ABSTRACT

THE EFFECTS OF WHOLE BODY VIBRATION VERSUS WOBBLE BOARD BALANCE EXERCISES ON DYNAMIC POSTURAL CONTROL IN RECREATIONALLY ACTIVE INDIVIDUALS WITH CHRONIC ANKLE INSTABILITY: A META-ANALYSIS

Objective: This meta-analysis examined the effectiveness of whole body vibration training versus wobble board balance exercises on dynamic postural control in recreationally active individuals with chronic ankle instability.

Methods: Studies analyzing whole body vibration training were compared to studies analyzing wobble board balance exercises. The studies were meta-analyzed to determine both treatment effect size and homogeneity of pooled studies.

Results: Four studies were included in this meta-analysis. A moderate effect size and homogeneity was found in favor of wobble board balance exercises for recreationally active individuals.

Conclusion: Findings of this meta-analysis reveal that wobble board balance exercises are more beneficial in improving dynamic postural control in active individuals with chronic ankle instability when compared to whole body vibration.

Study Design: A meta-analysis of experimental studies observing the effects of whole body vibration training versus wobble board balance exercises in recreationally active individuals with chronic ankle instability.

Jennifer Ray
May 2018
THE EFFECTS OF WHOLE BODY VIBRATION VERSUS WOBBLE BOARD BALANCE EXERCISES ON DYNAMIC POSTURAL CONTROL IN RECREATIONALLY ACTIVE INDIVIDUALS WITH CHRONIC ANKLE INSTABILITY:
A META-ANALYSIS

by
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submitted in partial fulfillment of the requirements for the degree of Doctor of Physical Therapy in the College of Health and Human Services
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APPROVED

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CHAPTER 1: INTRODUCTION

It is estimated that about 23,000 ankle sprains occur each day in the United States.\textsuperscript{1} Of these, lateral ankle sprains (LAS) are the most common and result from an inversion motion likely during weight bearing.\textsuperscript{1,2} Individuals aged 15 to 19 are more susceptible to a LAS. Participation in physical activity, being of the female gender and obesity also increases the risk of a LAS injury.\textsuperscript{3-5} Not only are ankle sprains painful, they can cause disability, time off work and cause time away from activity.\textsuperscript{1} Lateral ankle sprains account for 1.2 million spent in physician visits and 3.8 billion dollars in health care costs annually.\textsuperscript{1}

Anatomy of the Ankle

The ankle joint is composed of 3 bones: the tibia, fibula and the talus. Surrounding ligaments provide passive restraint to the lateral ankle complex. Ankle kinematics can resemble a screw-like motion which move clockwise and counter clockwise about the central ligamentous structures making the ankle a multiplanar joint.\textsuperscript{6} The ligaments of the lateral ankle include the anterior talofibular (ATFL), the calcaneofibular (CFL) and the posterior talofibular (PTFL). In addition to ligaments, muscles provide added stability to the ankle during dynamic activities by way of motor control.\textsuperscript{1,7} The muscles supporting the ankle joint are the ankle invertors and ankle evertors.\textsuperscript{7} The ankle evertors include the peroneus longus and the peroneus brevis. The peroneal muscles act concentrically to avoid inverted movement of the ankle. The invertors of the ankle, on the other hand, include the tibialis posterior, the tibialis anterior, the extensor digitorum brevis and the extensor digitorum longus. The muscles of inversion are important in controlling eccentric ankle motion. In addition, muscle spindles (MS) and Golgi Tendon Organs (GTO) are proprioceptors which help to maintain
When a muscle is stretched, these proprioceptors send information to the brain. The brain then sends efferent information to that muscle to contract in order to decrease the rate of stretch which translates into balance during movement. Muscle spindles are located in the muscle belly and detect muscle length and velocity while GTOs are in the muscle tendon and detect muscle tension. Golgi Tendon Organs signal active tension primarily, meaning during a muscle contraction.

Muscle spindles are exceptionally important in protecting the ankle during in the event of a sudden inversion motion. When the ankle rolls into inversion, the rapid stretch of the lateral muscles and MS fire rapid afferent information to the nervous system causing a rapid contraction of the stretched muscles. This quick response prevents a LAS.

When a LAS occurs, the lateral ligaments of the talocrural and talocalcaneal joints are stressed and in worse case, torn. Sprains are weighted on a 1 to 3 gradient depending on the severity. Grade 1 LAS is reported as stretching of the ligaments. Grade 2 LAS include mild torn ligaments, whereas grade 3 LAS are those in which the ligaments are torn completely. Regardless of the severity, acute healing occurs thereafter and involves collagen tissue formation around the lateral ligaments. Even after the initial sprain has healed, residual symptoms are likely to exist, often causing deficits in postural control, balance and strength. In addition, increased laxity typically observed after a sprain makes an individual 70% likely to encounter a subsequent sprain.

Mechanical and Functional Ankle Instability

Residual symptoms are common after ankle injury and can manifest in 2 categories, mechanical ankle instability (MAI) and functional ankle instability.
(FAI). Mechanical ankle instability includes pathological laxity, impaired arthrokinematics and synovial and degenerative changes joint changes.\textsuperscript{10,11} As a result of the local trauma, the ligaments and musculotendinous units can be damaged. Muscles may compensate for stability to prevent a subsequent sprain, but it is hypothesized that damage to the ligamentous mechanoreceptors is the main cause of postural control deficits.\textsuperscript{12,13}

Mechanoreceptors are sensory receptors that transmit mechanical distortion into a neural signal to the central nervous system in order to adjust efferent output.\textsuperscript{8} Even after rehabilitation of the ankle has occurred, mechanoreceptors can remain damaged resulting in altered afferent signals to the brain thereby contributing to repeated ankle sprains.\textsuperscript{10} Disruption of the sensory receptors can cause a form of instability called functional ankle instability (FAI). Functional ankle instability is the most common residual symptom following LAS and occurs in 17-58 percent of clients and most common in younger patients.\textsuperscript{11} Functional ankle instability is described as having normal joint movement, however, is the result of sensorimotor and/or neuromuscular deficits.\textsuperscript{11} Functional insufficiencies include decreased proprioception, altered neuromuscular control, strength deficits and impaired postural control.\textsuperscript{11} The inability to effectively respond to sensory input to facilitate joint stability is deemed as altered neuromuscular control (NMC).\textsuperscript{10} Neuromuscular control is defined as “the unconscious activation of dynamic restraints occurring in preparation for and in response to joint motion and loading”.\textsuperscript{10} Altered NMC likely contributes to FAI.\textsuperscript{10} Functional ankle instability can be present even in the absence of MAI.\textsuperscript{11} Previous research found impaired postural stability in patients with FAI with and without the presence of a mechanical deformity.\textsuperscript{4}
Chronic Ankle Instability

Thirty-three to 42% of LAS result in chronic ankle instability (CAI).\(^1\) Chronic ankle instability incorporates 1 or a combination of MAI, FAI and recurrent ankle sprains.\(^4,14\) Chronic ankle instability is generally accepted as an individual who has repeated ankle sprains, feelings of instability and who is experiencing reoccurring episodes of the ankle “giving way”.\(^15\) As many as 74% of individuals with CAI report continued feelings of the ankle giving way, joint instability, pain, swelling, loss of function, and/or repeated ankle sprains.\(^15,16\)

Changes in central nervous system processing and integration may also contribute to CAI.\(^1\) Research has stated that the central mechanism for NMC is delayed after an injury.\(^1\) Furthermore, studies have provided evidence that postural stability has improved after rehabilitation of acute and chronic ankle sprains demonstrating that deficits in NMC after ankle injuries could possibly be due to adaptations in central pathways.\(^1\) These neurological impairments include dynamic balance, postural control and muscle fatigue.\(^17\) Chronic ankle instability is not a condition that naturally improves over time.\(^4\) Previous research shows no significant improvement of CAI symptoms without physical therapy treatment.\(^18\)

Balance Training

Physical therapists practice a multimodal treatment approach when working with patient’s with CAI.\(^12,19\) The plan of care usually includes 1 or more of the following: modalities, strengthening, static and dynamic balance, manual therapy, taping and bracing.\(^12,19\) Cordova et al. proposed that rehabilitation programs for CAI must provide a graded therapeutic exercise routine that restores joint motion, muscle strength and sensorimotor control.\(^1\) Numerous studies have shown the importance of incorporating balance training into a rehabilitation program for patients with CAI.\(^5,18,20-23\) Balance training is thought to improve mechanoreceptor
function and balance by reeducating the proprioceptive system and normalizing the neuromuscular feedback loop.\textsuperscript{24} Balance training is associated with improved ankle stability for both postural control and self-reported function.\textsuperscript{20,22,25,26}

Despite the number of ankle sprains that occur each year, there is no standardized physical therapy protocol in the treatment of CAI. Throughout existing studies, balance training interventions have been heterogeneous. Balance training interventions to date are varied in type. For example, De Ridder et al. used a home-based balance program which included single leg stance with eyes closed and eyes open and different arm placements, crossed leg sway, single leg squat, double leg balance, lunge jump, heel raise and drop jump both on a foam pad and balance board.\textsuperscript{27} With these studies encompassing so many different types of exercises, it is hard to identify which specific balance exercise worked. Few studies compare similar balance training protocols. Balance training encompasses both static and dynamic balance, compliant\textsuperscript{18,28} and non-compliant surfaces, single limb and double limb stance. The contralateral ankle has also been treated as it has been found that training the uninvolved side results in bilateral improvements in postural stability.\textsuperscript{26}

Rehabilitation with a wobble board has shown significant improvement in patients with CAI.\textsuperscript{29} Wobble board balance exercises have the advantages of being simple to teach the patient, require a single piece of equipment that is often readily available, and can be completed independently by the patient in less than 10 minutes.\textsuperscript{23} A wobble board is a circular platform with different sized domes that screw into bottom of the board. Smaller domes make the exercise more challenging whereas larger boards make the balance exercise less challenging.\textsuperscript{18} Balance training and proprioceptive training have generally included wobble board activities.\textsuperscript{30,31} Linen’s et al. created a wobble board balance protocol that
researchers have duplicated. In the Linen’s et al. wobble board balance protocol, participants stand on a wobble board placed near a wall on their involved limb. Participants complete 5, 40-second sets of clockwise and counter-clockwise rotations, alternating direction every 10 seconds, with 60 seconds of rest between. Participants were allowed to place their fingers on the wall for stability. Training starts on the lowest level (level 1 out of 5) of the wobble board, and progresses based on ability to complete smooth circular motions in both directions along with smooth transitions between direction changes.23

In 2012, Kiers et al. proposed that that training on an unstable surface alone was not sufficient enough to stimulate ankle proprioceptors.32 He emphasized that muscle spindles are highly sensitive to vibratory stimulus and purported that muscle spindles are key to ankle proprioception and overall body orientation. The results of this study report that clinicians should research vibration as an adjunct to provide more effective exercises for patients with FAI.32

Whole Body Vibration
Whole body vibration (WBV) is a new biophysical modality to provide systemic vibration signals for mechanical stimulation that is gaining popularity in clinics and gyms.10,17,33-42 Whole body vibration training is a therapeutic technique in which a subject stands on a vibrating platform which can have the frequency, amplitude, or duration altered. The platform’s vibrations are highly stimulating to skin receptors, muscle spindles and joint mechanoreceptors.10 This, in turn, activates alpha motor neurons which create muscle contractions.10 These contractions could have an effect on joint stability and could therefore improve dynamic postural control.43 The transmitting vibrations from the platform leads to physiological changes in muscle spindles, joint mechanoreceptors, higher brain
activity and strength.\textsuperscript{17} Evidence suggests that WBV training adds positive effects beyond that of conventional exercises regarding strength gains, power, flexibility and adaptations in motor control.\textsuperscript{40}

WBV training in the literature is lacking. Studies on WBV training are studied in limited populations. Research on WBV mainly consists of evidence for use in the elderly population. Whole body vibration has shown positive outcomes for decreased risk of falls in the elderly following WBV treatment.\textsuperscript{34,44,45} In addition, Rees et al. saw improvements in postural steadiness after 8 weeks of WBV training in 66-85 year olds.\textsuperscript{39} Whole body vibration training studies in younger, more active groups are scarce in the current literature.

Limited studies have assessed the effects of WBV on balance and postural control in younger adults and even fewer in younger adults with CAI. Torvinen et al. conducted 2 long-term studies comparing WBV training on performance and balance in the younger population.\textsuperscript{41,42} The results of the studies showed no effect on balance but it is important to note that these individuals were healthy and did not present with neuromuscular deficits like individuals with CAI. Due to the ability to transmit vibrations that are highly stimulating to muscle spindles, WBV may have a positive effect on proprioception and postural control in individuals with CAI. Dickin et al. studied the effects of WBV on healthy younger adults using individualized frequencies. This study reported immediate impact on postural sway indicating that perhaps individualized frequencies and/or higher frequencies could be a factor in the efficacy of WBV treatment. An average frequency of 35.28 Hertz was used in this study.\textsuperscript{35} The greater frequency purportedly results in greater elongation of ligaments and muscles.\textsuperscript{46} Ritzmann et al. found that higher frequencies lead to higher EMG activity.\textsuperscript{40} Frequencies of about 30 Hertz are commonly seen in the literature.\textsuperscript{33}
There are incompatibilities in WBV training regarding experimental protocols and inconsistent parameters in WBV intervention studies. Vibration, direction and amplitude are all adjustments of WBV parameters. Each of these factors is known to significantly influence training and physiological responses such as blood flow and neuromuscular adaptation. These are highly dependent on the specific parameter selection. Due to the above mentioned, the potential benefits of WBV in comparison to traditional forms of exercise still remain unclear.

**Definitions**

For the purpose of this meta-analysis, “recreationally active” will be defined as individuals participating in more than 1.5 hours of moderate to vigorous physical activity per week, or current participation in a sport. Chronic ankle instability will be defined as having more than 1 ankle sprain and reoccurring feelings of “giving way” as described by Hiller et al.

**Star Excursion Balance Test**

The Star Excursion Balance Test (SEBT) is a dynamic stability test used to quantify improvements in postural control in patients with CAI. In order to maintain postural control, the body is in continuous movement to adjust center of gravity over base of support. It provides an accurate assessment of proprioceptive and neuromuscular performance. Studies have shown that the SEBT provides a fuller evaluation than the traditional measure of postural control (center of pressure from a force plate). Other measures of balance include self-reported outcome measures such as the Functional Ankle Instability Index (FADI), Balance Error Scoring System (BESS), Visual Analog Scale (VAS) and Fear Avoidance Belief Questionnaire (FABQ). Even though Houston et al. states that
patient-based outcomes are increasingly recognized in health care, the patient’s perception of their health status is different for each individual because each individual perceives things differently. The Foot Ankle Ability Measure (FAAM), figure 8 hop, side hop and Global Rating of Function (GRF), Time in Balance Test (TBT) are other forms of balance outcome measures. The sensitivity of these assessments has been questioned in patients with CAI. Most studies have not found various hopping and agility tasks to differ significantly between those with and without CAI.

Chronic Ankle Instability may be related to performance deficits in the entire affected extremity. The SEBT requires adequate strength, range of motion and balance throughout the hip, knee and ankle. The SEBT is a highly valid test for all populations as it is sensitive enough to expose deficits in the active population. In addition, the SEBT has been shown to have strong intrarater and interrater reliability.

Purpose

Based on existing literature, exercise in the form of balance training has been the generally accepted treatment pathway to improve postural stability in patients with CAI. Whole body vibration training is making a rise in the rehabilitation setting and appears to have a positive outcome in dynamic postural control as well. Until now, a meta-analysis has not compared WBV interventions to wobble board balance interventions to determine which is more beneficial. Physical therapists must use their time efficiently and be able to implement the most useful interventions for patients within a short treatment session. This meta-analysis will concentrate on the effects of WBV versus wobble board balance exercises in the recreationally active population assessed by the SEBT in the
posteromedial (PM) direction. The hypothesis is that WBV will show greater improvements in dynamic postural stability when compared to wobble board balance training in recreationally active individuals with CAI between the ages 16 and 40 years old. The stated alternate hypothesis is that wobble board balance exercises will show greater improvements compared to WBV training in recreationally active individuals with CAI, measured by the SEBT in the PM direction.
CHAPTER 2: METHODS

Literature Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to form the study’s procedures. A complete search of the literature began in August 2017. The following databases were searched for relevant articles: PubMed, EBSCOhost and ScienceDirect. Studies were considered for review if published after 2008 and examined the effects of WBV or wobble board balance exercises on dynamic postural stability in recreationally active individuals with CAI. Searches were limited to human studies, English language, and randomized control trials. The following search terms were used: ankle sprains, CAI, CAI AND balance training, CAI AND balance, whole body vibration training, ankle sprains AND whole body vibration training, CAI and wobble board and CAI and physical therapy interventions. Abstracts were reviewed for inclusion and exclusion criteria. The search for online articles ended in October 2017.

Selection Criteria

In order for studies to be included in the meta-analysis, inclusion and exclusion criteria had to be met. Wobble board balance exercises needed to use the Linens et al. protocol. Inclusion criteria included studies with subjects ranging in age from 16-38 years with CAI. For the purpose of this meta-analysis, CAI is defined as a history of at least 1 significant ankle sprain and self-reported sensation of “giving way.” Studies included had to have subjects with an initial sprain more than 1 year prior to the start this meta-analysis, and be recreationally active. Recreationally active will be defined as participating in any form of exercise. Whole body vibration interventions using greater than or equal to 30
Hertz were included. Exclusion criteria for all studies included the following: any vestibular deficits, current ankle sprain, knee or hip injury or history of fracture or surgery in the lower extremities.

Further exclusion of articles occurred if the articles did not include pre and post measures of the SEBT in the PM direction for means and standard deviations of normalized reach distances. Raw data was not included in the study by Rendos et al. An effort was made to contact the author for the data, in which she promptly obliged.

Assessment of Study Quality

The PEDro scale was used to assess threats of validity for each individual study. The PEDro scale is a valid and reliable measure with 11 criteria for analyzing the design of each study. 52

Outcome Measure

The SEBT is a dynamic clinical test that provides a significant challenge to athletes and physically active adults used to screen postural control deficits due to CAI. During the SEBT, the subject stands on their involved limb and reaches with the contralateral limb as far as possible while maintaining control in 8 different directions. The 8 directions are marked as lines 45 degrees apart in which the reaching limb moves in relation to the stance limb. Three trials are performed in each direction. Reaching distances are normalized to the participant’s leg length. These 8 directions are anterior, anteromedial, medial, PM, posterior, posterolateral, lateral and anterolateral. The anterior, PM and posterolateral directions appear to have significance when identifying individuals with CAI and athletes at higher risk for lower extremities. 47 The PM direction was used in this meta-analysis. According to Olmsted et al, the PM direction appears to be the
reach direction most representative of reach performance in all 8 directions in subjects with and without CAI.\textsuperscript{47}

The SEBT is shown to have strong intrarater and interrater reliability.\textsuperscript{49} The SEBT appears to be sensitive in detecting reach deficits both between and within athletes with unilateral CAI.\textsuperscript{47} The SEBT has been found to be both highly reliable and sensitive.\textsuperscript{47} In studies that compared involved limb versus uninvolved limb in patients with CAI, subjects with CAI reached significantly less when standing to their involved side compared with uninvolved and healthy subjects.\textsuperscript{49}

Data Extraction

Data was extracted from the results section of studies that met inclusion criteria. Data extracted for this meta-analysis included standard deviations and means for SEBT scores in the PM direction and sample sizes of the individual studies. Four studies were deemed suitable for this meta-analysis. Due to a lack of direct intervention comparisons between WBV and wobble board balance intervention, studies were grouped by similarity of mean SEBT post-intervention scores, and the number of subjects, resulting in 2 composite (to represent 4 studies) mean SEBT post intervention scores. The 2 composite scores (WBV and wobble board balance) were pooled and a combined effects for 2 groups was calculated.

Post-test measures from included studies were grouped and analyzed using a random effects model. Studies were paired by similarity of means and population size. Wright et al, who studied the effects of wobble board balance training, was matched with Rendos et al. who analyzed the effects of WBV on postural control. Similarly, Linens et al. was matched with Cloak et al.
Meta-Analysis

A random effects model was used to examine the effect size and heterogeneity of the SEBT data for 2 groups. Effect size and heterogeneity were assessed using Q value and Cohen’s standards for ES. A Q value of <0.3 indicates minimal effect, 0.3-0.8 indicates moderate effect and >.8 shows a large effect. The Q value correlates with the homogeneity of the studies. Significance was set at greater than 0.05 and was the p value associated with the data.
CHAPTER 3: RESULTS

Study Selection

A total of 68 studies were screened through the following databases: PubMed, EBSCOhost and ScienceDirect. Two studies were eliminated because they were not randomized control trials. Further, studies were excluded if they were not published in the last 10 years or if the article was not full text, leaving 55 articles. The remaining articles were screened and evaluated based on titles and abstracts. Fifty-one studies were removed due to incorrect population (not having to do with CAI), incorrect intervention (not having to do with wobble board balance training or WBV), and also excluded for not using the SEBT. Another study was excluded because it was published by a Master’s student as a Master’s thesis. Following in-depth reviews by a single reviewer, 4 studies remained that met the inclusion and exclusion criteria (see Figure 1). No studies were eligible from ScienceDirect.

Study Characteristics

All 4 studies elected were randomized controlled clinical trials either examining the effect of wobble board balance training or WBV training on active individuals with CAI. The 2 studies investigating the effects of balance training on postural control were Wright et al. and Linens et al.\textsuperscript{18,23} The 2 studies included to investigate the pooled effects of WBV training were Cloak et al. and Rendos et al.\textsuperscript{10,17} All studies measured postural control using the SEBT in the PM direction.\textsuperscript{10,17,18,23} The characteristics of all studies are summarized in Tables 1 and 2.

One study used in the meta-analysis presented statistical data in bar graph form. After contact with the author, a full set of raw data was obtained. From there, means, and standard deviations were calculated manually.
The quality of each study was considered using the PEDro scale score. For the studies included, the PEDro scores ranged from 4-6 out of a 10 point scale. The most commonly unsatisfied criteria included blinding of subjects, blinding of therapists, blinding of assessors, and intent to treat analysis. Rendos et al. was the only study to blind their subjects by using an inactive vibration platform.\textsuperscript{10} Intent to treat analysis was not necessary in these studies due to the 100\% follow-up with participants.\textsuperscript{10,17,18,23} The PEDro scores are presented in Table 3 and should be considered in interpreting the implications of this meta-analysis.

Due to the retrospective design of the studies, the studies lacked control over the grading criteria of the initial sprain(s) encountered by the participants with CAI. So, the severity of the ankle sprains in the patients’ history varied and were unknown unless otherwise diagnosed by a medical professional. In addition, there were differences in laxity and frequency with which participants reported performing some sort of rehabilitation following ankle injury. The duration of treatment also varied. In the study by Rendos et al., participants underwent only 3 days of treatment.\textsuperscript{10} Only female participants were included in the vibration training study by Cloak et al.\textsuperscript{17}

Two WBV training studies investigated the acute effects of WBV training. Cloak et al. incorporated single leg heel raises and single leg squats on the vibration platform while Rendos et al. had participants single-leg stand on the platform and hold.\textsuperscript{10,17} The 2 studies administered vibrations of 30Hz with each intervention lasting about 12 minutes.\textsuperscript{10,17} The difference was that Cloak et al. progressed treatment in increments of 5 Hz, totaling 45Hz by the end of 6 weeks.\textsuperscript{17}

Meanwhile, both studies involving wobble board training used the methods of Linens et al. as the treatment protocol.\textsuperscript{18,23} This included completing 5, 40-second sets of clockwise and counterclockwise rotation (alternating direction...
every 10 seconds), with 60 seconds of rest between sets. The protocol leaves room for progression starting at the lowest level (level 1 of 5) of the wobble board\textsuperscript{18}. Patients are able to progress once they are able to complete smooth circular rotations in both directions and make smooth transitions between direction changes\textsuperscript{18}.

All 4 studies assessed postural control using the SEBT in the PM direction. All participants were allowed 3 to 4 practice trials in both the WBV and balance training groups. All studies reported change but no statistical significance between groups in the PM direction of the SEBT.

**Data Analysis**

The hypothesis of this meta-analysis was that WBV training would demonstrate better outcomes in dynamic postural control compared to wobble board balance training in active individuals with CAI, ages 16 to 38 years old, as measured by improved change on the SEBT in the PM direction. This analysis disconfirms this hypothesis. The hypothesis is rejected, thus, the alternative hypothesis is accepted stating that wobble board balance is superior in improving dynamic postural control compared to WBV training.

The effect size (ES), standard error of ES, upper and lower confidence intervals (CI) based on a 95% confidence interval are shown in Table 4. A random effects excel chart was used for all data. The data was pooled from different studies by pairing comparable means, standard deviations, age and number of participants from the 4 studies. The Q value was .28 and p-value was 0.6 indicating the grouping of studies measuring SEBT reach scores in the PM direction was homogeneous. The combined data showed a moderate ES of -0.44 indicating wobble board training has a moderate but greater effect on improving
postural control when compared to WBV training according to Cohen’s effect size principle.\textsuperscript{53} The data are illustrated in the forest plot in Figure 2. According to the forest plot in Figure 2, the effect size is negative indicating that wobble board balance training is more effective as an intervention for improving reach scores in the PM direction of the SEBT.
CHAPTER 4: DISCUSSION

The purpose of this meta-analysis was to determine the effects of WBV compared to balance training on a wobble board on dynamic postural control measured by the SEBT in the PM direction in recreationally active individuals with CAI. It was hypothesized that WBV would demonstrate a greater statistically significant treatment effect compared to wobble board balance exercises in patients with CAI by improvements in SEBT scores in the PM direction. The results of the meta-analysis disconfirms this hypothesis, with a moderate effect size favoring wobble board balance interventions. Active individuals aged 16-38 with CAI who participated in wobble board balance interventions demonstrated better reach scores in the PM direction on the SEBT than those who underwent WBV. Of further note, all studies gathered post-intervention SEBT scores within 1-3 days after treatment indicating that these results can only represent short-term outcomes.

The following discussion will assess the results of this meta-analysis. The outcome measure used for postural control was the SEBT in the PM direction. The discussion will evaluate limitations in the current research body and the clinical relevance of the results from this study.

Review of Meta-Analysis Results

Based on the results of the analysis, a moderate effect size was generated in support of wobble board balance training over WBV training in improving postural control in active individuals with CAI. The hypothesis was rejected WBV was not more efficient at increasing postural control in active individuals with CAI aged 16-38 when compared to wobble board balance training. The results from the analysis also indicate that the studies included in this analysis were homogeneous.
which means that when pooled, the grouping of studies were not statistically significantly different from each other. The results from this study shoulder be considered with caution however because of the small number of studies included. However, the results were taken from studies that demonstrated strong qualities.

Strength of Studies

This meta-analysis was notable for using current research (50% of the studies included were published after 2016). Homogeneity between studies included in this meta-analysis was reinforced in many ways. For example, both Linens et al. and Wright et al. administered the same exercise protocol as used by Linens et al. Studies included used similar definitions for CAI and the participants in each study had relatively similar baseline measurements (see Table 5). In 3 out of the 4 studies, the criteria for being an active individual was the same meaning that participants exercised for at least 1.5 hours of moderate to vigorous activity per week. Never the less, differences did exist between the studies pooled for this analysis.

Limitations of this Meta-Analysis

It is important to acknowledge the limitations this meta-analysis when assessing the validity of the results. This meta-analysis contained 4 studies that were assessed with respect to SEBT scores in the PM direction. Each study was broken down to assess threats to validity. The main validity concerns pertaining to the studies were differences in duration of treatment and differences within the WBV training protocols.\textsuperscript{10,17}

For the purpose of this analysis, studies with similar baseline characteristics were compared in an attempt to limit heterogeneity. However, this method of pooling data may exclude the inclusion of additional relevant studies thereby
contributing to internal threat to validity. Although, with either pairing, the outcome of the analysis remained the same favoring wobble board balance training with a moderate effect size.

A source of variation among the studies is the age range of the participants. The subjects ranged in age 16-38 years. Age may be a factor in how a participant responds to WBV or wobble board balance training. A study looked at age-related differences and its effect on standing balance. When perturbed, they found that healthy elderly adults tend to exhibit greater excursions than young healthy adults suggesting that there are differences in balance responses with aging.54

Additionally, the inclusion criteria of “active individual” was broad. Individuals who participate in lower extremity sports and activities may be at more of an advantage when it comes to balance. Aydin et al. found that when a subject was perturbed, gymnasts were able to respond 73% faster than control subjects. The difference in response times was most notably seen in inversion motion.55 This suggests that the dancers included as subject in the meta-analysis may already have a good sense of balance and proprioception allowing them to reach higher SEBT scores than other “active individuals”.55 In the present meta-analysis, the participants in the study by Cloak et al. consisted of dancers.56

The limited number of subjects may also pose a concern. Only 7 participants had CAI and were in the intervention group in the Rendos et al. study. Small sample sizes may result in large standard deviations and potential type 2 error.

The durations of the studies ranged from 3 days long to 6 weeks. Rendos et al. treated patients for 3 days (see Table 6) resulting in a .66% improvement in SEBT scores from pre to post-intervention, whereas Cloak et al. treated patients
for 6 weeks and reported a 9.11% increase.\textsuperscript{10,17} The variation of treatment duration may affect the amount of improvement seen on the SEBT.

When interpreting these findings, differences in WBV protocols must be taken into consideration. Rendos et al. used WBV training consisting of 6 repetitions of 60 seconds in duration with a 60 second recovery time equaling out to 12 minutes of treatment. Each repetition had a frequency of 30 Hertz while participants performed a single-leg stance of the involved leg on the vibrating platform. Whereas in Cloak et al. study, the vibration program was progressive, increasing in vibration and frequency as the time progressed. Participants performed single leg heel raises and single leg squats. Participants in the Cloak et al. study also worked up to a frequency of 40 Hertz. See Table 7 for further review. The duration of each treatment was similar to Rendos et al. ranging from 10-14 minutes per session. Despite the differences in protocols, single-leg balance exercises alone were found to improve SEBT performance.\textsuperscript{10}

While this meta-analysis aimed toward assessing improvements in SEBT scores in the PM direction, studies which looked at other directions of the SEBT in addition to the PM direction reported significant findings in the other directions more so than the PM direction.\textsuperscript{10,17,18} As stated in the background, the PM direction is highly correlated with predicting postural control deficit in CAI. Caution should be taken when interpreting these results as they pertain to CAI. It is possible that these studies included relatively high CAIT scores amongst the participants indicating the severity of instability was less than those in previous research. Athletes and active individuals have a greater joint position sense and kinesthetic awareness due to the activity they compete in being largely focused on balance and correct form.\textsuperscript{55} This could explain why SEBT scores were not as statistically different.
Literature Supporting the use of Wobble Board Exercises as an Intervention for Chronic Ankle Instability

Despite the potential sources for heterogeneity, the findings of the meta-analysis are supported by several studies that found balance training in one form or another to improve dynamic postural control. Sefton et al. found improvements in dynamic postural control in individuals with CAI after 6 weeks of balancing on double limb on a marble maze with 4 levels of difficulty. Double limb support on the board could be as beneficial as single leg, especially in the earlier stages of treatment as it is difficult for even healthy individuals to maneuver a wobble board in single leg stance. Sefton et al. found that any gains achieved bilaterally would be detectable in a unilateral test. Additionally, the marble maze provided the patient with a cognitive task which incorporates attention and adherence to the program. Wright et al. found that patients preferred wobble board training as it was more engaging to resistance band training.

Hale et al. also found an increase in postural control in individuals with CAI after a 4 week balance program involving task-specific training in single and bilateral standing balance activities. Wobble board balance training is more functional and task-specific which could be why the results of the present meta-analysis favored wobble board balance exercises. The ankle is a multiplanar joint and should be trained that way. Studies show that the best way to relearn a given task, is to train specifically for that task. Rehab is moving toward a more functionally based approach, including more emphasis on functional movement and more closed-chain positioning.

Cruz-Diaz et al. found an increase in dynamic postural control after 6 weeks of balance training on different surfaces. Kidgell et al. found significant improvements in postural stability with a 6 week balance program using a dura
disc and trampoline. Both of these studies suggest the more unstable the surface, the greater increase in postural stability.

During wobble board exercise, the individual actively moves the board through their full ankle ROM causing stretch and tension to the structures. Muscle spindles and GTO are stretch and tension receptors, respectively, meaning they are likely stimulated during wobble board exercises. In addition, researchers have concluded that mechanoreceptors located in the joint capsule are only sufficiently stimulated through full range of motion to contribute substantially to proprioception. Joint capsular afferents are unlikely to signal joint position sense and kinesthesia information through the midranges of motion which may be why standing on a WBV platform does not elicit the same effects on postural control as wobble board balance training.

Previous studies have shown the significance of administering balance protocols for longer duration. A 12-week training program involving wobble board training for 15 minutes a day showed decreased CAI symptoms. Follow up testing was performed 230 days after treatment and, of the 24 patients involved, 6 had reoccurring sprains and none had subjective instability of the ankle joint after completing the rehabilitation program. Tropp et al. found similar results. This study found a reduction in the number of subsequent ankle sprains after a 10 week period of ankle disk training in soccer players. Potentially, the longer the intervention duration, the longer lasting the effects of the wobble board balance training.

Lastly, other studies which incorporated a multifaceted treatment approach targeting balance and proprioception took about 20-30 minutes to complete, whereas this meta-analysis shows that improvements can been seen in 10-12 minutes when using wobble board as a rehabilitation tool.
Improvements in PM reach scores in this meta-analysis are consistent with these multi-exercise rehabilitation protocols (5.3-11%).\textsuperscript{20,21}

\textbf{Literature Supporting the Use of Whole Body Vibration as an Intervention for Chronic Ankle Instability}

The findings from this meta-analysis are supported by several studies that found no significant effect of WBV on balance.\textsuperscript{38,64} Martinez et al. studied the effects of a 6-week WBV intervention on the reflex responses of the peroneus longus, peroneus brevis, and anterior tibialis when exposed to a sudden inversion mechanism in healthy, recreationally active individuals.\textsuperscript{64} No significant changes were found following the WBV intervention. Pollock et al. investigated the effects of low vs. high amplitude vibration on balance, joint position sense, and cutaneous sensation in young, healthy individuals, but found no significant effects of WBV.\textsuperscript{38}

While the wobble board moves in all directions, the WBV platform only oscillates medial/laterally. Additionally, subjects in the WBV studies (Rendos et al. and Cloak et al.) stood in the center of the platform which offers the least amount of amplitude.\textsuperscript{10,17} This provides the subject with no challenge or variability, both are important factors in creating a successful intervention to improve postural control.\textsuperscript{18,21,63,65,66} Dickin et al. found WBV to improve postural stability when the environment was more challenging.\textsuperscript{35} When the parameters of the platform were more challenging, it elicited lasting effects on balance, persisting for 20 minutes.\textsuperscript{35} Whereas, in less challenging environments, the effects dissipated quicker, 10-20 min.\textsuperscript{35}

Improvements in balance after WBV training are more likely to be seen in the elderly population.\textsuperscript{34,39,44,45,67,68} This is partially due to balance deficits associated with aging.\textsuperscript{41,42} Comparisons between the older and younger population
consistently demonstrate that balance is impaired with the aging process.\textsuperscript{41,42} The older population has a greater potential for improving balance, therefore, they are more likely to benefit from WBV. These conflicting findings depend largely on the varying parameters of the WBV stimulus, WBV protocols and differences in subject characteristics.

**Clinical Implications**

The implications for clinical practice suggest that wobble board balance training can be more effective than WBV training for the treatment of CAI in the younger, recreationally active population. These findings may be particularly relevant due to the fact that ankle sprains and CAI make up a large portion of cases seeking physical therapy treatment.\textsuperscript{1,3,4,12,14,20} Physical therapists practice prevention which further signifies the need for this meta-analysis and the importance of preventing re-occurring sprains and the treatment CAI.

Wobble board balance exercises can be performed in a variety of ways. Evidence shows whether training on single limb or double limb, or using a different type of unstable board or disk, postural control can improve in patients with CAI.\textsuperscript{18,22,23,30,69} This meta-analysis suggests that a 4-week long wobble board balance intervention can significantly improve dynamic balance. Longer programs, lasting 6-8 weeks, may provide long-term effects for postural control.\textsuperscript{59,61}

Based on the results of the analysis, WBV is not sufficient in treating younger more active patients.\textsuperscript{10,17,41,42} More research should be done to understand the effects of adding WBV as an adjunct to wobble board exercises for rehabilitation of patients with CAI.
The clinician should consider tailoring exercise type and difficulty to each individual’s assessed impairments. If a patient is unable to move the wobble board without success or without pain, WBV training is a viable option. Findings suggest that those with very poor balance, such as the elderly, are more likely to benefit from a vibration exercise intervention. Whole body vibration training offers a type of exercise stimulus that is safer for older adults.

In addition, it is important to keep in mind the sport or activity the client is involved in or wishes to get back to. Wobble board balance training could be used as it is functional and puts the client into the actual dynamic task. The therapist should consider using the wobble board for lower limb predominant sports like dancing, gymnastics and soccer players.

If time or space is limited, it should be noted that wobble board balance training and WBV use a single piece of equipment while offering equal or greater effect sizes compared with multi-station protocols.

**Future Directions**

In an attempt to better categorize subjects with CAI, the number of sprains and amount of laxity should be made apparent in the inclusion criteria for all CAI research and should be clearly reported within each study. This could provide better homogeneity within studies and a better understanding of indications that may better direct the intervention type; wobble board balance training versus WBV. Secondly, future studies should compare similar WBV protocols which involve the participant to perform voluntary muscle contraction as it has been suggested to increase the synchronization of the motor units when combined with a voluntary contraction. The next level of research should be follow up with participants of wobble board and WBV training studies months later to see if there
are long term effects and to see if it reduces the number of sprains. Furthermore, more self-reported outcome measures should be included in all CAI studies because 1 of the main components of CAI is having feelings of instability and “giving way” which can only be obtained subjectively. Anteromedial and medial directions should be included as these measurement directions best represent functional deficits related to CAI.\textsuperscript{49}
CHAPTER 5: CONCLUSION

With the goal of returning patients to high levels of function in a limited time frame, clinicians are challenged to find interventions that will improve ankle stability and prevent re-injury. The findings from this meta-analysis reveal that wobble board training is superior to WBV training when improving short term outcomes in postural control, however WBV should not be discounted as treatment for CAI especially in the elderly population. In addition, this meta-analysis found that only 4-weeks of wobble board training can provide significant positive effects on postural control.

However, it is clear that more high-quality research is needed in this area to ensure the efficacy of wobble board training over WBV training for those with CAI. Further studies are needed to clarify if wobble board balance training remains effective in more than 4 weeks of treatment and if WBV training can be just as effective as wobble board balance training if treated for similar duration.
REFERENCES
REFERENCES


53. Jewell DV. *Guide to Evidence-Based Physical Therapy Practice.* Canada: Jones and Bartlett Publishers; 2008


TABLES
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>Sample(n)</th>
<th>Intervention</th>
<th>Outcome Measure</th>
<th>Treatment Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wright 2016</td>
<td>RCT</td>
<td>N total=40</td>
<td>Wobble board balance training (Linens et al. protocol)</td>
<td>SEBT</td>
<td>4 weeks (3x/week, 5 min each) =12 sessions</td>
</tr>
<tr>
<td>Linens 2015</td>
<td>RCT</td>
<td>N total=34</td>
<td>Wobble board balance training (Linens et al. protocol)</td>
<td>SEBT</td>
<td>4 weeks (3x/week, 5 reps) =12 sessions</td>
</tr>
<tr>
<td>Cloak 2010</td>
<td>RCT</td>
<td>N total=38</td>
<td>Whole body vibration training</td>
<td>SEBT</td>
<td>6 weeks, 2x per week, 10-14 min sessions</td>
</tr>
<tr>
<td>Rendos 2017</td>
<td>RCT</td>
<td>N total=19</td>
<td>Whole body vibration training</td>
<td>SEBT</td>
<td>3 days (6 reps, 60 secs on/off) about 12 minutes</td>
</tr>
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</table>
Table 2. Whole Body Vibration and Wobble Board Balance Exercise Baseline Characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Whole Body Vibration</th>
<th>Wobble Board Balance Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>Mean age</td>
<td>30 ± 8.91</td>
<td>19 ± 0.8</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Male</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>FAAM score</td>
<td>86.5 ± 4.0</td>
<td>N/A</td>
</tr>
<tr>
<td>FAAM Sport score</td>
<td>70.4 ± 9.4</td>
<td>N/A</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>68.2 ± 11.2</td>
<td>60.3± 5.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.1 ± 11.90</td>
<td>164.5 ± 8.7</td>
</tr>
<tr>
<td>Exercise amount</td>
<td>30 min of mod-high level exercises 3x/wk</td>
<td>Female dancers</td>
</tr>
<tr>
<td>CAIT score</td>
<td>N/A</td>
<td>18.4 ± 1.3</td>
</tr>
</tbody>
</table>
Table 3. Methodological Quality Using PEDro Scale

<table>
<thead>
<tr>
<th>PEDro Criteria</th>
<th>Linens 2015</th>
<th>Wright 2016</th>
<th>Cloak 2010</th>
<th>Rendos 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligibility criteria specified</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Random allocation of subjects</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Similar groups at baseline</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Subjects blinded</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Therapists administering treatment blinded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessors blinded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One key outcome obtained from 85% of subjects initially allocated to groups</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>‘Intention to treat’ used for analysis of 1 key outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between-group statistics for 1 key outcome reported</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Point measures and measures of variability for 1 key outcome</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
<td><strong>6</strong></td>
<td><strong>5</strong></td>
<td><strong>6</strong></td>
</tr>
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Table 4. Effect Size of Postural Control Comparing Whole Body Vibration Training to Wobble Board Balance Exercises

<table>
<thead>
<tr>
<th>STUDY</th>
<th>ES</th>
<th>CI LOWER</th>
<th>CI UPPER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloak 2010/Wright 2016</td>
<td>-0.54</td>
<td>-1.18</td>
<td>0.10</td>
</tr>
<tr>
<td>Rendos 2017/Linens 2015</td>
<td>-0.25</td>
<td>-1.13</td>
<td>0.63</td>
</tr>
<tr>
<td>GRAND TOTAL</td>
<td>-0.44</td>
<td>-0.96</td>
<td>0.07</td>
</tr>
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</table>

Table 5. Wobble Board Balance Exercise Frequency and Duration

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of session</td>
<td>5 40 sec trials</td>
<td>5 40 sec trials</td>
</tr>
<tr>
<td>Frequency of sessions per week</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Number of weeks of sessions</td>
<td>4 weeks</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Total hours of intervention</td>
<td>40 minutes</td>
<td>40 minutes</td>
</tr>
</tbody>
</table>
Table 6. SEBT Score Change Differences Between Whole Body Vibration Groups and Wobble Board Balance Exercise Groups

<table>
<thead>
<tr>
<th>Study Author</th>
<th>SEBT Score Change</th>
<th>Difference in SEBT scores vs. control or other intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rendos et al. (2017)</td>
<td>0.61% increase</td>
<td>0.62% decrease</td>
</tr>
<tr>
<td>Cloak et al. (2010)</td>
<td>9.11% increase</td>
<td>2.3% decrease</td>
</tr>
<tr>
<td>Linens et al. (2015)</td>
<td>15.29% increase</td>
<td>3.1% increase</td>
</tr>
<tr>
<td>Wright et al. (2016)</td>
<td>5.1% increase</td>
<td>8.7% increase</td>
</tr>
</tbody>
</table>

Table 7. Whole Body Vibration Frequency and Duration

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration Platform used</td>
<td>Power Plate Platforms (Model Pro-5, Power Plate North America, Northbrook, IL, USA)</td>
<td>Vibration platform (Bosco, Greece)</td>
</tr>
<tr>
<td>Duration of Whole Body Vibration</td>
<td>6 minutes</td>
<td>10-14 minutes</td>
</tr>
<tr>
<td>Frequency</td>
<td>30 Hertz</td>
<td>30-40 Hertz</td>
</tr>
<tr>
<td>Frequency of sessions per week</td>
<td>3x/week</td>
<td>2x/week</td>
</tr>
<tr>
<td>Number of weeks of sessions</td>
<td>1 week</td>
<td>6 weeks</td>
</tr>
<tr>
<td>Total Minutes</td>
<td>18 minutes</td>
<td>144 minutes= 2.4 hours</td>
</tr>
<tr>
<td>Exercises performed on the vibration plate</td>
<td>Single-leg stance of the test leg while holding handlebars</td>
<td>Single leg heel raises and single leg squats</td>
</tr>
</tbody>
</table>
Figure 1. Consort
Figure 2. Forest plot