Jemni, 2006; Cronin, Nash, & Whatman, 2007). Although, a growing body of research is evolving that focuses primarily on segmental vibration therapy (Cronin et al., 2007).

In healthy young adult males, hip flexion is improved when measuring the modified sit and reach test using low frequency of applied cycloid vibration at 44 hertz on the thighs and lower back before and after each treatment when compared to stretching and a control group (Atha et al., 1976). A single treatment for 15 minutes can have a lasting effect for 24 hours (Atha et al., 1976). A 15-minute treatment with different parameters of frequency rate, intensity, amplitude could produce different positive or negative results (Atha et al., 1976).
Flexibility is affected from acute and chronic use of vibration in young highly trained male gymnasts relative to the forward split measurement. When using 30 hertz, the acute effects of vibration resulted in immediate and significant increase in range of motion (Sands et al., 2006). The chronic effects showed significant range of motion improvements in the forward split measurement (Sands et al., 2006).

Although vibration therapy has shown to improve range of motion, there is still uncertainty regarding optimal parameters for effecting short and long term changes in range of motion (Cronin et al., 2007). In a recent study, four different frequencies of vibration were shown to improve of range of motion (Cronin et al., 2007). Frequencies between 24 and 44 Hz on the hamstrings were shown to increase range of motion (Cronin et al., 2007).

BMS vibration therapy has an acute effect on lower back flexibility as measured by a sit and reach test assessment (Siegmund, 2011). A vibration therapy intervention from the Swisswing® at 20 hertz for two minutes on the gluteals, erector spinae, and hamstring muscles resulted in significant improvements in lower back flexibility with no negative side effects (Siegmund, 2011).

**Medicine Application—Parkinson’s Disease**

Special populations have been of increasing interest to BMS researchers. Parkinson's disease is a progressive neurological disorder that often results in joint rigidity, bradykinesia and decreased range of motion (Ridgel et al., 2011). Research has shown BMS to help increase range of motion. Further, single bouts of BMS and active-assist cycling can have positive effects on range of motion of the shoulder and hip
in individuals with Parkinson's disease (Ridgel et al., 2011). BMS and active-assist
cycling may suggest that this combination could alter central motor control processes
(Ridgel et al., 2011).

**Medicine Application—Wound Care**

Vibration therapy has also been examined as a therapeutic intervention with skin
care and wound healing. Earlier research has shown that gentle effleurage massage can
destroy newly formed lymph and vein vessels in a scar tissue (Leduc, Leivens, &
Dewald, 1981). By using multidirectional vibration therapy when applying to a newly
formed lymph vessels on scar tissue has shown to cause no damage and accelerate the
regeneration of severed vein and lymph vessels and decrease local edema (Leduc et al.,
1981). Vibration therapy has also been shown to help fight against the generation of
wrinkles and cellulites (Hansenberger et al., 2007).

**Medicine Application—Anesthesia**

Vibration therapy has also been used to act as anesthesia. When local anesthesia
does not adequately relieve pain, vibrations can be used to reduce discomfort (Smith,
Comite, Balasubramanian, Carver, & Liu, 2004). Vibration application has been used to
cause an analgesic effect. This analgesic effect is from activating the gate control theory
of pain. The gate control theory of pain works by stimulating alpha and beta nerve fibers
that transmit information from touch and vibration receptors in the skin (Smith et al.,
2004). Alpha and beta nerve fibers stimulate inhibitory interneurons in the spinal cord
which, act to reduce the amount of pain signal transmitted from alpha-delta and C nerve
fibers across the midline of the spinal cord and from there to the brain (Smith et al.,
Vibration will assist in limiting the pain by the gate control theory of pain in order for a procedure to be performed. Vibration anesthesia has been used to help with procedures including injection of botulinum type A for hyperhidrosis, injection of filler substances like Restylane™ and Juvederm™, laser therapy for leg veins, Q-switched laser ablation of tattoos, nailfold injections, injections for needle-phobic patients, incision and drainage of abscesses, and cautery of facial warts (Smith et al., 2004).

**Therapeutic Localized Vibration Application in Sports Medicine**

Vibration therapy has a long history in sports (Issurin, 2005). In athletic training, rehabilitation after injury and competitive performance using training protocols and sporting equipment that can cause specific alterations in muscle activity during exercise may have important implications from the use of vibration (Cardinale & Wakeling, 2005).

Vibration therapy has been investigated related to the performance aspect of athletics. Presently there is little to no research examining the therapeutic impact for BMS or the Swisswing® (Peer et al., 2009). Research has shown that range of motion can be improved in healthy individuals. After a first or second-degree ankle sprain or hamstring strain there is extreme loss of range of motion occurring surrounding the injury. The BMS treatment with the Swisswing® was delivered at 20 hertz for two minutes each and a minute rest in between (Peer et al., 2009).

The ankle injury subjects performed three positions of the treatment: the bottom of foot, heel, and gastrocnemius (Peer et al., 2009). Results revealed an increase in ankle dorsiflexion and eversion following Swisswing® treatment (Peer et al., 2009). This can
suggest after an ankle injury that the Swisswing® can improve ankle range of motion following the treatment.

The hamstring injury performed four positions of the treatment: gluteals, standing hamstrings, hamstrings resting/draped over drum, and seated gastrocnemius. After the Swisswing® treatment a significant increase in hamstring flexibility resulted (Peer et al., 2009). The Swisswing® treatment can improve hamstring range of motion after a hamstring injury has occurred.

**Summary**

Despite the high prevalence and diagnosis of CAI, it remains an occurrence that is inadequately understood by researchers and clinicians (Hiller et al., 2011). By continuing research with CAI, a better understanding can be obtained and can therefore enhance treatment and prevention. Due to the loss of proprioception and neuromuscular control resulting with CAI, vibration therapy can be a viable treatment to return the ankle joint to become more stable. By using the SEBT to assess deficits with CAI patients, the acute effects of vibration may increase excursion length in those particular directions and warrant investigation.
CHAPTER III

METHODOLOGY

Introduction

Chronic Ankle Instability (CAI) results when repeated structural damage happens to the ankle complex and functional instability occurs (Brown & Mynark, 2007; Demeritt et al., 2002; de Vries et al., 2010; Hertel, 2000; Hiller et al., 2011; O’Driscoll & Delahunt, 2011). The star excursion balance test measures the degree of functional instability occurring in the ankle. Functional instability that occurs with chronic ankle instability could possibly have an acute response to a therapeutic intervention of BMS. BMS has shown to improve range of motion, decrease stiffness, increase recovery from musculoskeletal injury, and decrease pain (Peer et al., 2009).

Subjects

Forty subjects aged 18 to 26 who participate in physical activity at least two times a week were recruited to participate in this study. Subjects were placed in two groups: chronic ankle instability (CAI) or Non-CAI group. Inclusion criteria for the CAI group required the subject to have had two or more ankle sprains with no injury more recent than the prior six months. In addition, CAI subjects had to have two of the following: reported recurrent episodes of ankle instability (“giving way”), a positive anterior or posterior drawer of the talocrural joint as measured by a certified athletic trainer, positive talar tilt of the subtalar joint for laxity as measured by a certified athletic trainer and a score less than eighty eight on the Foot and Ankle Ability Measurement tool (Carcia et al., 2008; O’Driscoll & Delahunt, 2011; Olmsted et al., 2002). The Non-CAI group
included subjects with one or less ankle sprains with no injury more recent than the prior six months, no reported episodes of “giving way,” no laxity when testing anterior and posterior drawer, and talar tilt, and a score more than 88 on the Foot and Ankle Ability Measurement tool. Exclusion criteria based on the contraindications of BMS for both groups (CAI and Non-CAI) are pregnancy, use of pacemaker, acute inflammation or diseases, acute thrombosis (blood clotting), advanced stage osteoporosis and freshly sutured wounds. The Institutional Review Board for the protection of Human Subjects reviewed this study. Consent was obtained from subjects for participation.

Instrumentation

The instrument used for the Biomechanical Stimulation is the Swisswing® BMR 2000. Swisswing® is an class II FDA-approved BMS device manufactured by Swiss Therapeutic Training Products in Twinsburg, Ohio, is used to deliver segmental vibration at 20 Hz (Peer et al., 2009). The Star Excursion Balance Test (SEBT) is a valid and reliable tool used to evaluate functional balance with an intrarater reliability of 67-97% (Gribble et al., 2004; Olmsted et al., 2002; Plisky et al., 2009). For this study, the Non-CAI subject stood on the dominant limb and the CAI subject stood on the injury limb and reached with the contralateral limb as far as possible in the anterior, anteromedial, anterolateral, medial, lateral, posterior, posteromedial, and posterolateral directions and had reach distances measured. Data were analyzed and processed by SPSS (version 21.0) to determine statistical significance.
Procedure

Forty physically active subjects between the age of 18 and 26 who participate in physical activity at least two times a week were placed into two groups based on inclusion and exclusion criteria of CAI. Twenty subjects qualified for inclusion and were in the CAI group. Twenty other healthy subjects were placed in the Non-CAI group. Subjects were randomly assigned to an experimental or control group.

All measures were taken in one testing session. In this session, all subjects provided consent and were instructed about the study. A questionnaire on demographics was taken for sex, height, weight, and age. Each subject had a true leg length measurement taken from the ASIS to Medial Malleolus (in centimeters) to normalize the SEBT score.

Subjects had four unscored practice attempts with the SEBT to eliminate a learning curve (Robinson & Gribble, 2008). To perform the SEBT the participant stood with the ball of the foot in the middle of eight intersecting lines by 45 degrees labeled anterior, anterior medial, anterior lateral, medial, posterior medial, posterior, posterior lateral, and lateral and the reach leg in a double leg stance in the start position.

The CAI group used the injured foot as the test leg. The Non-CAI group used their dominant leg. The subject used the opposite, or reach leg, from the start position to achieve the maximal distance possible. To perform correctly they touched the line using the most distal part of the reach foot without supporting the body weight with the reach leg and maintain the dominant leg in the center of the grid. Subjects were instructed to keep their hands on their hips and to keep the test leg on the ground at all times. The reach leg then immediately returned to the start position without disturbing the tested leg and
measurements were taken in centimeters. The order of the directional reach followed as anterior, anterior medial, medial, posterior medial, posterior, posterior lateral, lateral, and anterior lateral.

There was a five second rest between reaches and a two-minute rest in between practice and recorded tests (Bressel et al., 2007). After the practice attempts, the subject performed three recorded baseline SEBTs and an average was taken for the measurements in each direction. At that time, those in the Experimental groups (CAI and Non-CAI) received treatment with the Swisswing® and performed three seated BMS positions for two minutes each at 20 Hz: bottom of foot with both feet resting on the drum of the machine; heels of both feet resting on the drum of the machine; and gastrocnemius belly of both legs resting on the drum of the machine. One minute of rest was provided between each BMS position. After this intervention subjects performed three recorded posttest SEBT which was averaged. The subjects in the Control group (CAI and Non-CAI) simply sat for nine minutes, which allows for the same experimental time of the BMS treatment. After the intervention, the subjects performed three recorded posttest SEBTs and an average was taken for the measurements in each direction. Figure 1 represents the procedure outline. All measurements and interventions were performed by the principal investigator who is a BOC certified athletic trainer and a licensed athletic trainer of the state of Ohio.

**Statistical Analysis**

In this study, several independent and dependent variables were measured. The independent variables are group (CAI or Non-CAI) and condition (experimental or control). The outcome or dependent variable is performance score on the SEBT. The
Figure 1. Procedure outline.

analysis included both between and within subject comparisons. Between group comparison evaluated SEBT scores between CAI and Non-CAI for experimental and SEBT scores between CAI and Non-CAI for control. Within subject comparison analyzed SEBT scores within CAI group between experimental and control and SEBT scores within Non-CAI group between experimental and control. A delta score was calculated by finding the change score between pre and post for each excursion direction. A MANOVA was used to find statistical significance. Significance was established a priori at $p < .05$. 

CHAPTER IV
ANALYSIS OF THE FINDINGS

Demographics were calculated for age, height (cm), and weight (kg) for CAI and Non-CAI. The analysis revealed no statistical significant differences between CAI and Non-CAI. Table 1 features these results.

Table 1

Demographics of Age, Height, and Weight for CAI and Non-CAI

<table>
<thead>
<tr>
<th></th>
<th>CAI</th>
<th>Non-CAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>22 ± 2.294</td>
<td>23.2 ± 1.936</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.831 ± 10.236</td>
<td>173.863 ± 8.543</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.977 ± 19.412</td>
<td>73 ± 11.819</td>
</tr>
</tbody>
</table>

*Note. Mean avg ± Std Deviation*

The MANOVA for SEBT change scores reveal no statistically significant differences between CAI and Non-CAI in both experimental and control groups relative to excursion direction \( p > 0.05 \). Table 2 summarizes these findings.

Further analysis revealed a main effect of group (experimental and control) showing statistical significance \( F \geq 6.317, p \leq 0.017 \) when using change scores in all excursion directions. Specifically, when averaging mean scores for both CAI and Non-CAI experimental conditions. The same was not found when averaging mean scores
Table 2

*CAI and Non-CAI Comparison of Experimental and Control Change Scores for SEBT Excursion Directions*

<table>
<thead>
<tr>
<th>Excursion Directions</th>
<th>CAI Experimental</th>
<th>CAI Control</th>
<th>Non-CAI Experimental</th>
<th>Non-CAI Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta Anterior</td>
<td>1.65 ± 2.255</td>
<td>-0.656 ± 3.5755</td>
<td>2.433 ± 2.555</td>
<td>0.217 ± 2.112</td>
</tr>
<tr>
<td>Delta Anterior Medial</td>
<td>1.39 ± 2.194</td>
<td>-0.388 ± 1.574</td>
<td>2.263 ± 2.354</td>
<td>-2.257 ± 4.401</td>
</tr>
<tr>
<td>Delta Medial</td>
<td>2.753 ± 2.034</td>
<td>-0.016 ± 3.409</td>
<td>3.003 ± 3.077</td>
<td>-2.027 ± 5.201</td>
</tr>
<tr>
<td>Delta Posterior Medial</td>
<td>4.697 ± 2.64</td>
<td>0.545 ± 3.1635</td>
<td>4.783 ± 3.574</td>
<td>-1.23 ± 4.5996</td>
</tr>
<tr>
<td>Delta Posterior</td>
<td>5.11 ± 1.782</td>
<td>0.617 ± 2.663</td>
<td>3.86 ± 2.664</td>
<td>0.757 ± 4.838</td>
</tr>
<tr>
<td>Delta Posterior Lateral</td>
<td>7.003 ± 2.679</td>
<td>0.696 ± 3.353</td>
<td>6.093 ± 4.858</td>
<td>1.93 ± 4.386</td>
</tr>
<tr>
<td>Delta Lateral</td>
<td>6.27 ± 3.83</td>
<td>0.215 ± 2.869</td>
<td>3.287 ± 4.784</td>
<td>1.827 ± 5.44</td>
</tr>
<tr>
<td>Delta Anterior Lateral</td>
<td>3.11 ± 2.859</td>
<td>-2.415 ± 3.087</td>
<td>2.253 ± 2.394</td>
<td>1.16 ± 5.175</td>
</tr>
</tbody>
</table>

*Note.* Mean avg ± Std Deviation
for both CAI and Non-CAI control conditions. The experimental group mean change scores improved compared to the control group. Figure 2 reflects these measures.

\[ \text{Figure 2. Change scores between experimental and control groups for excursion directions. \* = statistical significance} \]

There was a main effect of gender in the posterior medial excursion direction change scores showing statistical significance \((F = 5.257, p = 0.029)\). Males change score in the posterior medial excursion direction were greater than females. Table 3 reflects these results. There was no main effect of gender in the other excursion directions \((p > 0.05)\).
Table 3

*Comparison of Male and Female Change Scores in the Posterior Medial Excursion Direction*

<table>
<thead>
<tr>
<th>Excursion Direction</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta Posterior Medial</td>
<td>3.415 ± 4.691</td>
<td>0.983 ± 3.664</td>
</tr>
</tbody>
</table>

*Note.* Mean avg ± Std Deviation

There was a group and gender interaction showing statistical significance in the posterior lateral excursion direction (F = 5.074, *p* = 0.031) and lateral excursion direction (F = 4.428, *p* = 0.043). By further analyzing the group and gender interaction, an independent samples *t*-test examining the posterior lateral excursion direction determined males in the experimental group reached farther than the males in the control group (*p* < 0.001). In the lateral excursion direction, males in the experimental group reached farther than the males in the control group (*p* = 0.001). Table 4 represents these findings. There was no group and gender interaction in any other excursion directions (*p* > 0.05). There was no injury and group, injury and gender, or injury, group and gender interaction that showed statistical significance (*p* > 0.05).

In summary, statistical analysis revealed BMS intervention to the lower extremity improved performance on SEBT scores in people with CAI. BMS intervention to the lower extremity also improved SEBT scores in people classified as Non-CAI. This BMS
Table 4

*Males Comparison of Experimental and Control Change Scores for Posterior Lateral and Lateral Excursion Directions*

<table>
<thead>
<tr>
<th>Excursion Direction</th>
<th>Experimental</th>
<th>Males</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta Posterior Lateral</td>
<td>8.78 ± 3.005</td>
<td>0.927 ± 3.533</td>
<td></td>
</tr>
<tr>
<td>Delta Lateral</td>
<td>6.257 ± 2.889</td>
<td>-0.36 ± 4.205</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Mean avg ± Std Deviation

intervention was equally effective on neurological control in people with CAI and Non-CAI. This can be used as a viable intervention to positively effect neurological control during SEBT post testing.
CHAPTER V
DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

Discussion

The aim of this study was to investigate if the acute effects from BMS would improve SEBT scores in people with and without CAI. Previous studies have evaluated other performance enhancing or therapeutic effects from BMS but have not focused on enhancing functional aptitude as measured by the validated and reliable SEBT. Following the BMS intervention, subjects with and without CAI who received the BMS treatment in this study had significant increases in distance reached in all excursion directions compared to the control group as illustrated in Figure 2. These findings were consistent between CAI and Non-CAI subjects. By using the change scores for both CAI and Non-CAI experimental and CAI and Non-CAI control groups these statistically significant findings were obtained. This suggests that localized biomechanical vibration caused by the Swisswing® can improve SEBT scores in a variety of populations including the chronically injured and non-injured. It is believed that this change is due to a dynamic three-part relationship of range of motion, strength, and postural endurance.

Range of motion is the first part of this dynamic relationship with biomechanical vibration. This physiological mechanism from BMS is called a tonic vibratory response (Peer et al., 2009). This tonic vibratory response is a reflex invoked from stimulating the muscle spindle that leads to the contraction of the muscle being simulated (Peer et al., 2009). This response helps increase range of motion when applied to areas around the joint as seen in previous studies. This increase in range of motion may also be attributed
to reciprocal inhibition that results in the stretching of an opposing muscle group (Peer et al., 2009).

Strength is another part of this dynamic relationship of biomechanical vibration. Strength has been previously studied with WBV. The results of WBV studies have shown increased strength in measures of, jump height, peak force, peak power, and muscle activity (Cardinale & Wakeling, 2005; Luo et al., 2005; Mikhael et al., 2010). Strength is required when performing the SEBT (Robinson & Gribble, 2008). Without adequate strength, the performance on the SEBT will result in a shorter reach distance in the excursion directions.

Postural endurance is the last part of this dynamic relationship of biomechanical vibration. Prior studies have examined postural endurance with WBV. These results have revealed an increase in static balance performance and postural control in those with Parkinson’s Disease (Mikhael et al., 2010). Postural endurance is an important aspect when performing the SEBT (Robinson & Gribble, 2008). A decrease in SEBT performance will result when there is a deficit in postural endurance.

Although repeated measures are taken when using the SEBT as a measurement tool, there is no reported learning curve in one session from test to test. The practice trials eliminate a learning curve by an act of a “warm up” so recorded trials are accurate (Robinson & Gribble, 2008). This is no evidence available that states from recorded test to recorded test that these scores will be affected from a learning curve.

Results of this study indicate that reach distances in all excursion directions of the SEBT increased after the BMS intervention for both groups—CAI and Non-CAI. Prior
research found CAI subjects demonstrate a lack of reach distance in the anterior, posterior medial, and posterior lateral excursion directions (Plisky et al., 2009). This can be a viable acute intervention for people with CAI and Non-CAI because of the increased ability to reach in all excursion directions acutely following Swisswing® intervention. This could suggest that BMS has a positive effect on dynamic balance in people with and without CAI when dynamic balance performance is lacking.

Using parameters established in a prior study (Peer et al., 2009), applying BMS to the bottom of foot with both feet resting on the drum of the machine; heels of both feet resting on the drum of the machine; and gastrocnemius belly of both legs resting on the drum of the machine at 20 hertz for two minutes was sufficient to increase certain ranges of motion in the lower extremity. These same parameters created an increase SEBT reach distance in all excursion directions in this study. It may be possible to establish these parameters and application sites as acceptable protocols to help improve SEBT performance for an acute effect on neuromuscular control.

The analysis demonstrated differences between genders as well. The data reflected that males were able to reach farther in the posterior medial excursion direction. There was a group and gender interaction showing that males who received the BMS intervention were able to perform better in the posterior lateral and lateral excursion directions. There is no relevance nor can no generalizations be made from these findings.

The trained researcher who is a BOC certified athletic trainer and licensed in Ohio tested laxity. Laxity was tested in the ankle joint with anterior drawer, posterior drawer, and talar tilt tests. Laxity was tested from a subjective standpoint by the trained
researcher. The anterior drawer test for the ankle joint has a specificity of 75 and sensitivity of 78 (Cook & Hegedus, 2007). The talar tilt test has a specificity of 75 and sensitivity of 67 (Cook & Hegedus, 2007). The specificity and sensitivity of these tests make them excellent manual options when testing for laxity in the ankle joint. Although there was no objective measuring of joint excursion, these laxity tests and the fact that the trained researcher performed them demonstrate consistency.

**Implications**

Implications of findings are that the BMS intervention can improve performance on the SEBT in all eight directions. This can improve performance in both CAI and Non-CAI populations alike. The SEBT is used to clinically screen athletes to assess physical performance and identify risk of lower extremity injury due to limited reach distances (Plisky et al., 2009). Using the Swisswing® to improve reach distances in all eight directions could suggest that this intervention could lower the risk for lower extremity injury. This could also help other specific injuries because of their poor performance on the SEBT with people having anterior cruciate ligament reconstruction and patellofemoral pain syndrome (Gribble & Hertel, 2003; Olmsted et al., 2002; Plisky et al., 2009; Robinson & Gribble, 2008). BMS application could be seen in a variety of settings, for example, athletic training rooms and clinics. This could be incorporated especially in prevention and rehabilitation programs for an injury. By using the Swisswing® intervention, it may be possible to enhance neuromuscular control, range of motion, and strength (Cardinale & Wakeling, 2005; Luo et al., 2005; Mikhael et al.,
2010; Peer et al., 2009). It could be used for prevention and rehabilitation programs to facilitate performance on the SEBT to improve reach distances.

The limitations of this study are SEBT distances were marked and measured manually, although the trained researcher measured them. Manual determinations of joint laxity, although standardized by clinical testing, were subject to human interpretation. FAAM scores were the only scores to determine functional instability. Subject interpretation of “giving way” was clearly subjective and open to the individual perception.

**Recommendations**

Since this study examined only acute effects, recommendations for future research can investigate the chronic effects of BMS on the lower extremity using the Swisswing® on SEBT scores in persons with and without CAI. This can be investigated by either evaluating the lasting effects of the BMS intervention from day to day or by having the subject receive the BMS intervention daily and see the results on the SEBT scores over time.

Other research can be conducted by applying the BMS intervention in a different order for the three application sites. In this study, we applied the vibration therapy distal to proximal. Switching the application order of the stimulation may determine if sequence of stimulation or simply the stimulation itself caused the effect. This can determine if there is a physiological difference elicited during application relative to the order for the BMS intervention to be most beneficial. Also, applying the BMS intervention to the knee flexors and extensors and hip flexors and extensors as the most
proximal portions of the kinetic chain can determine which parts of the kinetic chain respond to this modality and if more stimulation will further increase reach on the SEBT. This could determine if there is a continued increase in reach distances or a point of diminished returns in increasing SEBT reach distances with stimulation.

Although this study only evaluated the effect of BMS on chronic ankle injuries as measured by the SEBT, research has demonstrated that other injury conditions have deleterious effects on SEBT performance. The SEBT has been used for a variety of injury conditions specifically related to the knee. SEBT testing has shown functional deficits for anterior cruciate ligament reconstruction and patellofemoral pain syndrome patients (Gribble & Hertel, 2003; Olmsted et al., 2002; Plisky et al., 2009; Robinson & Gribble, 2008). Another future project can investigate to see if SEBT scores can be improved after a BMS intervention for these specific injuries in a variety of populations to determine the potential widespread use of this modality in treating a variety of chronic musculoskeletal injuries.

**Conclusion**

BMS has a great potential promise as a therapeutic intervention. BMS produces positive physiological effects on range of motion (Peer et al., 2009), strength (Cardinale & Wakeling, 2005; Luo et al., 2005; Mikhael et al., 2010), and postural endurance (Mikhael et al., 2010). These physiological effects can assist in performance enhancement or rehabilitation for a range of individuals.

This study has shown that BMS can increase range of motion, strength, and postural control due to the demands from the SEBT. These increases in range of motion,
strength, and postural control can improve performance on the SEBT in both CAI and Non-CAI patients. This can suggest that BMS can be a therapeutic intervention to improve dynamic balance in a variety of populations.
REFERENCES
REFERENCES


