A Thesis

Entitled

Effects of Joint Mobilization on Ankle Dorsiflexion Range of Motion, Dynamic Postural Control and Self-Reported Patient Outcomes in Individuals with Chronic Ankle Instability

by

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Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Exercise Science

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An Abstract of

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Objective: The purpose of this study was to evaluate the effects of joint mobilization on ankle dorsiflexion range of motion, dynamic postural control, and self-reported patient outcomes in individuals with chronic ankle instability (CAI). A secondary purpose was to determine which contributing factor or factors can improve a participant’s performance on the Star Excursion Balance Test. Design: This research study was a single-blinded, randomized control trial with one between factor (2 levels: intervention and control) and one within factor (pre- and post-intervention). Participants: Seventeen participants with self-reported unilateral CAI, between 18 and 35 years of age, were recruited from the University of Toledo community and were randomly allocated to two groups, intervention and control. Methods: Participants completed one testing session that included a non-weight bearing dorsiflexion measurement using a bubble inclinometer, a weight-bearing dorsiflexion measurement using the Weight Bearing Lunge Test and dynamic postural control measured by the Star Excursion Balance Test (SEBT) pre- and post-intervention. The intervention consisted of a Maitland Grade IV oscillatory anterior-
to-posterior talar joint mobilization. **Main Outcome Measures:** The main outcome measures were dorsiflexion range of motion, dynamic postural control and self-reported patient outcomes. Factors contributing to the performance of the SEBT in individuals with CAI were also determined. **Statistical Analysis:** The means and standard deviations of the absolute change scores were used for statistical analysis. The independent sample t-test was used to compare each dependent variable between the intervention and control groups. A Cohen’s $d$ effect size along with 95% confidence intervals (CI) was calculated for each comparison between groups and between pre-and post-intervention measurements to determine the magnitude of the joint mobilization effect. A multiple linear backward regression model analysis was also performed to determine which dependent variables influence the improvement of the SEBT performance. **Results:** There were no statistically significant results for the main outcome measures. However, large effect sizes were identified for the anterior reach of the SEBT, non-weight bearing dorsiflexion and a reduction in pain when comparing the two groups. A large effect size was also determined for non-weight bearing dorsiflexion, pain, and stability when comparing pre- and post-intervention scores for the joint mobilization group and for weight-bearing dorsiflexion for the control group. **Conclusion:** A single dose of a Maitland Grade IV anterior-posterior talar glide joint mobilization did not result in statistically significant improvements in DF range of motion, dynamic postural control, and self-reported patient outcomes, but some of the outcome measures resulted in large effect sizes. This indicates that joint mobilizations may provide potential clinical benefits for the improvement in DF range of motion, dynamic postural control, and pain in patients with CAI.
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List of Abbreviations

% MAXD………………………………..Normalized Percentage of the Reach Distance

BESS………………………………Balance Error Scoring System

CAI…………………………………..Chronic Ankle Instability
CI……………………………………Confidence Interval

DF…………………………………Dorsiflexion

ES………………………………….Effect Size

FADI………………………………Foot and Ankle Disability Index

ICC…………………………………Intraclass Correlation Coefficients

JM…………………………………Joint Mobilization

MWM………………………………Mobilization with Movement

NWB………………………………Non-Weight Bearing

PL…………………………………Posteriorlateral
PM…………………………………Posteriormedial

RICE………………………………Rest, Ice, Compression, Elevation

ROM………………………………Range of Motion

SEBT………………………………Star Excursion Balance Test

VAS………………………………Visual Analog Scale

WB…………………………………Weight Bearing

WBLT………………………………Weight Bearing Lunge Test
Chapter 1

Introduction

Ankle sprains are considered to be the most common orthopedic injury that occurs among the physically active.\textsuperscript{1-5} It has been reported that 32\% of those who suffer from an initial ankle sprain develop recurrent ankle sprains and 72\% of those with residual symptoms had functional impairment in the ankle;\textsuperscript{6} however this rate has been reported as high as 80\%.\textsuperscript{7,8} This recurrent ankle sprain with residual symptoms, such as a subjective feeling of the ankle “giving way”, has been referred to as chronic ankle instability (CAI).\textsuperscript{9} Residual symptoms of recurrent ankle sprains could significantly impair individuals’ functions and movement patterns, decreasing their activity level over the life span.\textsuperscript{10} Additionally, a lateral ankle sprain is one of the risk factors associated with development of ankle osteoarthritis.\textsuperscript{11}

Dorsiflexion (DF) range of motion (ROM) at the ankle joint is usually restricted following lateral ankle sprains.\textsuperscript{9,12,13} Restricted DF following a lateral ankle sprain may contribute to functional and mechanical instability with residual symptoms.\textsuperscript{9} Limited DF may result in excessive supination of the ankle during functional activities, such as walking, impairing ankle stability.\textsuperscript{14} Therefore, limited DF may be a predisposing factor
to repetitive ankle sprains. Not surprisingly, previous studies have observed deficits in ankle DF in the CAI population.\textsuperscript{12-14}

It has been proposed that restricted ankle DF may be associated with altered arthrokinematics at the talocrural joint.\textsuperscript{15,16} Joint mobilizations (JM) have been considered as a possible modality for rehabilitation of ankle sprains, especially to restore proper accessory motion.\textsuperscript{1,16} Previous studies demonstrated an improvement of ankle DF ROM following joint mobilization applications in individuals with CAI.\textsuperscript{16-20} In addition to limited DF, previous studies\textsuperscript{1,12,21} used JMs to address altered postural control in the CAI population and sensorimotor impairments at other joints in the lower extremity. Neuromuscular and postural control deficits in individuals with CAI have been previously reported during dynamic tasks,\textsuperscript{23-25} such as the Star Excursion Balance Test (SEBT), and related to increased risk of re-injury.\textsuperscript{26,27} Hoch and McKeon\textsuperscript{21} reported that a Maitland Grade III anterior-to posterior JM to the ankle improved static postural control and ankle DF; however, these outcome variables were not measured prior to a treatment session in their study. Therefore, the effect of JM on postural control and ankle DF demonstrated by their study is inconclusive.

1.1 Statement of the Problem

There is mounting literature that has reported an improvement in arthrokinematics and sensorimotor function with the presence of CAI following JM.\textsuperscript{17,20,21} However, these studies are coupled with heterogeneous effects and lack of patient-oriented evidence that may limit the clinical relevance of JM treatment effects on arthrokinematic restriction and sensorimotor function. Finding a valid intervention that would improve DF ROM,
dynamic postural control, and self-reported patient outcomes may be clinically important for treating those with CAI and reducing the number of future ankle sprains.

1.2 Statement of the Purpose

The purpose of this study was to evaluate the effects of JM on ankle DF ROM, dynamic postural control, and self-reported patient outcomes in individuals with CAI. A secondary purpose was to determine the contributions of selected factors on a participant’s performance on the SEBT.

1.3 Research Hypotheses

1. We hypothesized that ankle DF ROM would be improved following one session of a posterior talar glide JM in individuals with CAI.

2. We hypothesized that dynamic postural control would be improved following one session of a posterior talar glide JM in individuals with CAI.

3. We hypothesized that self-reported patient outcomes would be improved following one session of a posterior talar glide JM in individuals with CAI.

4. We hypothesized that contributing factors, such as pain, stiffness, stability, and function, would determine the improvements in performance of dynamic postural control following one session of a posterior talar glide JM in individuals with CAI.

1.4 Assumptions

We assumed participants would truthfully complete the health questionnaire, the Foot and Ankle Disability Index (FADI) and the FADI sport instruments, as well as, the visual analog scale (VAS) for pain, stiffness, stability, and function. We also assumed the
individuals would perform to the best of their ability on all tasks required of them. We assumed the tools needed for the assessments will be reliable and valid.

1.5 Significance

The information gained from this study would be used to determine possible treatment options for individuals with CAI. If improvements in ankle DF and dynamic postural control following a single application of JM are observed in this study, this technique could be considered as a treatment option in a rehabilitation plan.

1.6 Operational Definitions

Ankle Sprain- an incident in which the rearfoot was inverted or supinated, which resulted in a combination of swelling, pain, and time lost or modification of normal function for at least one day.21

Arthokinematics- the physiology of joint movement.28 The manner in which two articulated joint surfaces move relative to one another.28

Chronic Ankle Instability (CAI)- subjective feeling of the ankle “giving way” after an ankle sprain along with multiple bouts of instability that results in additional ankle sprains.21

FADI- Foot and Ankle Disability Index

Joint Mobilization (JM)- aims to increase physiologic and accessory motion by increasing the extensibility of the noncontractile capsular and ligamentous tissues and improve the transmission of afferent information by stimulating joint mechanoreceptors.29
PM- Postiormedial

PL- Postiorlateral

Postural Control- static: attempting to maintain a position with minimal movement; dynamic: maintaining a stable base of support while completing a prescribed movement.\textsuperscript{30}

SEBT- Star Excursion Balance Test

VAS- Visual Analog Scale

WBLT- Weight Bearing Lunge Test
Chapter 2

Literature Review

2.1 Introduction

Ankle sprains are considered to be the most common orthopedic injury that occurs among the physically active.\textsuperscript{1-5} The mechanism of injury is typically an inversion type of trauma\textsuperscript{15,17} along with extremes of plantar flexion.\textsuperscript{18} The anterior talofibular ligament and calcaneofibular ligament are relatively weak and are prone to rupture with minimal amounts of force.\textsuperscript{18} Common signs and symptoms of an acute lateral ankle sprain are swelling, tenderness, and pain with movement and full weight bearing.\textsuperscript{9} A history of previous sprains is one of the most common risk factors for an ankle sprain.\textsuperscript{1,31-37} A history of ankle sprains consists of multiple ankle instability occurrences along with decreased functional abilities.\textsuperscript{1} Multiple ankle sprains in athletes can occur at a rate greater than 70% and as high as 80%.\textsuperscript{8,38,39} Several mechanical and functional deficits have been recognized in individuals with a history of ankle sprains.\textsuperscript{1} The purpose of this literature review was to evaluate the techniques used for the research study and the evidence pertaining to CAI, DF ROM and limitations, methods of measurement, SEBT, and JM techniques.

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Restricted DF ROM is one of the deficits recognized following ankle sprains.\textsuperscript{1,31-33,38,40,41} Restricted DF often leads to development of alterations in the axes of rotation of the ankle, as well as, the alignment and tracking of bony surfaces, influencing the sensorimotor system.\textsuperscript{1} These deficits may result in recurrent ankle sprains and lead to ankle osteoarthritis.\textsuperscript{1,11,42,43} Decreased ankle DF, proprioceptive deficits and a reduced posterior glide of the talus in the ankle mortise are contributing factors to re-injury of an ankle sprain.\textsuperscript{17} The loss of DF ROM and muscle strength leads to gait dysfunction,\textsuperscript{44} specifically walking gait stride and speed.\textsuperscript{45} A lack of DF also limits normal functional activities, such as descending stairs and kneeling.\textsuperscript{45}

Common initial treatment for ankle sprains is rest, ice, compression, elevation (RICE) and electrotherapy modalities to control inflammation and pain.\textsuperscript{4,18} Trevino et al\textsuperscript{4} suggests using functional treatment for ankle sprains. Immobilization may also be used as a treatment for ankle sprains depending on the severity of the injury.\textsuperscript{4} Treatment options also include crutches, elastic wrap, and the transition to weight bearing when possible.\textsuperscript{4} To improve movement and strength following an ankle sprain, manual therapy and therapeutic exercise techniques should be implemented.\textsuperscript{18} The therapeutic exercise that may help with DF include weight-bearing and non-weight bearing stretching of the gastrocnemius-soleus complex.\textsuperscript{15} Trevino et al\textsuperscript{4} believes these exercises should focus on peroneal and dorsiflexor strengthening along with Achilles tendon stretching. However, normal talocrural joint arthrokinematics will not be restored with time and therapeutic exercise alone.\textsuperscript{15} The final stage of the treatment program includes agility and endurance exercises and proprioception retraining.\textsuperscript{4}
2.2 Chronic Ankle Instability

Chronic Ankle Instability is defined as a subjective feeling of the ankle “giving way” after an ankle sprain along with multiple bouts of instability that results in additional ankle sprains. Hertel\textsuperscript{9} defines CAI as the occurrence of repetitive bouts of lateral ankle instability resulting in numerous ankle sprains. Individuals that have experienced repetitive ankle sprains have been described as having functional instability, chronic instability, and residual instability.\textsuperscript{9} Lateral ankle instability is the existence of an unstable ankle because of lateral ligamentous damage caused by excessive supination or inversion of the rearfoot.\textsuperscript{9}

Chronic Ankle Instability has been related to two theories: mechanical and functional instabilities.\textsuperscript{9} Mechanical instability is related to pathologic laxity after a ligament injury in the ankle.\textsuperscript{9} It has also been defined as motion beyond the physiologic ROM.\textsuperscript{4} Mechanical instability may be caused by mechanical alterations of joints in the ankle.\textsuperscript{9} Examples of mechanical insufficiencies related to mechanical instabilities include pathologic laxity, impaired arthrokinematics, synovial inflammation and impingement, and degenerative changes.\textsuperscript{9} These are all anatomical changes that occur in the joint itself.\textsuperscript{9} Pathological laxity occurs most often in the talocrural and subtalar joints of the ankle.\textsuperscript{9} An arthrokinematic restriction associated with repetitive ankle sprains is a positional fault at the inferior tibiofibular joint.\textsuperscript{9}

Kavanagh\textsuperscript{46} conducted a study to determine if a positional fault occurs at the distal tibiofibular joint when the foot is inverted beyond its normal range. The results of this study determined that a significantly greater amount of movement per unit force was
available in the anterior and posterior direction in two out of six individuals with acutely sprained ankles (P=0.01) and (P=0.09), respectively.\textsuperscript{46} However, the second individual’s resulting P value was above the \textit{a priori} level of P<0.05. This may be explained by laxity of the anterior talofibular ligament resulting from a positional fault at the distal inferior joint.\textsuperscript{46} Kavanagh\textsuperscript{46} concludes that a positional fault occurs at the inferior talofibular joint of a proportion of individuals that experience an ankle sprain. Treatment used to correct this positional fault will have a positive effect on the individual’s symptoms.\textsuperscript{46}

Functional instability is related to reoccurring ankle instability and the sense of joint instability because of the contributions of proprioceptive and neuromuscular deficits.\textsuperscript{4,9} Functional ankle instability is associated with insufficiencies in proprioception, neuromuscular control, postural control, or strength.\textsuperscript{9} Deficits in postural control are caused by impaired proprioception and neuromuscular control.\textsuperscript{9} Chronic functional instability is believed to be associated with mechanical instability and peroneal weakness.\textsuperscript{4}

There have been several studies that have shown a proprioceptive deficit following a lateral ankle sprain. Glencross and Thornton\textsuperscript{47} were the first researchers to report impaired ability to actively replicate joint positions in individuals with a history of a lateral ankle sprain. The individuals that had experienced a severe lateral ankle sprain demonstrated a greater error in the procedure compared to those who only experienced a mild lateral ankle sprain.\textsuperscript{47} This study required the individuals to replicate various degrees of plantar flexion,\textsuperscript{47} not DF, which is typically decreased following an ankle sprain. The results of this study were contradicted by a research study conducted by
Gross,\textsuperscript{43} which did not find impaired active or passive joint position sense in individuals with repetitive lateral ankle sprains.

Bosien et al\textsuperscript{48} conducted a research study which proved that peroneal weakness was prevalent in individuals with residual disability after sustaining a lateral ankle sprain. In contrast, Lentell et al\textsuperscript{49} found no significant differences in the strength of injured and noninjured ankles of individuals with a history of lateral ankle sprains. Both research studies evaluated the eversion strength of the individual’s ankle,\textsuperscript{48,49} but had conflicting results. Invertor weakness in individuals with functional instability was determined by Ryan.\textsuperscript{50} Greater inversion deficits compared to eversion deficits were determined by concentric isokinetic testing in individuals with a history of lateral ankle sprains by Wilkerson et al.\textsuperscript{51}

To determine levels of neuromuscular function for injury prevention and rehabilitation, postural control should be measured and is a very important tool.\textsuperscript{52} There are two types of postural control: static and dynamic.\textsuperscript{52} Static postural control is when the individual maintains a position with minimal movement while standing on one or two feet.\textsuperscript{52} An example of a test used to assess static postural control is the modified Rhomberg test.\textsuperscript{9,52} This involves the individual standing motionless on one foot as tasks are asked to be completed to challenge the postural control system.\textsuperscript{9,52} Examples of tasks are closing the eyes, titling the head up, and touching an index finger to the nose.\textsuperscript{9,52} Another examination tool to measure static postural control is the Balance Error Scoring Test, or BESS.\textsuperscript{53} This test utilizes different stances and support surfaces to challenge the individual’s ability to maintain balance.\textsuperscript{53}
Dynamic postural control can be assessed when the individual maintains a stable base of support while completing various functional movement tasks.\textsuperscript{52,54} When testing the dynamic postural control, not only is the individual trying to remain upright and steady, proprioception, ROM, and strength are also challenged.\textsuperscript{9,52,54,55} The SEBT is a test used to challenge an individual’s postural control system,\textsuperscript{52,54} as well as, multiple neuromuscular insufficiencies.\textsuperscript{9} Interventions that address mechanical and functional impairments are critically important for restoring levels of activity and participation in those with CAI.\textsuperscript{21}

\subsection{Star Excursion Balance Test}

The SEBT consists of lower extremity maximal reach tests while balancing on the opposite limb,\textsuperscript{52-54,56-58} without disrupting the base of support of the stance leg.\textsuperscript{52} The individual makes a light touch on the line with the most distal part of the reaching leg and returns to the starting position.\textsuperscript{52} Previous literature reported the SEBT is a reliable and valid assessment of dynamic stability. Munro and Herrington\textsuperscript{54} determined that the reliability scores were high with Intraclass Correlation Coefficients (ICC) ranging from 0.84 to 0.92. Hertel et al\textsuperscript{53} determined an ICC ranging from 0.78 to 0.96 for intratester reliability for the eight reach direction protocol.

Hertel et al\textsuperscript{53} suggested that only six practice trials in each direction is appropriate due to the learning effect with measured trials following. Munro and Herrington\textsuperscript{54} suggested that the SEBT protocol should include only four practice trials, instead of the six practice trials that have been suggested by Hertel et al.\textsuperscript{53} Robinson and Gribble\textsuperscript{57} demonstrated that only four practice trials are needed without diminishing validity of the
test. Based on the ICC’s determined by Munro and Herrington,\textsuperscript{54} the reliability of four practice trials is the same as six practice trials for the SEBT. Robinson and Gribble\textsuperscript{57} found that the validity of the test was not affected when the number of practice trials was reduced from six to four. Three measured trials has been recommended after the practice trials for clinical and research purposes.\textsuperscript{54}

This test has been used to screen for functional limitations that are related to musculoskeletal injuries and impairments, such as CAI,\textsuperscript{59} quadriceps strength deficits,\textsuperscript{60} and patellofemoral pain syndrome.\textsuperscript{61} The distance reached determines the subject’s performance on the SEBT.\textsuperscript{55,56} If a short reach distance is achieved, there is often a mechanical or sensorimotor system deficit.\textsuperscript{56} If the individual has a history of a foot or ankle pathology, there may be a triceps surae tightness or an ankle arthrokinematic restriction, which is related to a decrease in posterior talar glide.\textsuperscript{56} However, there is little evidence about the relationship between DF ROM and performance on dynamic postural control, such as the SEBT.\textsuperscript{56} Hoch et al\textsuperscript{56} investigated a correlation between maximum weight-bearing DF ROM and performance on the anterior reach direction of the SEBT. The authors found that there was a significant relationship between DF ROM and the anterior reach direction while there is no relationship between DF ROM and the other 2 reach directions.\textsuperscript{56} This suggests that the anterior reach direction may be a better indicator of lower extremity function in those with a lower extremity injury when DF ROM is a concern.\textsuperscript{56}

Plisky et al\textsuperscript{55} conducted a research study to determine if there is a link between SEBT reach distances and risk of lower extremity injury among high school basketball
players. The results of this study showed there were certain SEBT performance differences associated with the individuals that were injured throughout the basketball season.\textsuperscript{55} They found that an anterior right-to-left reach distance greater than or equal to 4 cm, decreased normalized right anterior reach distance and decreased normalized posteriormedial, posteriorlateral, and composite reach distances bilaterally were significant predictors of lower extremity injury.\textsuperscript{55} Specifically, they determined that if an individual had an anterior right-to-left reach distance difference of more than 4 cm, they were 2.5 times more likely to have a lower extremity injury occur.\textsuperscript{55}

Kinzey and Armstrong\textsuperscript{58} used diagonal reach directions for the SEBT in their research study to test dynamic balance: right anterior, right posterior, left anterior, left posterior. The results of the study revealed an ICC for the right anterior reach direction of 0.67 and 0.82 for the right posterior reach direction.\textsuperscript{58} To achieve reliability, Kinzey and Armstrong\textsuperscript{58} believe that at least six practice sessions of five trials in each direction per session must be performed.\textsuperscript{58} The average of the best three reaches would be used for analysis.\textsuperscript{58} This yielded a reliability measure between 0.86 and 0.95.\textsuperscript{58} To gain the measure of 0.95, 18 separate practice trials of five trials per direction per session would need to be performed.\textsuperscript{58} Kinzey and Armstrong\textsuperscript{58} suggest that the star-excursion test might not be an appropriate test to assess dynamic balance, but may be an important tool in rehabilitation. The researchers feel that the movement associated with the SEBT are not movements individuals normally perform, such as activities of daily living or those performed in sports.\textsuperscript{58} The test may be a better indicator of dynamic balance if the movements mimicked activities of daily living.\textsuperscript{58} They believe that practice may improve
the reliability of the test, but this may take a large amount of time that clinicians may not have.\textsuperscript{58}

There is evidence supporting the use of only three reach directions (anterior, posteriormedial, and posterirolateral)\textsuperscript{56} and it may be sufficient and more efficient compared to using the data from the normal eight reach directions.\textsuperscript{52} Robinson and Gribble\textsuperscript{57} suggested that the SEBT protocol could be simplified by reducing the number of reach directions from eight to three, such as anteriormedial, medial, and posteriormedial. The protocol of reaching in only three directions and performing four practice trials is still valid according to research conducted by Robinson and Gribble.\textsuperscript{57}

The SEBT performance may be influenced by specific anthropometric measures and normalization of the reach distances may be needed. Gribble and Hertel\textsuperscript{52} found a stronger correlation between leg length and reach distances for six of the eight reach directions. This has led to the normalization of the data retrieved from the SEBT.\textsuperscript{52} The leg length is determined by measuring from the anterior superior iliac spine to the medial malleolus of the individual while laying supine.\textsuperscript{54} Normalization is achieved by dividing each reach distance by the individual’s leg length and multiplying this value by 100,\textsuperscript{52,54} expressed as a percentage of the reach distance in relation to the participant’s leg length (\%MAXD).\textsuperscript{52} Normalization of reach distances is important when comparing separate individuals, not when comparing two results for the same individual.\textsuperscript{54} The raw reach distances for men were significantly greater than raw reach distances for the women in the study by Gribble and Hertel.\textsuperscript{52} But, the normalized reach distances determined there were no differences between males and females.\textsuperscript{52} Composite reach distance is
determined by the sum of the three reach directions divided by three times limb length multiplied by 100.\textsuperscript{55}

Hoch et al\textsuperscript{56} found that the anterior reach direction of the SEBT was significantly correlated to the Weight Bearing Lunge Test (WBLT) (p<0.001). There was no correlation between the other two reach directions of the SEBT and the WBLT.\textsuperscript{56} Hoch et al\textsuperscript{56} concluded that there is a significant correlation between maximum weight-bearing DF ROM and performance on the anterior direction of the SEBT. The researchers determined that DF ROM accounted for an estimated 28% of the variance in the anterior reach.\textsuperscript{56} A suggestion based on the results of this study is that the anterior reach direction of the SEBT may be a more useful clinical indicator of lower extremity function for individuals with a lower extremity injury in which DF ROM is a clinical consideration.\textsuperscript{56} Hoch et al\textsuperscript{56} suggested that a decreased performance on the anterior reach direction in those with a history of foot and ankle pathology may be indicative of triceps surae tightness or ankle arthrokinematic restriction specifically related to decreases in posterior talar glide. The researchers believe the anterior reach direction of the SEBT may be a good clinical test to assess the effects of DF ROM restrictions on dynamic balance.\textsuperscript{56}

2.4  Dorsiflexion

The talocrural joint of the ankle is formed by the articulation of the dome of the talus, the medial malleolus, the tibial plafond, and the lateral malleolus.\textsuperscript{9} The axis of rotation of the talocrural joint passes through the malleoli.\textsuperscript{9} During normal ankle DF, the talus rolls and glides posteriorly relative to the calcaneus.\textsuperscript{21} Closed kinetic chain dorsiflexion occurs when the tibia moves anteriorly on the fixed talus during weight
bearing. The lateral and medial collateral ligaments supporting the ankle are very important for the stability of the joint.

The anterior talofibular ligament prevents anterior displacement of the talus and excessive inversion and internal rotation of the talus on the tibia. This ligament is the most frequently injured lateral ligament, which may be due to its lower maximal load and energy to failure value under stress. The integrity of the joint can be assessed using the anterior drawer, which determines the amount of anterior displacement of the talus from the tibiofibular mortise. The posterior talofibular ligament restricts inversion and internal rotation of the loaded talocrural joint and is the least commonly sprained lateral ankle ligament. The calcaneofibular ligament restricts excessive inversion and internal rotation of the rearfoot and is taut during DF. This ligament is the second most injured ligament of the lateral talocrural joint ligaments. This ligament can be assessed by determining the amount of talar tilt when inverting the rearfoot when the talocrural joint is dorsiflexed. Another injured ligament seen with a lateral ankle sprain is the bifurcate ligament due to its role of resisting supination. The peroneal longus and brevis muscles are important in controlling against supination and preventing lateral ankle sprains as much as possible.

2.5 Dorsiflexion Limitations

There are many theories that have been proposed to explain why DF is limited in the ankle after ankle sprains. It can be limited by tightness in the muscles that plantar flex the ankle, specifically the gastrocnemius and soleus. It can also be limited by capsular
and soft tissue restrictions, loss of normal posterior glide of the talus in the mortise and loss of other accessory motions at the tibiofibular, subtalar, and midtarsal joints.\textsuperscript{15}

Dorsiflexion ROM deficits can also be caused by restrictions in contractile or non-contractile tissue.\textsuperscript{21} These deficits could be caused by a talar positional fault in the form of anterior talar displacement\textsuperscript{21} and restricted posterior talar glide.\textsuperscript{19,21} A loss of DF ROM may contribute to an impaired sensorimotor system function.\textsuperscript{21} This occurs by disrupting the normal transmission of afferent information related to alterations in ankle rotation and tracking of the articular surfaces.\textsuperscript{21} Leanderson et al\textsuperscript{40} determined that there was no difference in ankle ROM between basketball players with and without an ankle sprain. But, there was limited DF ROM between the group of basketball players compared to the control group.\textsuperscript{40}

It has previously been demonstrated that individuals with CAI had improved DF ROM after the application of a JM.\textsuperscript{16-21} Specifically, Hoch and McKeon\textsuperscript{21} reported significant differences in DF ROM between the JM and control groups (P=0.01). Green et al\textsuperscript{16} determined that an anteroposterior mobilization of the talus along with RICE resulted in greater increases in DF ROM than RICE alone.

Dorsiflexion can be restored, but there could still be a restriction of posterior talar mobility.\textsuperscript{15} Dorsiflexion can be restored by developing an abnormal axis of rotation at the talocrural joint or hypermobility of the surrounding joints.\textsuperscript{15} Dorsiflexion ROM improvements occur through mechanisms other than that associated with the pain system.\textsuperscript{17} Increases in DF after an ankle sprain could be due to the correction of an anterior positional fault of the talus after JM applications.\textsuperscript{19} Improvement in DF ROM
will help decrease future ankle sprains, as well as restoring full function following a lateral ankle sprain.\textsuperscript{17}

There is a theory that after a lateral ankle sprain, a positional fault at the talocrural joint develops,\textsuperscript{17} which is when the talus is subluxated anteriorly and becomes “stuck.”\textsuperscript{19} Mulligan has developed a positional fault theory which states that a loss of posterior talar glide may be due to an anterior positional fault of the talus on the tibia, which leads to an abnormal axis of rotation at the talocrural joint.\textsuperscript{9,19} If the lateral malleolus is “stuck” in this abnormal position, the anterior talofibular ligament may be more slack in its resting position.\textsuperscript{9} This allows the talus to move in a greater ROM before the ligament becomes taut during supination.\textsuperscript{9} Positional faults may be corrected after the use of JMs or arthrometer testing.\textsuperscript{19}

A decrease in DF ROM can be caused by hypomobility.\textsuperscript{9} If the talocrural joint is unable to dorsiflex correctly, the joint will not be able to reach its closed pack position during stance.\textsuperscript{9} This leads to an easier attempt at inverting and internally rotating.\textsuperscript{9} Hertel\textsuperscript{9} believes that individuals that experienced an acute ankle sprain and received posterior mobilization of the talus on the tibia as a treatment were able to regain DF ROM sooner than those that did not receive this treatment. Collins et al\textsuperscript{18} found a significant treatment effect for DF from pre- to post-application of the mobilization with movement technique. However, Collins et al\textsuperscript{18} did not observe a significant difference between the placebo and control conditions used for this study. This research study used subjects that had sustained a subacute lateral ankle sprain and the mobilization with movement (MWM) technique was able to improve DF immediately.\textsuperscript{18} It is unknown, based on this study,
how these results would relate to individuals with CAI. Vicenzino et al.\textsuperscript{62} examined the effects of weight-bearing (WB) and non-weight-bearing (NWB)-MWM on WB-DF ROM in CAI subjects, and demonstrated significant improvement in WB-DF following both MWM techniques.

2.6 Methods of Measurement

To measure talocrural DF ROM, a WB lunge has previously been used.\textsuperscript{17} The individual stands with the second toe, center of the heel, and knee in a plane perpendicular to the wall with the heel staying on the ground.\textsuperscript{17} The individual lunges forward until the front of the knee is in contact with the wall with the heel remaining on the ground, which is when maximum DF is achieved.\textsuperscript{17} The distance between the great toe and the wall is measured and recorded.\textsuperscript{17} Collins et al.\textsuperscript{18} reported an ICC of 0.99 for the knee-to-wall principle of the WBLT.

Dorsiflexion ROM of the ankle may also be measured using a bubble inclinometer.\textsuperscript{19} Denegar et al.\textsuperscript{15} used a fluid-filled bubble inclinometer to measure ROM. Joint laxity was measured using an anterior drawer test, a talar tilt test, and a medial subtalar glide test.\textsuperscript{15} Dorsiflexion ROM was measured in 4 positions: sitting straight knee, prone bent knee, standing straight knee, and standing bent knee.\textsuperscript{15} A posterior talar glide was performed and the angle of knee flexion was recorded once maximum posterior glide was felt by an end feel.\textsuperscript{15} Denegar et al.\textsuperscript{15} reported intratester reliability estimates for the ROM measurements as 0.88 to 0.99. Significant differences were revealed for all 3 joint laxity tests. A significant difference was revealed between injured and non-injured ankles by the posterior talar glide test at passive knee flexion.\textsuperscript{15} The joint laxity that was
determined shows that there is indeed laxity after an ankle sprain.\textsuperscript{15} Denegar et al\textsuperscript{15} determined that the posterior talar glide was able to prove that a DF restriction was present and was not caused by a lack of flexibility of the gastrocnemius and soleus muscles.

A lack of flexibility of these two muscles is a theory as to why DF ROM is limited. The subjects that participated in this study did have a restricted posterior talar glide, but normal physiological DF ROM.\textsuperscript{15} Denegar et al\textsuperscript{15} believe this could be due to the hypermobility at other joints or rotation about an abnormal axis of rotation at the talocrural joint. These researchers believe that WB and NWB stretching of the gastrocnemius and soleus muscles and time will restore DF ROM, but not normal talocrural joint arthrokinematics.\textsuperscript{15} Joint mobilizations are used to restore accessory motion that has been lost due to an injury or some other pathology.

2.7 Joint Mobilizations

A posterior talar glide JM is used to assess the posterior glide of the talus in the ankle mortise.\textsuperscript{17} Joint mobilizations can not only be used to assess the posterior glide of the talus, but can also be used as a treatment technique. It is performed with the thigh supported on the table, the subtalar joint in neutral, and the foot parallel to the floor.\textsuperscript{17} A glide is applied to the talus posteriorly with the use of direct manual contact over the anterior talus.\textsuperscript{17} Dorsiflexion of the foot is also involved during this technique.\textsuperscript{17} A method of measuring the posterior talar glide involves pushing the talus forward and the ankle is put into DF until a firm capsular end-feel is achieved.\textsuperscript{17} There seems to be a correlation between reduced posterior talar glide and DF ROM.\textsuperscript{17} Posterior talar glide is
an accessory motion component of ankle DF. An individual that has returned to normal activities and has had time to recover from the initial ankle sprain injury often has a reduced posterior talar glide and a lack of DF in the ankle that was injured. In order to improve posterior talar glide and a lack of DF, a JM technique should be applied.

Improving accessory and physiological motion at the talocrural joint should be a clinical consideration. Accessory motion of a joint can be restored by the use of a JM. Joint mobilizations could be an effective intervention to address the DF and posterior talar glide deficits during rehabilitation. This technique is able to increase this motion because of the increase in extensibility of the non-contractile capsular and ligamentous tissues. Joint mobilizations also improve the transmission of afferent information by the stimulation of joint mechanoreceptors. This method has consistently been able to improve DF ROM and posterior talar glide in individuals with acute or recurrent ankle sprains. Combining the increase of afferent activity and the enhancement of neuromuscular function of the joint stabilizing muscles may allow the enhancement of postural control with the use of JMs. Examination of the effect of JM on dynamic postural control may allow us to understand its ability to increase the function of the sensorimotor system in those with CAI.

Mulligan introduced the MWM technique to improve joint ROM by combining accessory mobilization with active or passive physiological movement. This technique is used to increase ROM, improve pain, and promote return to function following an ankle sprain sooner. To reduce a residual anterior displacement of the talus, a WB DF anteroposterior glide MWM technique should be used. There is moderate evidence
supporting the use of the talocral MWM technique to improve DF in individuals with a history of ankle sprains.¹

The WB-MWM technique requires the individual to stand while the therapist applies a posteroanterior glide to the tibia.¹⁷ This can be achieved by using a non-elastic belt and leaning backwards.¹⁷ This is similar to applying a posterior glide of the talus in the ankle mortise.¹⁷ The individual produces a slow DF movement until pain is felt or reaches the end of the range.¹⁷ After a 10 second hold, the individual returns to the beginning position and the mobilization force is ceased.¹⁷ A treatment session contains four sets of four glides, each followed by a 20 second rest period.¹⁷

A NWB-MWM technique consists of the therapist performing an anteroposterior glide to the ankle, while the individual performs active DF until pain is felt or has reached the end of the ROM.¹⁷ If the individual did not feel pain during the technique, the therapist applies overpressure into DF and sustains the glide for 10 seconds.¹⁷ An example of a treatment session consists of four glides of movement per set and four sets were performed.¹⁷ There seems to be no difference between the use of NWB and WB mobilization techniques in regards to improvements in DF ROM.¹⁷ Weight-bearing is used more often due to it mimicking functional activities.¹⁷

Hoch and McKeon¹ systemically evaluated the literature regarding the MWM technique. Three research studies were included and were graded as being Level 2 evidence or higher.¹ Other inclusion criteria included a MWM treatment on subjects with a history of ankle sprains and required the study to measure the effect of the treatment on DF ROM.¹ This appraisal of literature concluded that all three studies resulted in
improvements in DF ROM after a treatment of MWM.¹ Hoch and McKeon¹ reported that even though there were improvements seen, the MWM treatments had small to moderate effect sizes (0.16-0.38) with 95% confidence intervals (CIs) that crossed zero. Confidence intervals that crossed zero indicate that subjects did not report any improvements from the treatment or experienced negative effects from the treatment of MWM. Hoch and McKeon¹ believe that MWM can be a possible treatment option for individuals with CAI due to the arthrokinematic restrictions, degenerative joint changes, impaired postural control, altered proprioception, and decreased functional capacity due to the pathology.

Mulligan believes that normal joint kinematics can be restored if the restricted posterior glide is corrected.¹⁸ This can be achieved by using repetitive DF movements with a sustained anteroposterior talar mobilization.¹⁸ This technique is able to increase talocrural DF initially after the application of the mobilization in subacute ankle sprains.¹⁸ Movement during mobilizations do not cause pain, but rather relieve pain that the individual once had with movement and tasks.¹⁷ Improvements seen from the use of the MWM technique may be from accessory joint motion and not a change in talar position.¹⁷

Passive JMs consist of gentle oscillations of the articular surfaces that move the joints other than the musculotendinous units that normally produce this movement.¹⁹ To decrease the time required to restore DF ROM, a posterior talar mobilization should be considered.¹⁵ If this type of JM is not used, the motion may be improved through excessive stretching of the plantar flexors, excessive motion at the joints surrounding the
ankle, or by forcing an abnormal axis of rotation at the talocrural joint. Maitland developed different grades of JMs. Grades I and II are used as treatment options to decrease joint pain, while Grades III and IV are used to increase joint ROM. Grade III JMs for the ankle are used to increase the posterior capsular endpoint and provide stimulation of articular mechanoreceptors from oscillations that are as large as the available accessory motion. The oscillations should be performed from the mid-range to the end-range with as much translation as the tissue will allow. This technique combines a posteroanterior glide of the tibia on the talus or an anteroposterior glide of the talus on the tibia with active DF. Weight-bearing DF movement during the technique is preferred because it is considered to be more functional than a NWB mobilization.

Vicenzino et al performed a research study with a primary aim of proving that the WB and NWB-MWM technique improves posterior talar glide and DF ROM. The outcome measures of this study were posterior talar glide and WB ankle DF. An ICC of 0.99 was determined for posterior talar glide and 0.95 for DF. The results of this research study revealed that WB and NWB MWM techniques produced significant changes in posterior talar glide and DF ROM. Vicenzino et al states that the WB-MWM technique was no more effective than the NWB-MWM technique based on the effects of posterior talar glide. The effect sizes for WB and NWB-MWM techniques are 0.8 and 0.9, respectively. Therefore, if a MWM technique is warranted, a WB or NWB method can be applied. However, the CIs did cross zero. Therefore, an individual did not receive improvements or an individual had a negative experience.
There is evidence supporting a single treatment of Maitland Grade III anterior-to-posterior JMs that results in increased DF ROM and improves postural control based on a single-limb stance with the eyes open.\textsuperscript{21} Green et al\textsuperscript{16} compared the use of RICE alone with the use of RICE and a JM. The anteroposterior mobilization of the talus used in this study was performed with gentle force to avoid pain.\textsuperscript{16} The JM treatment along with RICE improved DF greater than RICE alone.\textsuperscript{16}

Hoch and McKeon\textsuperscript{21} performed a study to determine the effect of a single treatment of anterior-to-posterior talocrural JMs on WB-DF ROM, posterior talar displacement and stiffness, and measures of static and dynamic postural control in those with CAI. These researchers reported that measuring posterior displacement is associated with high-intratester reliability, with an ICC of 0.96.\textsuperscript{21} A significant between-group difference in DF ROM was determined for the JM treatment (p=0.01).\textsuperscript{21} Each reach direction of the SEBT was significantly different from the others.\textsuperscript{21} Hoch and McKeon\textsuperscript{21} concluded that a single treatment of Maitland Grade III anterior-to-posterior JM creates improvements in DF ROM and eyes open, single-limb stance postural control. The researchers believe that JM can address mechanical and functional impairments experienced by individuals with CAI.\textsuperscript{21} The increase in DF ROM was significant, but the actual gain was about 1.5 to 2°.\textsuperscript{21} Hoch and McKeon\textsuperscript{21} suggest future research that determines the immediate effects of JM. However, this study is inconclusive because there were no pre-treatment DF measurements obtained. Therefore, it is difficult to conclude that DF did improve following a single treatment. This is a limitation to this study.
Landrum et al\textsuperscript{19} performed a research study to determine if a one-time JM intervention applied after immobilization would increase DF ROM and posterior ankle joint stiffness, and decrease posterior talar translation. Dorsiflexion ROM was measured using a bubble inclinometer with the subject in a straight knee position.\textsuperscript{19} The reliability of this type of measurement was reported to be strong (0.96 to 0.97).\textsuperscript{19} Results of this study showed a significant main effect for time for DF ROM, with an increase in DF ROM that greatly exceeded the reported Standard Error of Measurement (SEM).\textsuperscript{19} This proves that the JM intervention works and that it was not due to measurement error.\textsuperscript{19} The conclusion of this study is that a single application of Grade III anterior-to-posterior talocrural JMs can increase DF ROM in individuals with a DF ROM deficit.\textsuperscript{19} This study used subjects that had been immobilized for some time in order to answer their research questions.\textsuperscript{19} However, the inclusion criterion was not specific to one type of injury or condition, which may be a limitation.

These findings suggest that JM may improve mechanical and functional impairments that individuals with CAI experience.\textsuperscript{21} This improvement may result from stimulating the articular mechanoreceptors’ afferent pathway that was impaired to these individuals.\textsuperscript{21} The stimulation of the mechanoreceptors may increase the afferent input from the talocrural joint and surrounding tissues.\textsuperscript{21} A single treatment with Grade III anterior-to-posterior talocrural JMs improves DF in individuals following ankle sprains.\textsuperscript{19}
Chapter 3

Methods

3.1 Experimental Design

This research study was a single-blinded, randomized control trial with one between factor (2 levels: intervention and control) and one within factor (pre- and post-intervention). The main outcome measures were DF ROM, dynamic postural control and self-reported patient outcomes. Factors contributing to the performance of the SEBT in individuals with CAI were also determined.

3.1.1 Independent Variables

1) Group
   a. Intervention
   b. Control

2) Time
   a. Pre
   b. Post

3.1.2 Dependent Variables

1) Absolute Change Scores for:
   a. Ankle DF ROM
1. NWB Active DF Measurement (degrees)

2. WB Lunge Measurement (cm)
   
b. SEBT- 3 directions (the normalized reach distance: %MAXD) and composite reach

c. Self-Reported Patient Outcomes
   
   1. VAS (cm)
      
      i. Pain
      
      ii. Stiffness
      
      iii. Stability
      
      iv. Function

3.2 Participants

Seventeen participants with self-reported unilateral CAI, between 18 and 35 years of age, were recruited from the University of Toledo community. We included participants with a history of at least one acute ankle sprain causing or disrupting daily activities for at least one day due to pain, swelling, an inability to move or stand, and a loss of function. The most current ankle sprain must have occurred at least six months prior to the inclusion in this research study. Within the past three months, the participant had to have at least two episodes of feeling of giving way or being unstable. The participant was included if he or she scored below a 90% on the FADI and scored below an 80% on the FADI Sport subscale.\(^6\) This questionnaire has been proved to be reliable at detecting functional limitations in individuals with CAI.\(^6\) Furthermore, participants completed a health history questionnaire to detect the presence of a balance disorder, vestibular disorders, headaches, history of concussions or any other disorder or condition
affecting the neural system. Participants were also excluded if there was a history of any lower extremity injuries (besides an ankle sprain), surgeries, fractures, or active pain anywhere but the ankle. Exclusion from this study also occurred if participants received any treatment or rehabilitation for a lower extremity injury in the past six months. Diagnosis of joint hypermobility or connective tissue disorders resulted in the exclusion of the participants with these pathologies. Participants with a history of low back pain within the past 6 months were excluded from this study. Participants were excluded if narcotics were being used or if ibuprofen had been ingested within 24 hours. The participants were not permitted to consume caffeine or exercise within 8 hours of the data collection.

The participants were randomly allocated into two groups: intervention or JM group (n= 9) and control group (n= 8). This allocation was determined by concealed envelopes prepared by an investigator.

All participants signed an informed consent form approved by the University of Toledo Institutional Review Board at the beginning of the pre-treatment testing session.

Table 3.1. Demographics for JM and Control Groups (Mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>JM</th>
<th>Control</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
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<td>8</td>
<td></td>
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<tr>
<td>Gender</td>
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<td>2M, 6F</td>
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<td>Age (years)</td>
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<td>Height (cm)</td>
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<tr>
<td>Mass (kg)</td>
<td>73.21 ± 11.35</td>
<td>63.99 ± 12.91</td>
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</tr>
<tr>
<td>FADI (%)</td>
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</tr>
<tr>
<td>FADI Sport (%)</td>
<td>59.28 ± 18.07</td>
<td>67.69 ± 7.82</td>
<td>0.24</td>
</tr>
</tbody>
</table>
3.3 **Prior Sample Size Calculation**

The prior sample size calculation was based on data reported by Hoch and McKeon\(^{21}\) and Green et al\(^{16}\) and performed using an online statistical calculator\(^6^4\) (DSS Research: A Full Service Health Care Marketing Research and Consulting Firm, Fort Worth, TX) with the normal distribution 2-sample option and a power level of 0.80. Although, Green et al\(^{16}\) reported both pre-and post-treatment measurements, Hoch and McKeon\(^{21}\) reported only post-treatment measurements. In this proposed study, we hypothesized to observe differences in means between pre-and post-treatment measurements, as well as, the JM and control group that would produce strong effect sizes (\(d=0.80\)) for all the selected dependent variables. In order to determine the sample size, we used the means of the WB lunge DF ROM and the three reach directions for the SEBT provided by Hoch and McKeon\(^{21}\) and NWB-DF ROM provided by Green et al\(^{16}\) to project comparison means that would produce these desired effect sizes. Using the differences in the two means and the online statistical calculator,\(^6^4\) it was determined that 20 participants per group were needed to achieve our purposes and reach a power level of 0.80 for all planned comparisons. Therefore, our current study had hoped to include 20 participants in each group, for a total sample size of 40.

3.4 **Instrumentation**

A Baseline bubble inclinometer (Fabrication Enterprises, Inc., White Plains New York, USA) was used to assess NWB active DF ROM at the talocrural joint for the seated measurement. Two Velcro straps were used to secure the bubble inclinometer to the foot. Two Velcro straps were also used to secure the legs to the treatment table during the measurement. A tape measure was used to measure the distance of the great toe from
the wall (cm) during the WBLT. Three tape measures were adhered to the floor at a 45° angle and were used to measure the reach distances (cm) while performing the SEBT. A 10 cm VAS (cm) was used to determine self-reported patient outcomes for pain, stiffness, stability, and function.

3.5 Procedures

Participants reported to the Joint Injury and Muscle Activation Laboratory in the Health and Human Services Building at the University of Toledo. At the beginning of the pre-treatment testing session, the participants completed four VASs based on the pain, stiffness, stability and function of their involved ankle prior to the intervention. The leg length was measured (cm) from the anterior superior iliac crest to the distal portion of the medial malleolus for each participant. This measurement was used in the normalizing process to calculate the maximum reach distance in anterior, PM, and PL directions during SEBT after the raw data was recorded. Following measuring the leg length, the assessor conducted pre-treatment measurements, including NWB active DF ROM, WB-DF ROM and normalized maximum reach distances in 3 directions of SEBT. The order of the three measurements was randomized for each participant, as well as, the three reach directions for the SEBT. The assessor measuring the dependent variables was blinded to the group placement.

3.5.1 Non-Weight-Bearing Active Dorsiflexion Measurement

The participant was seated on a treatment table with the knee extended and the lower leg resting on the table. The ankle was in neutral (0°) off the end of the table and an inclinometer was attached on the dorsum of the foot between the second and third toes.
over the metatarsals. The thigh and lower leg was secured to the table by Velcro straps for stabilization. (See Figure 3-1) The participants actively dorsiflexed the ankle to their perceived maximum and the measurement was recorded (degrees). (See Figure 3-2) Three trials were performed and recorded.

![Figure 3-1](image1.png)

**Figure 3-1:** Starting position for the NWB-DF measure using a bubble inclinometer attached to the dorsum of the foot between the second and third toes.

![Figure 3-2](image2.png)

**Figure 3-2:** Performance of the NWB-DF measure.
3.5.2 Weight-Bearing Dorsiflexion Measurement

The participant performed a WBLT to measure DF ROM by the knee-to-wall principle. Participants positioned their great toe 2 cm from the wall to begin the measurement. (See Figure 3-3) This measure was determined by having the participant’s second toe, center of the heel and knee perpendicular to the wall with the heel remaining on the ground while moving the foot backwards by 1 cm. A lunge was performed until the front of the knee made contact with the wall while the heel was still in contact with the ground. This was the point of maximum DF. If the heel was lifted from the floor, the foot was moved backward in smaller increments (less than 1 cm) and the distance was measured to the closest 0.1 cm. The measurement was taken from the great toe to the wall with a tape measure. (See Figure 3-4) Three trials were performed and recorded.

Figure 3-3: Starting position for the WB-DF measure 2 cm from the wall using the WBLT method.
3.5.3 Star Excursion Balance Test

The participant placed the foot of the testing leg in the center of the testing grid formed by three tape measures adhered to the floor while moving the non-testing leg to reach as far as possible in the designated reaching direction. These directions included anterior, PM, and PL. For the anterior reach direction, the toe of the stance leg was placed at the beginning of the tape measure that was adhered to the floor. (See Figure 3-5) For the posterior reach directions, the heel of the stance leg was placed at the beginning of the tape measure. (See Figures 3-6 and 3-7) The participant made a light touch with the toe of the reach leg on the tape measure that was adhered to the floor. The reach distances were marked by the assessor and recorded as the distance from the center of the grid to the point of maximum excursion of the reaching leg. Participants were required to practice four times in each direction. After four practice trials in each reach direction, participants performed three testing trials. If the participant did not keep their hands on
their hips, lost their balance, their heel was lifted from the floor, or their foot was moved from the starting position, the trial was discarded and repeated. The composite reach of the SEBT was also calculated with the following formula: [(% MAXD of anterior reach + % MAXD of posterior medial reach + % MAXD of posterior lateral reach)/3]. The reach distances of the SEBT were normalized by dividing the distance reached by the leg length and multiplied by 100, denoted as % MAXD.52

Figure 3-5: Performance of the SEBT in the anterior direction.

Figure 3-6: Performance of the SEBT in the PM direction.
3.5.4 Self-Reported Patient Outcomes

Participants were requested to complete a VAS based on the pain, stiffness, stability and function of their involved ankle. This was completed prior to the assessment of the NWB-DF, WB-DF, and the SEBT outcome measures. For all self-reported patient outcomes, the directions were: Place an X over the spot that best represents your ankle ________ (pain, stiffness, stability, or function). To interpret the results, a tape measure was used to measure the placement of the participant’s mark. For example, zero was absolutely no pain, while 10 was worst pain imaginable. Once the participant received the intervention or control treatment, the VAS was presented to them once again and they were asked to complete the VAS for pain, stiffness, stability and function based on how their involved ankle felt post-intervention.
3.6 Intervention

Participants received either a Maitland Grade IV oscillatory anterior-to-posterior talar JM or the control treatment. The JM was performed by a Certified Athletic Trainer with 6 years of clinical experience. Participants were seated on a treatment table with the knee extended and the ankle positioned off of the edge of the table in a neutral position. The clinician stabilized the distal aspect of the lower leg with one hand and a c-shape was formed by the opposite hand and was placed just below the medial and lateral malleoli contacting the anterior talus. This hand performed the JM technique by gliding the talus posteriorly. (See Figure 3-8) Three 60-second anterior-posterior mobilizations were applied with a one minute rest period between sets. The JM was applied with low amplitude, one-second rhythmic oscillations at the joint’s physiologic end range. Following the treatment session, participants were asked to complete the VAS for pain, stiffness, stability, and function as self-reported patient outcomes for the involved ankle. The participants assigned to the control group sat for five minutes with no contact by the clinician. After the intervention or control was performed, the post-treatment measurements were conducted.

Figure 3-8: Maitland Grade IV oscillatory Anterior-to-Posterior Talar JM
3.7 Statistical Analysis

The dependent variables included absolute change scores of NWB-DF, WB-DF, %MAXD in three directions of the SEBT and self-reported patient outcomes on the VAS from pre-intervention to post-intervention measurements. The absolute change scores were calculated with the following formula: (post-intervention-pre-intervention). The means and standard deviations of the absolute change scores were used for statistical analysis. The independent sample t-test was used to compare each dependent variable between the JM and control groups. An independent t-test was also performed to compare demographics and FADI and FADI Sport absolute scores to determine whether groups were similar at baseline (Table 3.1). The alpha level was set a priori at p<0.05. All statistical analyses were performed with the Statistical Package for the Social Sciences for Windows (version 19.0; SPSS Inc, Chicago, IL).

A Cohen’s $d$ effect size along with 95% CIs was calculated for each comparison between groups and between pre-and post-intervention measurements to determine the magnitude of the JM effect. Effect sizes were calculated by subtracting the control group or pre-intervention measurement mean from the JM group or post-intervention measurement mean and dividing by the pooled standard deviation. The effect size was interpreted as follows: $>0.8 =$ large, $0.5-0.8 =$ moderate, and $<0.5 =$ small.$^{55,66}$

A multiple linear backward regression model analysis was also performed to determine which dependent variables influence the improvement of the SEBT performance. The absolute change scores were used in the analysis to determine the influence on the performance by the joint mobilization group only.
Chapter 4

Results

There were no statistically significant group differences in the Age ($t_{15} = 1.105, p = 0.29$), Mass ($t_{15} = 1.57, p = 0.14$), FADI ($t_{15} = -1.33, p = 0.20$) and FADI sport instruments ($t_{15} = -1.22, p = 0.24$) at baseline (Table 3.1). This indicates that there was no difference in the age, mass, and degree of self-reported impairment in ankle joint function between the JM and control groups. There was a significant difference in height between the groups ($t_{15} = 2.38, p = 0.03$), with the JM group being taller than the Control group at baseline.

4.1 Comparison of the Joint Mobilization and Control Groups

Means, standard deviations, and effect sizes of absolute change scores of all dependent variables are found in Table 4.1. A positive value for the effect sizes for all reach directions of the SEBT and DF measures indicates a better outcome when comparing the JM to the control group. A negative value for the effect sizes for all self-reported patient outcomes indicates a better outcome.

4.1.1 Normalized Reach Distances of the SEBT
No statistically significant group differences were found in the absolute change scores for %MAXD for any of the SEBT scores. However, for the anterior reach, the JM group had observable improvements (1.74 ± 1.91) compared to the control group (-0.46 ± 2.66) that was not statistically significant (t\textsubscript{15} = 1.98, p = 0.07), but did have a strong associated effect size (d = 0.96). All other effect sizes were small (<0.39). The 95% CIs for all of the SEBT reach directions crossed 0 (Table 4.1).

4.1.2 Ankle Dorsiflexion Range of Motion

There were no significant group differences in DF using the NWB-DF (t\textsubscript{10.84} = 1.82, p = 0.10) or the WB-DF (t\textsubscript{15} = 0.06, p = 0.95) measurements. The large effect size for NWB-DF did support a greater improvement in DF in the JM group compared to the control group, but its associated 95% CI crossed zero (d = 0.85, 95% CI = -0.19, 1.79). The effect size for WB-DF was small and its associated 95% CI also crossed 0 (d = 0.03, 95% CI = -0.92, 0.98).

4.1.3 Self-Reported Patient Outcomes

There were no statistically significant group-differences in any of the self-reported patient outcomes (Table 4.1). However, there was a nearly significant difference in the absolute change of pain (t\textsubscript{15} = -2.02, p = 0.06) between the JM and control groups. However, a strong effect size (d = -0.98) supported that the JM group had a reduction in pain compared to the control group, while the other self-reported measures had small effect sizes. However, all 95% CIs for self-reported patient outcomes crossed 0 (Table 4.1).
Table 4.1. Absolute Change Scores of All Dependent Variables for Joint Mobilization (JM) and Control Groups (Mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>JM</th>
<th>Control</th>
<th>t(15)</th>
<th>P-value</th>
<th>ES (95%CI)</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBT (%MAXD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>1.74 ± 1.91</td>
<td>-0.46 ± 2.66</td>
<td>1.98</td>
<td>0.07</td>
<td>0.96 (-0.09, 1.91)*</td>
<td>0.62</td>
</tr>
<tr>
<td>PM</td>
<td>0.55 ± 4.01</td>
<td>0.01 ± 4.06</td>
<td>0.27</td>
<td>0.79</td>
<td>0.13 (-0.83, 1.08)</td>
<td>0.09</td>
</tr>
<tr>
<td>PL</td>
<td>3.12 ± 7.48</td>
<td>2.07 ± 4.39</td>
<td>0.35</td>
<td>0.73</td>
<td>0.17 (-0.79, 1.11)</td>
<td>0.01</td>
</tr>
<tr>
<td>Composite</td>
<td>1.80 ± 3.63</td>
<td>0.54 ± 2.78</td>
<td>0.80</td>
<td>0.44</td>
<td>0.39 (-0.59, 1.33)</td>
<td>0.20</td>
</tr>
<tr>
<td>Ankle DF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NWB (°)</td>
<td>3.71 ± 6.04</td>
<td>-0.29 ± 2.47</td>
<td>1.82*</td>
<td>0.10</td>
<td>0.85 (-0.19, 1.79)*</td>
<td>0.57</td>
</tr>
<tr>
<td>WB (cm)</td>
<td>0.81 ± 1.77</td>
<td>0.74 ± 2.90</td>
<td>0.06</td>
<td>0.95</td>
<td>0.03 (-0.92, 0.98)</td>
<td>0.06</td>
</tr>
<tr>
<td>Self-Reported Patient Outcomes on Visual Analog Scale (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>-1.71 ± 3.03</td>
<td>0.58 ± 1.06</td>
<td>-2.02</td>
<td>0.06</td>
<td>-0.98 (-1.94, 0.07)*</td>
<td>0.69</td>
</tr>
<tr>
<td>Stiffness</td>
<td>-0.73 ± 2.20</td>
<td>-0.20 ± 1.78</td>
<td>-0.55</td>
<td>0.59</td>
<td>-0.26 (-1.21, 0.71)</td>
<td>0.14</td>
</tr>
<tr>
<td>Stability</td>
<td>-2.66 ± 2.78</td>
<td>-1.64 ± 1.89</td>
<td>-0.87</td>
<td>0.40</td>
<td>-0.42 (-1.36, 0.56)</td>
<td>0.23</td>
</tr>
<tr>
<td>Function</td>
<td>-0.43 ± 1.44</td>
<td>-0.94 ± 1.16</td>
<td>0.79</td>
<td>0.44</td>
<td>0.39 (-0.59, 1.33)</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*Large Effect Size was Determined. # Degrees of freedom is 10.84. SEBT = Star Excursion Balance Test. %MAXD= Percentage of Maximum Distance Reached. PM= Posteriormedial. PL= Posteriolateral. DF= Dorsiflexion. NWB= Non-Weight Bearing. WB= Weight Bearing.

4.2 Comparison of Pre- and Post-Intervention for the Joint Mobilization Group

In addition to absolute change scores of the dependent variables, means, standard deviations and effect sizes for pre- and post-intervention assessments are provided in Table 4.2 for the JM group and in Table 4.3 for the control group.

The effect sizes for pre- and post-improvement in all of the SEBT reach directions were small for the JM group, with associated 95% CIs that crossed 0 (Table 4.2). The
immediate effect of JM on NWB-DF was moderate \((d = -0.73, 95\% \text{ CI} = -1.64, 0.26)\), while the improvement in WB-DF following JM was small \((d = -0.31, 95\% \text{ CI} = -1.23, 0.63)\). The effect sizes for pre- and post-improvement in self-reported outcomes ranged from 0.22 to 1.01 following a single application of passive oscillatory JM with 95% CIs crossing zero (Table 4.2).

### Table 4.2. Pre- and Post-Intervention Assessments for the Joint Mobilization Group (Mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Effect Size</th>
<th>95% CI</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEBT (MAXD)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>-0.29</td>
<td>(-1.20, 0.66)</td>
<td>63.07 ± 6.10</td>
<td>64.82 ± 6.12</td>
</tr>
<tr>
<td>PM</td>
<td>-0.07</td>
<td>(-0.99, 0.86)</td>
<td>84.49 ± 7.98</td>
<td>85.04 ± 7.55</td>
</tr>
<tr>
<td>PL</td>
<td>-0.32</td>
<td>(-1.23, 0.62)</td>
<td>79.53 ± 9.46</td>
<td>82.65 ± 10.04</td>
</tr>
<tr>
<td>Composite</td>
<td>-0.27</td>
<td>(-1.19, 0.67)</td>
<td>75.70 ± 6.39</td>
<td>77.50 ± 6.79</td>
</tr>
<tr>
<td><strong>Ankle DF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NWB (°)</td>
<td>-0.73*</td>
<td>(-1.64, 0.26)</td>
<td>16.63 ± 5.66</td>
<td>20.33 ± 4.44</td>
</tr>
<tr>
<td>WB (cm)</td>
<td>-0.31</td>
<td>(-1.23, 0.63)</td>
<td>8.68 ± 2.51</td>
<td>9.50 ± 2.73</td>
</tr>
<tr>
<td><strong>Self-Reported Patient Outcomes on Visual Analog Scale (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>0.69*</td>
<td>(-0.29, 1.61)</td>
<td>3.67 ± 2.82</td>
<td>1.96 ± 2.06</td>
</tr>
<tr>
<td>Stiffness</td>
<td>0.30</td>
<td>(-0.64, 1.22)</td>
<td>3.16 ± 2.49</td>
<td>2.42 ± 2.37</td>
</tr>
<tr>
<td>Stability</td>
<td>1.01*</td>
<td>(-0.02, 1.94)</td>
<td>5.09 ± 2.96</td>
<td>2.43 ± 2.27</td>
</tr>
<tr>
<td>Function</td>
<td>0.22</td>
<td>(-0.71, 1.14)</td>
<td>3.12 ± 1.85</td>
<td>2.69 ± 2.00</td>
</tr>
</tbody>
</table>

*Large Effect Size was Determined. SEBT= Star Excursion Balance Test. MAXD = Percentage of Maximum Distance Reached. PM= Posteromedial. PL= Posterior lateral. DF= Dorsiflexion. NWB= Non-Weight Bearing. WB= Weight Bearing.

### 4.3 Comparison of Pre- and Post-Intervention for the Control Group

For the control group, pre-and post-improvement effect sizes for all reach directions of the SEBT, NWB-DF, and self-reported pain and stiffness scores were small, with associated 95% CIs that crossed zero (Table 4.3). Pre-and post-WB-DF measurements resulted in a large effect size \((d = -1.01)\) and the effect of the control
intervention on self-reported stability and function scores were moderate (Table 4.3).

However, 95% CIs around the effect sizes crossed 0 (Table 4.3).

Table 4.3. Pre- and Post-Intervention Assessments for the Control Group (Mean ±SD).

<table>
<thead>
<tr>
<th></th>
<th>Effect Size</th>
<th>95% CI</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEBT (%MAXD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>0.08</td>
<td>(-0.91, 1.05)</td>
<td>65.53 ± 5.64</td>
<td>65.07 ± 6.42</td>
</tr>
<tr>
<td>PM</td>
<td>0.00</td>
<td>(-0.98, 0.98)</td>
<td>79.11 ± 11.91</td>
<td>79.12 ± 11.00</td>
</tr>
<tr>
<td>PL</td>
<td>-0.16</td>
<td>(-1.14, 0.83)</td>
<td>68.41 ± 13.40</td>
<td>70.47 ± 11.57</td>
</tr>
<tr>
<td>Composite</td>
<td>-0.06</td>
<td>(-1.04, 0.92)</td>
<td>71.02 ± 9.56</td>
<td>71.56 ± 8.74</td>
</tr>
<tr>
<td>Ankle DF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NWB (°)</td>
<td>0.04</td>
<td>(-0.94, 1.02)</td>
<td>20.67 ± 6.20</td>
<td>20.38 ± 7.01</td>
</tr>
<tr>
<td>WB (cm)</td>
<td>-1.01*</td>
<td>(-1.99, 0.08)</td>
<td>9.12 ± 1.87</td>
<td>11.04 ± 1.93</td>
</tr>
<tr>
<td>Self-Reported Patient Outcomes on Visual Analog Scale (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>-0.24</td>
<td>(-1.21, 0.75)</td>
<td>2.19 ± 2.32</td>
<td>2.76 ± 2.40</td>
</tr>
<tr>
<td>Stiffness</td>
<td>0.08</td>
<td>(-0.90, 1.06)</td>
<td>3.65 ± 2.31</td>
<td>3.45 ± 2.43</td>
</tr>
<tr>
<td>Stability</td>
<td>0.59</td>
<td>(-0.44, 1.56)</td>
<td>4.76 ± 2.83</td>
<td>3.13 ± 2.65</td>
</tr>
<tr>
<td>Function</td>
<td>0.55</td>
<td>(-0.48, 1.52)</td>
<td>2.81 ± 2.05</td>
<td>1.88 ± 1.23</td>
</tr>
</tbody>
</table>

*Large Effect Size was Determined. SEBT= Star Excursion Balance Test. %MAXD = Percentage of Maximum Distance Reached. PM= Posteriormedial. PL= Posteriorlateral. DF= Dorsiflexion. NWB= Non-Weight Bearing. WB= Weight Bearing.

4.4 Regression Analysis

A regression analysis was performed to determine if the variances in self-reported variables and the measures of DF would predict the variance in the pre-post change in anterior reach direction of the SEBT. The regression analysis was only performed for the anterior reach direction due to no improvements in the posterior directions following the application of the JM. Combination of the absolute change scores for self-reported pain, stiffness, stability and function along with NWB-DF and WB-DF explained 32.6% of the variance in the improvement in the SEBT performance in the anterior direction (R²= 43
While the absolute changes in NWB-DF alone predicted only 0.1% of the variance of the improvement in anterior %MAXD of the SEBT in the model, the improvement in WB-DF alone explained 5.8% of the variance in the increase in anterior reach distance of the SEBT. After removing variables that were weak contributors to the improvement in the SEBT performance in the anterior direction, self-reported stiffness remained in the final model and explained 9.2% of variance in the improvement in the anterior reach distance of the SEBT ($R^2 = 0.092$, $p = 0.427$). However, adding self-reported pain with stiffness increased the predictive value by approximately 15% ($R^2 = 0.243$, $p = 0.433$). Therefore, following a posterior glide JM, the greatest contributors of the increase in anterior reach distance of the SEBT were self-reported pain and stiffness (24.3%).
### Table 4.4. A Multiple Linear Backward Regression Model Predicting the Absolute Change in the Anterior Reach Direction of the SEBT in the Joint Mobilization Group

<table>
<thead>
<tr>
<th>Variables</th>
<th>$R^2$</th>
<th>$p$</th>
<th>Sx·y</th>
<th>% prediction in Absolute Change in Anterior Reach Direction of SEBT in Joint Mobilization Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function, Stiffness, WB-DF, Pain, NWB-DF, Stability</td>
<td>0.326</td>
<td>0.965</td>
<td>3.132</td>
<td>NWB-DF = 0.1%</td>
</tr>
<tr>
<td>Function, Stiffness, WB-DF, Pain, Stability</td>
<td>0.325</td>
<td>0.893</td>
<td>2.561</td>
<td>Function = 0.2%</td>
</tr>
<tr>
<td>Stiffness, WB-DF, Pain, Stability</td>
<td>0.323</td>
<td>0.755</td>
<td>2.221</td>
<td>Stability = 2.2%</td>
</tr>
<tr>
<td>Stiffness, WB-DF, Pain</td>
<td>0.301</td>
<td>0.583</td>
<td>2.018</td>
<td>WB-DF = 5.8%</td>
</tr>
<tr>
<td>Stiffness, Pain</td>
<td>0.243</td>
<td>0.433</td>
<td>1.916</td>
<td>Pain = 15.1%</td>
</tr>
<tr>
<td>Stiffness</td>
<td>0.092</td>
<td>0.427</td>
<td>1.943</td>
<td>Stiffness = 9.2%</td>
</tr>
</tbody>
</table>

SEBT = Star Excursion Balance Test. Sx·y= Standard Error of the Estimate. WB-DF= Weight-Bearing Dorsiflexion. NWB-DF= Non-Weight-Bearing Dorsiflexion.
Chapter 5

Discussion

This preliminary study was conducted to evaluate the effectiveness of a passive oscillatory talar JM on the improvements in ankle DF ROM, dynamic postural control, and self-reported patient outcomes in individuals with CAI. A single dose of a Maitland Grade IV anterior-posterior talar glide JM did not result in statistically significant improvements in DF ROM, dynamic postural control, and self-reported patient outcomes, but some of the outcome measures resulted in large effect sizes, which indicates that JMs may provide potential clinical benefits for the improvement in DF ROM, dynamic postural control, and pain in patients with CAI. However, the 95% CI associated with the effect sizes did cross zero, which is not surprising given the small sample size of the study.

5.1 Discussion of Main Outcome Measures

5.1.1 Star Excursion Balance Test

Altered dynamic postural control as measured with the SEBT has been observed in individuals with CAI.\textsuperscript{59} In this current study, there were no statistically significant
findings in the absolute changes in any of the directions of the SEBT when comparing the JM to the control group. However, a nearly significant group-difference was observed in the absolute change of the SEBT performance in the anterior direction with a large effect size \( (d = 0.96) \), indicating that the JM technique may have a potential positive benefit for performance of the anterior direction of the SEBT. It has been suggested that JMs may be able to stimulate sensory receptors within and around the ankle joint, possibly influencing motor neuron pool availability and efferent motor output.\(^67,68\) Grindstaff et al\(^69\) observed an acute increase in spinal excitability of the soleus muscle following a distal tibiofibular joint manipulation in CAI patients. Joint mobilizations may stimulate sensory receptors and result in an increase in afferent activity along with the enhancement of neuromuscular function of the joint stabilizing muscles, ultimately leading to dynamic postural control improvement during the SEBT in the CAI group. However, we did not quantify muscle activation or spinal excitability of muscles surrounding the ankle joint in this study. Therefore, further investigation should examine the effect of JM on muscle activation or spinal excitability, as well as, the association between changes in dynamic postural control and muscle activation or spinal excitability following JM.

Hoch and McKeon\(^21\) reported no difference in dynamic postural stability as measured with the SEBT between a JM and a control group. However, their study did not assess dynamic postural stability with the SEBT before providing the treatment, making it difficult to determine if the SEBT performance was improved following a single application of passive oscillatory JM. While we found large effect sizes for group-difference in the anterior SEBT performance, both groups had small effect sizes for pre- and post-intervention measurements of the SEBT in all directions, with 95% CIs that
crossed zero, thereby limiting this clinical significance. Since difference in the absolute changes in the anterior normalized reach distance of the SEBT was approaching significance with a large effect size for group-difference in the absolute changes, we believe that if more participants were enrolled in the study, the power of the study would improve, potentially resulting in a detectable statistically significant difference for the SEBT.

5.1.2 Dorsiflexion Range of Motion

There were no statistically significant group-differences in the absolute changes in NWB-DF and WB-DF. While our small sample size does raise the potential for a Type II error, our findings contradict previous reports\textsuperscript{16-21} that a single JM treatment could improve DF ROM in individuals with CAI. Hoch and McKeon\textsuperscript{21} reported that a Maitland Grade III anterior-to-posterior JM to the ankle improved ankle DF. However, these outcome variables were not measured prior to the treatment. Therefore, the clinical relevance of conclusion drawn in their study is limited. In our study, we conducted pre-treatment measurements, but we did not establish a cut-off point of ankle DF as a part of the inclusion criteria. Therefore, we do not know if all of the participants in this current study had deficits in ankle ROM. Denegar et al\textsuperscript{15} demonstrated that individuals with CAI restored full ankle DF ROM without proper restoration of posterior talar glide, and suggested that this restoration of ankle DF with restricted arthrokinematics may be due to flexibility of the gastrocnemius-soleus complex and hypermobility of other joints. Even though all included participants suffered from CAI, it is possible that these patients may not have had a DF restriction. Landrum et al\textsuperscript{19} reported that a single application of a
Grade III anterior-to-posterior talocrural JM improved DF ROM in individuals with ankle pathologies. In contrast to our study, the authors included patients with various ankle pathologies and all patients in their study had been immobilized for a certain period before receiving the passive oscillatory JM.

While we found no statistical significance in WB-and NWB-DF improvements following JM, we observed a large effect size for the magnitude of group-difference in NWB-DF. Additionally, the effect sizes for the improvement in NWB-DF following a single dose of passive JM were large in the JM group and small in the control group. These findings indicate that the passive oscillatory JM may have a potential clinical benefit for NWB-DF improvement in patients with CAI. Regardless of intervention, both groups demonstrated an increase in WB-DF. Changes in ankle WB-DF may have resulted from repeated performance of the outcome assessment tests. The WBLT required motion at the ankle joint that reached maximal DF and had components similar to what is used in mobilization techniques. Previous studies have demonstrated an improvement in WB-DF following a single application of MWM in CAI patients. It is possible that performing the WBLT at or near end range DF increased availability of ankle DF ROM, even in the group that did not receive the mobilization intervention. In addition, no practice or warm-up trials may influence initial measures during the WBLT. Three warm-up trials prior to performing three testing trials have been recently suggested. However, caution is needed when interpreting the effect sizes because the associated 95% CIs crossed zero, meaning that it is not possible to determine a truly beneficial effect that would be present in 95% of the samples collected. Therefore, large effect sizes but
large 95% CIs crossing zero limits the clinical significance of the effect of passive JM on NWB-DF in the CAI patients. No statistical significance observed in this study may be due to a small sample size. Therefore, the effect of a passive oscillatory JM on ankle DF ROM should be studied with a larger sample size.

5.1.3 Self-Reported Patient Outcomes

The results from our study indicate that the posterior talar JM had a potentially positive effect on self-reported pain and stability, but not on stiffness or function in individuals with CAI. Previous investigations\textsuperscript{18,71,72} have shown that JM reduces pain and pressure threshold in patients with acute or subacute ankle sprains. Reduction of the pain and increase of stability following posterior talar JM may be due to altered afferent sensory input from the ankle which may block perception of pain and efferent motor output via a gating mechanism.

5.1.4 Regression

Dynamic postural control deficits, measured by the SEBT, have been observed in patients with CAI.\textsuperscript{59} Identifying which contributing factors to the improvement in the SEBT following a passive JM may help clinicians and researchers to develop a more effective intervention to target dynamic postural control deficits associated with CAI. We found potential clinical benefits of JM for the improvement in the SEBT in the anterior direction. Therefore, we performed a regression analysis to determine which of our variables influenced the improvement in the SEBT performance. In this study, 24.3% of the variance in the improvement of the anterior reach of the SEBT was explained by the improvements in self-reported pain and stiffness.
Hoch and McKeon\textsuperscript{56} reported a significant relationship between WB-DF and the SEBT performance in the anterior direction and found that WB-DF accounted for 28\% of the variance in the anterior reaching distance of the SEBT in healthy participants. They suggested that the availability of ankle DF may be a significant indicator of the SEBT performance in the anterior direction.\textsuperscript{56} We found that the improvements in WB-DF alone predicted only 5.8\% of the variance in the increase in anterior reaching distance of the SEBT. In our study, the greatest contributors to the increase in anterior reaching distance of the SEBT were reduction of pain (15.1\%) and increase in stiffness (9.2\%) although we must note that the regression analysis was not statistically significant. In our preliminary study, a passive talar JM likely reduced pain as quantified by VAS, but did not have an effect on self-reported stiffness in the JM group. The effect size for the group-difference in the absolute changes in self-reported stiffness was moderate. The JM group may meet one of the conditions for improvement in the SEBT performance. However, it is important to note that CAI has been associated with deficiencies in various factors, such as strength,\textsuperscript{73,74} static postural control,\textsuperscript{75} and laxity.\textsuperscript{76} No researchers have investigated what factors individually or in combination have the greatest impact on the SEBT. Therefore, further study should determine which treating aspect of the multifactorial effects on CAI is the most beneficial in the improvement of the SEBT, particularly in a larger sample.

5.2 Limitations

The limitation of the measurement technique and design for this study should be acknowledged.
An *a priori* sample size calculation was conducted and resulted in a total of 40 participants. However, because of availability of participants and time constraints, we collected data from only 17 participants in this current preliminary study (JM=9, Control=8). Post hoc power analyses showed that we had small to moderate observed power to detect group-differences (observed powers= 0.01 to 0.69) in the variables. The small sample size with lower observed power does pose a Type II statistical error threat. However, some of our non-statistically significant differences were associated with large effect sizes, indicating that these differences are likely associated with a clinically significant difference. These differences may reach a desired power level of 0.80 if the sample size increases.

In our study, three examiners assessed ankle DF, % MAXD of the SEBT, and self-reported patient outcomes, and the same examiner did not measure each participant at each time-measurement. This may influence measurement reliability and validity. The bubble inclinometer used to measure NWB-DF may have an impact on internal validity, especially. However, previous investigations proved all measurement tools we used in this study are reliable and valid.\textsuperscript{15,18,19,53,55,57} Denegar et al\textsuperscript{15} reported intratester reliability estimates for the ROM measurements in their study to be 0.88 to 0.99. Landrum et al\textsuperscript{19} reported the reliability of this type of measurement to be strong (0.96 to 0.97). The SEBT was proved to be reliable by previous researchers\textsuperscript{53,55} and that four practice trials compared to six practice trials is valid and reliable.\textsuperscript{57} Collins et al\textsuperscript{18} reported an ICC of 0.99 for the knee-to-wall principle of the WBLT.
Finally, the JM group was statistically taller than the Control group at baseline. However, Gribble and Hertel\textsuperscript{52} demonstrated that height is not an influencing factor on SEBT performance if the reach distances are normalized to leg length, which was the procedure we used in our study.

5.3 **Clinical Implications**

Based on the results of this study, the single use of a Maitland Grade IV oscillatory anterior-to-posterior talar JM could be a treatment option to improve NWB-DF, anterior reach of the SEBT, and self-reported pain in individuals with CAI. Additionally, the results in our study provide clinicians an insight to consider what may be the contributing factor to mechanical and functional impairments associated with CAI. If this is determined, the most appropriate treatments and interventions can be selected. Individualized treatments and interventions are more important when treating a patient than using the “cookie-cutter method” to treat all individuals with CAI. Some patients may have laxity, impaired arthokinematics or degenerative changes, while others may have insufficiencies in proprioception, neuromuscular control, postural control or strength. Ankle instability may be associated with various factors that need to be addressed on an individual basis. Our overall findings suggest that the selected JM technique may still provide clinical benefits. A clinician may use the SEBT to determine the dynamic postural control deficits in individuals with CAI, specifically in the anterior direction. Based on the regression analysis of this study, if pain and stiffness are decreased using a JM technique, the individual with CAI may be able to improve their dynamic postural control. We cannot conclude from this study if this also has an
improvement on injury rate reduction or self-reported outcomes, areas of study that can be conducted in the future.

5.4 Conclusion

In conclusion, a single dose of a Maitland Grade IV anterior-posterior talar glide JM did not result in statistically significant improvements in DF ROM, dynamic postural control, and self-reported patient outcomes. However, some of the outcome measures had large effect sizes, indicating that JMs may provide potential clinical benefits for the improvement in DF ROM, dynamic postural control, and pain in patients with CAI. Future research should examine the effects of the JM technique on DF ROM, dynamic postural control and self-reported patient outcomes with a larger sample size.
References


Appendix A

Human Subjects Consent Form

ADULT RESEARCH SUBJECT INFORMATION AND CONSENT FORM
THE EFFECTS OF JOINT MOBILIZATIONS ON LOWER LEG REFLEX EXCITABILITY AND DYNAMIC STABILITY IN PEOPLE WITH CHRONIC ANKLE INSTABILITY

Principal Investigator: Brian Pietrosimone PhD, ATC
Other Staff (Co-Investigator): Philip Gribble PhD, ATC, Masafumi Terada MS, ATC, Michelle McLeod M.S. PhD, Matthew Harkey ATC, Ashley Wells ATC

Contact Phone number(s): (419) 530-4467

What you should know about this research study:
• We give you this consent/authorization form so that you may read about the purpose, risks, and benefits of this research study. All information in this form will be communicated to you verbally by the research staff as well.
• Routine clinical care is based upon the best-known treatment and is provided with the main goal of helping the individual patient. The main goal of research studies is to gain knowledge that may help future patients.
• We cannot promise that this research will benefit you. Just like routine care, this research can have side effects that can be serious or minor.
• You have the right to refuse to take part in this research, or agree to take part now and change your mind later.
• If you decide to take part in this research or not, or if you decide to take part now but change your mind later, your decision will not affect your routine care.
• Please review this form carefully. Ask any questions before you make a decision about whether or not you want to take part in this research. If you decide to take part in this research, you may ask any additional questions at any time.
• Your participation in this research is voluntary.

PURPOSE (WHY THIS RESEARCH IS BEING DONE)
You are being asked to take part in a research study looking at the nerve function of leg, balance and self-reported pain, stiffness and stability. The purpose of the study is to determine if people with previous ankle injuries will have changes in reflex and brain activation, balance, range of motion and self-reported stiffness, pain and stability following small movements to the ankle joint. You were selected as someone who may want to take part in this study because you have chronic ankle instability. There will be approximately 50 people participating in this study at the University of Toledo.
DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT
If you decide to take part in this study, you will be asked to report to the Joint Injury and Muscle Activation (JIMA) Laboratory in the Health Science and Human Services building (Room 1409). You will be asked to fill out Ankle Injury Questionnaires about how your ankle feels during different activities. You will also be asked to fill out an Exclusion Criteria Screening Sheet regarding your history of injury and rehabilitation to your lower extremity; joint hypermobility or connective tissue disorders; concussion or head injuries; stroke; heart condition; cranial neurosurgery; epilepsy; migraines, cancer in the brain or thigh musculature; diagnosed psychiatric disorder; cardiac pacemaker placement; implanted cardiac defibrillator; and/or intracranial metallic clips.

After filling out the Ankle Injury Questionnaires and Exclusion Criteria Screening Sheet, we will then test the neural function of both of your legs using Reflex Testing and brain testing and have you perform some range of motion and balance tests. You then may be randomized to have small joint movements applied to your ankle or you may be asked to sit quietly for a short period of time. After you receive the joint mobilizations or sit for a period of time you will again perform the reflex, balance testing and ankle questionnaires. This study will consist of one session lasting approximately 1.5 hours.

Ankle Injury Questionnaires
- You will be asked to provide us information regarding your previous history of your joint injury, current and past level of activity and how your joint injury currently affects you during different activities. You will also let us know how stiff, stable and painful your ankle feels during two points in the study. You will be excluded from this study if you have any of the following: Injuries to the lower extremity other than the ankle in the previous six months, Rehabilitation for a lower extremity injury in the last 6 months, joint hypermobility of connective tissue disorder, history of concussion or head injury in the past 6 months, history of stroke, cardiac condition, epilepsy, cranial neurosurgery, migraines, cancer in the brain or thigh musculature, diagnosed psychiatric disorder, or has a cardiac pacemaker, implanted cardiac defibrillator or intracranial metallic clips.

Reflex Testing
This testing provides an estimate of how well nerves in the lower leg are functioning. You will be instructed to stand on your dominant leg or lie on a table. You will have sticky electrodes placed on your lower legs and thigh. These electrodes are called EMG electrodes which stand for Electromyography which is a recording of the electrical (reflex) activity in skeletal muscle. The sites of the EMG electrodes will be shaved and cleaned with alcohol. An electrode that provides a stimulus will be taped behind your knee and in the front of your hip. Several reflex measurements will be taken while you are balancing or lying down.
- These measurements include a 1-millisecond stimulus.
- The intensity of this stimulus will vary depending on the reflex being elicited.
- The stimuli in this study feel similar to static electricity felt as you touch a door knob after walking across a carpet.
- A series of measurements will be taken on both legs

Brain Testing
This testing provides us important information regarding how your brain is sending messages to muscles in your legs. You will be asked to lie on a table with your hands at your side. We will position a coil over your head and adjust the position of the coil until it is in the correct spot. We will ask you to wear a bathing cap and ear plugs. A brief magnetic stimulus will then be produced which will sound like a "click." You will not have and associated pain or discomfort in your head, but rather may feel a brief
muscle contraction in the muscles of your leg or thigh. You will be asked to flex certain leg muscles at a small to moderate intensity while we provide a series of brief magnetic stimuli to your head.

Balance Testing
A member of the research team will demonstrate the dynamic balance test, called the Star Excursion Balance Test (SEBT). The SEBT requires you to stand on one leg in the middle of a grid on the floor and then try to reach with the other leg to touch a spot on the floor as far as you can along a line on the grid. If you lose your balance, put too much weight on your reaching foot or move the foot of the leg you are standing on, the reaching trial is repeated. After the demonstration, you will practice the SEBT standing on their right leg 6 times and then on their left leg 6 times so that they can become familiar with how to do perform the test. Then will be given 5 minutes to rest.

Range of Motion Testing
We will test how far you are able to comfortably move your ankle. You will first be asked to point your toes by moving your ankle joint toward your head as far as you feel comfortable. We will measure this in a standing position and while you are lying on your back.

Joint Mobilizations
You may be asked will lie down on a padded table while a member of the research team apply mild pressure to the front of the ankle. You will not feel pain in your ankle during this technique, yet you may feel pressure. If you do feel pain you should notify the investigator.

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH

Likely Risks
- Mild discomfort for a very brief period during the electrical stimulation.

Less Likely Risks
- Mild, transient skin irritation from the sticky electrodes.

Very Unlikely Risks
- Mild, transient soreness from the joint mobilizations
- Possible risk that you fall when you are performing the balance testing.
- Mild, transient headache following magnetic stimulation
- In people with a history of seizures there is a slight possibility of causing a seizure with the magnetic stimulation; therefore you must tell us prior to testing if you have ever had a seizure so we can exclude you from the study.

RISKS TO UNBORN CHILDREN
It is unknown how the electrical stimulation used in this study would affect an unborn fetus; therefore, if you are pregnant you will not be allowed to participate in this study.

POSSIBLE BENEFIT TO YOU IF YOU DECIDE TO TAKE PART IN THIS RESEARCH
Although information that is gained from this research that may be used to assess and treat various ankle injuries, we cannot and do not guarantee or promise that you will receive any benefits from this research.

COST TO YOU FOR TAKING PART IN THIS STUDY
You are not directly responsible for making any type of payment to take part in this study. However, you are responsible for providing the means of transportation to the Joint Injury and Muscle Activation Laboratory. You will not be compensated for gas for travel or any other expenses to participate in this study.

UNIVERSITY OF TOLEDO IRB
APPROVAL DATE: 6/18/2012
EXPIRATION DATE: 6/17/2003
This space for IRB Approval Data Entry
PAYMENT OR OTHER COMPENSATION TO YOU FOR TAKING PART IN THIS RESEARCH
You will not be compensated for participating in this study.

ALTERNATIVE(S) TO TAKING PART IN THIS RESEARCH
The only alternative is not to participate in this study.

CONFIDENTIALITY
The researchers will make every effort to prevent anyone who is not on the research team from knowing that you provided this information, or what that information is. The consent forms with signatures will be kept separate from responses, which will not include names and which will be presented to others only when combined with other responses. Although we will make every effort to protect your confidentiality, there is a low risk that this might be breached.

IN THE EVENT OF A RESEARCH-RELATED INJURY
In the event of injury resulting from you taking part in this study, treatment can be obtained at a health care facility of your choice. You should understand that the costs of such treatment will be your responsibility. Financial compensation is not available through The University of Toledo or The University of Toledo Medical Center. By signing this form you are not giving up any of the legal rights of your son/daughter/legal charge as a research subject. In the event of an injury, contact Brian Pietrosimone, PhD, ATC (419) 530-4467

VOLUNTARY PARTICIPATION
Taking part in this study is voluntary. You may refuse to participate or discontinue participation at any time without penalty or a loss of benefits to which you are otherwise entitled. If you decide not to participate or to discontinue participation, your decision will not affect your future relations with the University of Toledo or The University of Toledo Medical Center

NEW FINDINGS
You will be notified of new information that might change your decision to be in this study if any becomes available.

Continued On Next Page
OFFER TO ANSWER QUESTIONS
Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have questions regarding the research at any time before, during or after the study, you may contact: Dr. Brian Pietrosimone- (419) 530-4467. If you have questions beyond those answered by the research team or your rights as a research subject or research-related injuries, please feel free to contact the Chairperson of the University of Toledo Biomedical Institutional Review Board at 419-383-6796.

SIGNATURE SECTION (Please read carefully)
YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED ABOVE, YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED, AND YOU HAVE DECIDED TO TAKE PART IN THIS RESEARCH.

BY SIGNING THIS DOCUMENT YOU AUTHORIZE US TO USE OR DISCLOSE YOUR PROTECTED HEALTH INFORMATION AS DESCRIBED IN THIS FORM.

The date you sign this document to enroll in this study, that is, today’s date, MUST fall between the dates indicated on the approval stamp affixed to the bottom of each page. These dates indicate that this form is valid when you enroll in the study but do not reflect how long you may participate in the study. Each page of this Consent/Authorization Form is stamped to indicate the form’s validity as approved by the UT Biomedical Institutional Review Board (IRB).

Name of Subject (please print)                      Signature of Subject or Person Authorized to Consent                      Date  

Relationship to the Subject (Healthcare Power of Attorney authority or Legal Guardian)  

Name of Person Obtaining Consent (please print)                      Signature of Person Obtaining Consent                      Date  

Name of Witness to Consent Process (when required by ICH Guidelines) (please print)                      Signature of Witness to Consent Process (when required by ICH Guidelines)                      Date  

YOU WILL BE GIVEN A SIGNED COPY OF THIS FORM TO KEEP.
Appendix B

Exclusion Criteria Form

Exclusion Criteria Screening Sheet for Joint Mobilization Study
Joint Injury and Muscle Activation Laboratory

Please indicate if you have a history of any of the following conditions, experiences or pathologies. If "yes" please briefly explain.

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Injury to the lower extremity other than the ankle in the previous 6 months</th>
<th>Explain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rehabilitation for a lower extremity injury in the last 6 months</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Joint hypermobility of connective tissue disorder</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>concussion or head injury in the past 6 months</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stroke</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A heart condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>cranial neurosurgery</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>epilepsy</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Migraines</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>cancer in the brain or thigh musculature</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>diagnosed psychiatric disorder</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>cardiac pacemaker</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>implanted cardiac defibrillator</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>intracranial metallic clips</td>
<td></td>
</tr>
</tbody>
</table>

UT IRB #107092
Assigned Version Date: 02/17/2011
**Appendix C**

**FADI**

<table>
<thead>
<tr>
<th>Activity</th>
<th>No difficulty at all</th>
<th>Slight difficulty</th>
<th>Moderate difficulty</th>
<th>Severe difficulty</th>
<th>Unable to do</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on even ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on uneven ground without shoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking up hills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking down hills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Going up stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Going down stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleeping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Getting up on your toes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Getting up initially</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking 5 minutes or less</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking approximately 10 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking 15 minutes or greater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Foot and Ankle Disability Index (FADI)**

Please answer every question with your response that most closely describes your condition within the past week.

If the activity in question is limited by something other than your foot or ankle, mark not applicable (NA).

---

**UT IRB #107092**

**1999 FADI Interim 1/2**

**APPROVED BY UNIVERSITY OF TOLEDO IRB**

72
Because of your foot and ankle how much difficulty do you have with:

<table>
<thead>
<tr>
<th>Activity</th>
<th>No difficulty at all</th>
<th>Slight difficulty</th>
<th>Moderate difficulty</th>
<th>Extreme difficulty</th>
<th>Unable to do</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home responsibilities</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Activities of daily living</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Personal care</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Light to moderate work (standing, walking)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heavy work (push/pulling, climbing, carrying)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recreational Activities</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Please rate your pain level as it relates to your foot and ankle:

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Unbearable</th>
</tr>
</thead>
<tbody>
<tr>
<td>General level of pain</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>At rest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>During your normal activity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>First thing in the morning</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

FADI Sports Scale

Because of your foot and ankle how much difficulty do you have with:

<table>
<thead>
<tr>
<th>Activity</th>
<th>No difficulty at all</th>
<th>Slight difficulty</th>
<th>Moderate difficulty</th>
<th>Extreme difficulty</th>
<th>Unable to do</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jumping</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Landing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Starting and stopping quickly</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cutting/lateral movements</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low impact activities</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ability to perform activity with your normal technique</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ability to participate in your desired sport as long as you would like</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

1999 FADI exam 2/2
Appendix D

VAS

Place an X over the spot that best represents your ankle pain during the last contraction

Absolutely
No Pain

Worst Pain
Imagineable

Place an X over the spot that best represents your ankle stiffness during the last contraction

Absolutely
No stiffness

Worst Stiffness
Imagineable

Place an X over the spot that best represents your Ankle Stability during the last contraction

Completely
Stable

Worst Stability
Imagineable

Place an X over the spot that best represents your Ankle Function

Completely
Functional

No function
at all

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UNIVERSITY OF TOLEDO IRB
Appendix E

Data Recording Form - DF ROM

Range of Motion Measurements

Subject #: ______________________

**Posterior Talar Measurement-Seated**

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<tr>
<td>T2</td>
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<tr>
<td>T3</td>
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<tr>
<td>Avg</td>
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**Dorsiflexion Measurement-Seated**

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**Knee-to-Wall Measurement-Standing**

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Assigned Version Date: 02/17/2011
**Appendix F**

**Data Recording Form- SEBT**

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### Star Excursion Balance Test

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<th>Foot Width:</th>
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UT IRB #107092

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Approved by

University of Toledo IRB