THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

THE EFFECT OF JOINT MOBILIZATION TO THE ANKLE AND LOWER LEG ON STATIC AND DYNAMIC POSTURAL CONTROL MEASURES

JACLYN MARIE FISSINGER
SPRING 2014

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Kinesiology
with honors in Kinesiology

Reviewed and approved* by the following:

Sayers John Miller, III
Assistant Professor of Kinesiology
Thesis Adviser

Giampietro “John” L. Vairo
Instructor of Kinesiology
Co-Thesis Adviser

Steriani Elavsky
Assistant Professor of Kinesiology
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

THE EFFECT OF JOINT MOBILIZATION TO THE ANKLE AND LOWER LEG ON STATIC AND DYNAMIC POSTURAL CONTROL MEASURES

Objective: To determine if an ankle and lower leg joint mobilization intervention improves dorsiflexion (DF) and static and dynamic postural control in individuals with limited DF range of motion (ROM) in one ankle. **Design:** A pretest-posttest experiment design was used for this prospective cohort study. The independent variable was the intervention, either ankle mobilization or a placebo taping. The dependent variables included ankle DF ROM, static and dynamic postural control measures, and self-reported function. **Participants:** Twenty-eight (17 male, 11 female) healthy participants with limited ankle DF ROM in one ankle were enrolled in this study. Each participant was randomly assigned to one of two interventions: ankle mobilizations (Age=20.79±0.80 years, Height=170.50±10.00 cm, Weight=69.20±14.20 kg, BMI=23.59±14.20 kg/m^2) or placebo taping (Age=20.50±1.29 years, Height=166.42±5.49 cm, Weight=70.60±14.50 kg, BMI=25.48±5.17 kg/m^2). **Measurements:** Foot and Ankle Ability Measure (FAAM) score for the Activities of Daily Living and Sport Subscales, weight-bearing DF ROM, and center of pressure data (path length, average velocity, path/area, time to boundary mean minima, and standard deviation of time to boundary mean minima) during 10 and 30 second trials of single-legged quiet stance with eyes opened and eyes closed, and during a repetitive sub-maximal single-legged squatting task were collected. Baseline measures were obtained on the first day of the study, and the first intervention session followed. The second intervention session was two days later, with post-intervention data collection occurring two days after the second intervention session. **Results:** FAAM score for the Activities of Daily Living Subscale was significantly higher post-intervention in the manipulation intervention group (p=0.007) and taping intervention group (p=0.036). FAAM score for the Sport Subscale was also significantly higher post-intervention in the manipulation intervention group (p=0.016) and taping intervention group (p=0.005). No other significant differences existed when group, intervention, and time were considered together. **Conclusions:** Our finding suggest there is no significant change in DF or static or dynamic postural control ability after two treatment sessions of ankle and lower leg mobilization in healthy individuals with one ankle with limited DF ROM. FAAM changes indicate an improvement in perceived function with either ankle and lower leg mobilization or placebo tape intervention.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

Writing a thesis seemed like an impossible feat as a freshman and sophomore. However, with the help of my thesis advisors, my assistants, and my friends and family, I was able to complete this thesis without becoming overwhelmed.

First and foremost I would like to thank Dr. Miller for all of his help throughout the process of completing the thesis. I would not have been able to develop and complete the research study without his insight, and physical therapy skills. Dr. Miller put a lot of time into editing my thesis and ensuring that it was complete as well as professional.

I would like to acknowledgement John Vairo for helping in the development process of the study as well, and for helping with the data analysis. John also put numerous hours into reviewing my thesis, and I was very grateful to have his input as I was putting the finishing touches on the thesis.

Dr. Steri Elavsky was also a crucial part of my editing team. I appreciated having her help as an outside perspective to look over the content of my thesis, as well as review it for formatting and grammar errors.

I would like to thank Dr. Challis as well for writing the MATLAB program for me to use to analyze my data. He made it possible to obtain the time to boundary measures, which have been proven to be a more reliable measure.

I would also like to thank my four lab assistants, Sal Liberto, Brynja Winnan, Alexia Desa, and Rex Lutz. I would not have been able to make things run so smoothly in the lab without them. Having the extra set of hands was crucial in completing the data collection in a timely manner.

I would like to acknowledge my friends and family for supporting me throughout my college career and in the process of completing my thesis. My parents and brothers were always there for me if I needed encouragement to keep up the hard work. I would also like to acknowledge my excellent study buddies Brandon, Chelsea, and Ashlee for keeping the mood light as we studied so we could stay positive and motivated.

Lastly, I would like to thank the Schreyer Honors College for providing me with a grant to cover the expenses of my research study.

Chapter 1

Introduction

Serious chronic issues can persist following an ankle injury. This is a major concern because ankle injuries are one of the most common musculoskeletal injuries to sustain. In Western Countries, approximately 1 ankle sprain occurs per 10,000 people every day.[1] Over 40% of ankle sprains result in chronic problems.[2] Fractures in the ankle and distal leg can also produce chronic issues.[3] Impairments such as mechanical instability due to ligamentous laxity, functional instability due to diminished neuromuscular control, and ankle dorsiflexion (DF) range of motion (ROM) deficits are common sequalae of ankle sprains.[4] These impairments put the individual at a higher risk for ankle re-injury.[4] Deficits in ankle DF ROM have been found to adversely impact balance and functional movement capabilities.[4] Dynamic postural control has been shown to be impaired more than static postural control by a deficit in ankle DF ROM, and it is an important concern following ankle injuries.[4-6] The ability to perform functional activities such as squatting, jogging, and stepping has also been found to be impaired by ankle DF ROM limitations.[4] These impairments often persist despite the use of rehabilitation programs that were originally thought to address the impairments thoroughly.[4]

One possible cause of the limited ankle DF following an ankle injury is a restricted posterior glide of the talocrural joint.[4,7] Although some clinicians address this impairment in the acute stages of rehabilitation, many focus solely on gastrocnemius and soleus flexibility as the means to improve DF ROM.[4,7] Persistent ROM deficits and restricted talocrural joint mobility may be the result of failure to restore the arthrokinematic motion of posterior talar glide at the talocrural joint.[8] A common treatment for addressing this type of impairment is talocrural joint mobilization, which has been shown to produce significant increases in DF ROM and improve dynamic postural control.[4,8-16] Hoch et al[9] found that following a 2-week period of ankle joint mobilization treatments in patients with chronic ankle instability, there were significant increases in the reach distances in the anterior, posteromedial, and posterolateral directions using the Star Excursion Balance Test (SEBT). The SEBT is a common assessment tool for dynamic balance ability.[5,9,10,17]

There are no known research studies that have explored the effects of joint mobilization on dynamic postural control that do not use the SEBT as the assessment tool. Since DF has been seen to impact squatting[4] and squatting is a challenge to dynamic balance[18], squatting will be used to test dynamic postural control. There are also no known research studies that evaluate the effects of ankle joint mobilizations on both dynamic and static balance using measures of postural control. The purpose of this study is to determine the effects of ankle and lower leg joint mobilization on ankle DF ROM, static balance during quiet stance, and dynamic balance during squatting as compared to a placebo taping intervention. Based on the findings of Hoch et al[9], we hypothesize that participants with a lack of DF ROM will have increased ankle DF ROM and static and dynamic postural control responses following two joint mobilization treatment sessions, but that these measures will be unaffected following the placebo taping intervention.

Chapter 2

Methods and Materials

Experimental Design:

A pretest-posttest experimental design was used for this prospective cohort research study. The independent variable in the study was the intervention. The participants received either ankle mobilization or a placebo Kinesiology Tape (Nitto Denko, Tokyo, Japan) intervention. Self-reported function, ankle ROM, and static and dynamic postural control were the dependent variables of interest. The researchers collecting ROM and postural control data were blinded to the intervention each participant received. Baseline measures were taken on the first day of the experiment, followed immediately by the first intervention session. The participant then had a second intervention two days later, and two days after the second intervention the final post-intervention measures were obtained. Baseline and final measures were used for comparative analysis.

Participants were recruited from the Pennsylvania State University Park community using the recruitment materials approved by the University's Institutional Review Board (IRB) (Appendix G). The approved recruitment materials included a flyer (Appendix A), a script (Appendix B), and an email (Appendix C). Potential participants answered the eligibility screening question set (Appendix D) to determine if they met the eligibility criteria of the study. If the participant met the criteria of the questions, then they were scheduled to come in to lab. During their first appointment, they were asked to read and sign an IRB approved informed consent form (Appendix E). If the participant agreed to the terms of the study, then ROM of each ankle was tested using the weight-bearing lunge test (WBLT). The participant was considered eligible if there was a 2 centimeter difference in the lunge distance of their two legs.[19]

If the participant was eligible based on the WBLT, then the first data collection session was completed. The WBLT information was used for the ankle DF ROM measures, and then age, height, weight, and leg length were determined for each participant. After these measures were taken, each participant was asked to fill out the Foot and Ankle Ability Measure (FAAM) survey (Appendix F). Next, static postural control of both legs was assessed by having the participant balance in a quiet single-legged stance on the force plate (AccuSway Plus force plate, AMTI Corp., Watertown, MA), for 10 and 30 second trials, with eyes opened and eyes closed. Lastly, maximum squat depth was measured and dynamic balance was assessed by having the participant squat three times in a row to 80% of their maximum squat depth on the force plate. Following their first data collection, the participant obtained one of the two interventions, either ankle mobilization or the placebo taping intervention. The intervention each participant received was determined by a computer-generated random number sequence. Participants received the same intervention a second time two days later. Two days after the second intervention session, the participant completed a final data collection session which included the WBLT, FAAM survey, and the static and dynamic postural control assessments. Figure 1 illustrates the experimental design in chronological order.

Figure 1. Experimental Design

Participants:

Twenty-eight participants, 17 male and 11 female, met all inclusion and exclusion criteria. Each participant had one ankle with limited ankle DF ROM. This was determined using the WBLT, and the participants were required to have a 2 cm lunge distance asymmetry between the both sides.[19] Each participant met the criteria of the eligibility screening (Appendix D), which required them to be healthy and physically-active young adults, without a current back or lower extremity injury.

The criteria for inclusion were:

- Between the ages of 18 and 40 years old
- One ankle that is stiffer (has less range of motion) than the other
- Recreationally active
- English speaking

The criteria for exclusion were:

- Currently in a formal rehabilitation program for a low back or lower extremity injury
- Pain above 2 out of 10
- History of back problems or an injury to the back
- Significant injury to either lower extremity within the last 6 months
- Ankle sprain within the last 6 months
- Diabetic
- Sustained a concussion within the last 6 months
- Neurological deficits in the legs such as numbness, tingling, or weakness

There was no significant difference in the anthropometric measurements between the two treatment groups, as Table 1 illustrates.

Table 1. Participant Anthropometric Data

	Manipulation Group	**Tape Group**	**P-Value***
Sex (male/female)	8/6	9/5	N/A
Age (years)	20.79±0.80	20.50±1.29	0.488
Height (cm)	170.50±10.0	166.42±5.49	0.201
Weight (kg)	69.2±14.2	70.6±14.5	0.802
Body Mass Index (kg/m^2)	23.59±14.2	25.48±5.17	0.240

N=14 for both groups; Values are Mean Standard Deviation
*T-Test of Difference=0 between groups and P-Value<0.05 denotes statistical significance

Ankle Dorsiflexion Range of Motion Test Procedures:

The WBLT, utilizing the knee-to-wall principle, was used for the DF ROM measurement because it has be found to be a reliable method for measuring DF in a functional weight-bearing position.[19] A metric ruler was butted up against the wall and taped to the floor. The participant was asked to face the wall with their foot lined up with the ruler and their big toe at the 1 cm mark. In this position, participants were asked to lunge down to try to touch their knee to the wall without lifting their heel (Fig. 2). Participants were allowed to place their back foot on the ground behind their testing foot and put their hands on the wall for balance. The foot was moved away from the wall at 1 cm increments until the participant was unable to touch the wall with their knee without lifting their heel. At the point where their heel came up, the foot was moved forward 0.5 cm to find their maximum lunge distance to the nearest 0.5 cm. This procedure was performed 6 times on each foot during baseline and final data collection sessions. In order to be eligible to participate in the study, the average of the last three trials had to demonstrate a 2 cm difference in the maximum lunge distance between their two ankles. Hoch and McKeon[19] found that a 2 cm asymmetry is the clinically relevant criteria to use to find participants with DF impairments.

Figure 2. Weight-Bearing Lunge Test

Static Postural Control Test Procedures:

Quiet single legged standing was used to assess static postural control. Center of pressure measures using a force plate have been shown to be a valid and reliable method of assessing postural control impairments in previous studies assessing limited DF ROM and ankle impairments.[20-23] Three 10 second and three 30 second trials were performed under both eyes opened and eyes closed conditions. Thirty second trials are thought to provide more accurate center or pressure data, but few subjects with ankle impairments are able to complete trials of this duration. Eyes opened and eyes closed trials were included to remove visual cues and require the participant to rely on proprioceptive and vestibular afferent sensory information to control balance.[21]

Participants were asked to step onto the force plate (AccuSway Plus force plate, AMTI Corp., Watertown, MA) with both feet in the middle of the plate, about an inch apart. A piece of tracing paper covered the surface of the force plate, and the investigator traced both feet so that their foot was positioned at the same place on the force plate during each trial of both data collection sessions. The participant was instructed to stand as still as possible with their hands on their hips and their non-stance foot about 2 inches off of the ground next to the stance leg malleolus, but not touching their standing leg (Fig. 3). During eyes opened trials participants were asked to focus on a white “X” at eye level on the wall in front of them. For eyes closed trials participants were asked to focus on the “X”, and then close their eyes for the remainder of the trial. If the participant was unable to balance for the entire trial, then the time was recorded when they touched their foot down. Three practice trials were performed under both eyes open and eyes closed conditions, and both trial durations prior to the data collection trials. One minute of rest was given between each set of trials, as well as 45 seconds of rest between each 30 second trial, and 30 seconds of rest between each 10 second trial. Center of pressure data was collected through a computer that used Balance Clinic software (AMTI corp., Watertown, MA) to import the data from AccuSway Plus force plate (AMTI corp., Watertown, MA).

Figure 3. Single Legged Stance Quiet Standing

<u>Dynamic Postural Control Test Procedures:</u>

The SEBT has been a very common way to test dynamic balance. There are no known studies that have been conducted that used another test to determine the effects of joint mobilization on dynamic postural control in people with DF ROM deficits. Limited DF has been shown to impact the mechanics of squatting[4], and single-legged squat performance has been shown to be influenced by dynamic balance ability,[18] so a repeated single-legged squat task was created to test dynamic postural control. The participant was asked to squat to 80% of their maximum single-legged squat depth three times in a row in a 10 second period. Pilot testing revealed that squatting to 80% of their maximum squat depth was challenging, but achievable for all participants.

The maximum squat of each participant was measured by taping a string to the greater trochanter which hung so that it just touched the floor. The participant was asked to perform their maximum squat and the investigator marked the amount of string that laid on the ground as the participant reached their maximum squat depth. The string that was on the ground was measured to determine the maximum squat depth. Three trials were performed and the 80% was calculated from the maximum of the three trials. The string was then shortened by 20% of the maximum squat depth re-taped on the participant's greater trochanter. The greater trochanter was used to standardize the squat depth measurement because it is an easy bony landmark to find with palpation. During repeated squat trials, the participant was asked to squat down far enough each repetition that the string just met the force plate, which ensured that they squatted to 80% of their maximum squat depth each repetition (Fig. 4). During the data collection trials, the participant was instructed to remain balanced in single-legged stance for 2 seconds, then squat three times in a row, descending in one second and ascending in one second, and then hold the single-legged stance balance position for 3 seconds. A metronome was playing at 60 beats per minute so that the participant could follow the beats of the metronome for the timing of the dynamic balance task. The investigator said ready, set, go, in time with the metronome so the participant knew when to start. The participant was instructed to keep their hands on their hips throughout the trial. Non-stance leg movement was unrestricted.

The participant performed three practice trials before the three data collection trials. A 90 second rest period was given between each trial and between the practice and data collection trials. The maximum squat depth was measured during the second data collection, but the 80% of maximum squat depth from the first data collection was used for the repeated squat trials for both data collection sessions to ensure that the same perturbation was encountered in both data collection sessions. Center of pressure data was collected from the force plate (AccuSway Plus, AMTI corp., Watertown, MA) using the Balance Clinic software (AMTI corp., Watertown, MA).

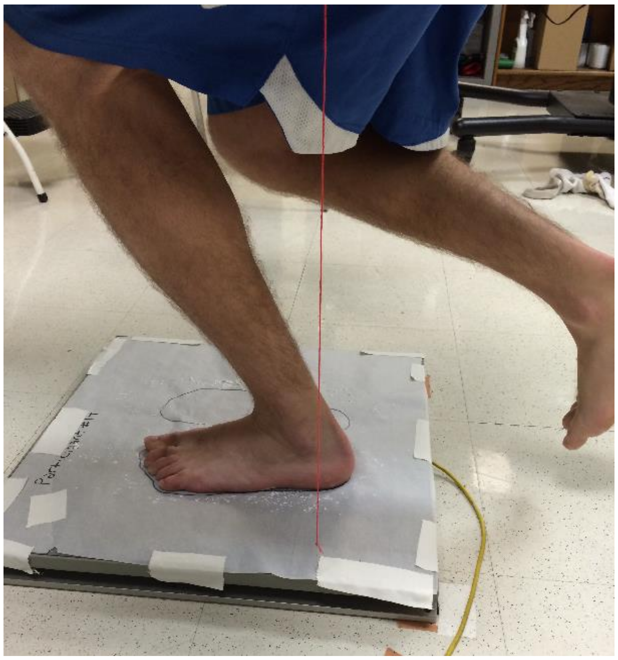

Figure 4. Repeated Single Legged Squat to 80% of Maximum

<u>Intervention Techniques:</u>

The ankle mobilization interventions were performed during the first and second intervention sessions by a licensed physical therapist/athletic trainer with over 30 years of clinical experience. During the experimental intervention sessions, the physical therapist performed a series of mobilizations that are similar to those commonly used in related literature and in clinical practice.[4,8-16,24] The mobilizations included rearfoot distraction, posterior talar glide, distal tibiofibular joint mobilization, proximal tibiofibular posterior joint mobilization, proximal tibiofibular anterior joint mobilization, and calcaneal distraction. All mobilizations were performed as Grade IV mobilizations, with small amplitude, oscillatory movements well into resistance at the end of the available ROM.[25]

Rearfoot Distraction Mobilization:

The participant was placed in a supine position with their ankle just off the end of the table. The investigator supported the participant's foot with both hands with his ring fingers over the anterior aspect of the talus. The ankle was positioned in 10 degrees of plantar flexion and the investigator applied a longitudinal and caudal high velocity, low amplitude Grade V mobilization force to the talus. Two distraction mobilizations were performed. Figure 5 shows this technique.

Figure 5. Rearfoot Distraction Mobilization

Posterior Talar Glide Mobilization:

Participant was positioned supine on the table with the foot just off the end of table. The investigator supported the foot with both hands and positioned the ankle at 10 degrees of plantar flexion. The investigator placed both thumbs on the anterior surface of the talus and provided a posterior directed oscillatory force to the talus. Figure 6 shows this technique.

Figure 6. Posterior Talar Glide Mobilization

Distal Tibiofibular Joint Mobilization:

Participant was positioned supine on a treatment table with their foot on the table. The investigator supported the posterior aspect of the distal tibia with one hand and provided a posterior directed oscillatory force to the lateral malleolus with the other hand. Figure 7 shows this technique.

Figure 7. Distal Tibiofibular Joint Mobilization

Proximal Tibiofibular Posterior Joint Mobilization:

Participant was positioned supine on a treatment table with their leg fully supported by the table. The investigator internally rotated the leg 30 degrees and supported the posteromedial aspect of the knee and proximal tibia with one hand. The investigator then provided a posterior directed oscillatory force to the proximal fibular head with the other hand. Figure 8 shows this technique.

Figure 8. Proximal Tibiofibular Posterior Joint Mobilization

Proximal Tibiofibular Anterior Joint Mobilization:

Participant was positioned in on hands and knees on the table with the hip of the leg to be mobilized flexed to approximately 70 degrees. The investigator supported the anterolateral aspect of the proximal tibia with one hand and applied an anterolateral oscillatory force to the posteromedial aspect of the fibular head with the other hand. Figure 9 shows this technique.

Figure 9. Proximal Tibiofibular Anterior Joint Mobilization

Calcaneal Distraction Mobilization:

The participant was placed in a prone position with the foot in a plantar flexed position. The investigator supported the anterior part of the ankle with one hand and applied a longitudinal and caudal high velocity, low amplitude, Grade V mobilization force to the calcaneus. Two distraction mobilizations were performed. Figure 10 shows this technique.

Figure 10. Calcaneal Distraction Mobilization

Placebo Intervention:

The placebo intervention involved the placement of a piece of Kinesiology Tape (Nitto Denko, Tokyo, Japan) on the medial portion of the distal upper leg, about an inch above the patella. Figure 11 shows the placement of the tape. Participants were told that the tape may act to improve their ROM and balance via mechanisms similar to acupuncture. During the first intervention session, the physical therapist told the participant to wear the tape until their next treatment, and for the second intervention session they were told to wear it until just prior to their next data collection session. Participants were instructed not to inform data collection investigators of which intervention they received.

Figure 11. Kinesiology Tape Placebo Intervention

Statistical Analysis:

The data for postural control included COP and TTB measures. The COP measures obtained were from the Balance Clinic software (AMTI corp., Watertown, MA) and included path length, path/area, velocity. The TTB was computed using the MATLAB (Mathworks Inc., Natik, MA) program, and the TTB mean minima and TTB mean minima standard deviation was computed by the MATLAB program. The maximum of the three trials for each of these variables was identified and used for the statistical comparisons. During the 10 second eyes closed trials, 1 participant in the manipulation group did not complete a single trial, so the data of this participant was excluded for all of the 10 second eyes closed data. To make the data sets even, an outlier from the tape group was excluded as well. To determine the outlier in the tape group, a normative probability plot was graphed. During the 30 second eyes closed trials, 9 participants in the tape group did not complete a single trial and 8 participants in the manipulation group did not complete a single trial. The rest of the data from these participants was excluded for the 30 second eyes closed COP path length and path area, leaving 5 participant in the tape group and 6 participants in the manipulation group. T-tests were conducted for these variables because we did not want to exclude any more data from this set and an analysis of variance (ANOVA) test cannot be completed with uneven groups.

Descriptive statistics, including groups' means and standard deviations were calculated for all dependent variables of interest. Two-tailed, two sample t-tests were calculated to determine statistically significant differences between the manipulation and tape groups for demographic and anthropometric measures as well as FAAM scores and 30 second eyes closed path length and path/area measures. Paired t-tests were calculated to determine statistically significant differences between pre- and post-intervention FAAM scores and 30 second path length and path/area measures for the manipulation and tape groups. Multi-factor repeated measures ANOVA with Tukey's Honestly Significant Difference (HSD) post hoc analysis was calculated to determine statistically significant between-participants and within-participant differences for ROM and center of pressure measures. A 95% simultaneous confidence interval (SCI) was used to denote statistically significant pairwise comparisons. Residual analyses were conducted to ensure data met necessary assumptions for ANOVA. An *a priori* alpha level of $P \leq 0.05$ denoted statistical significance for all comparisons.

Chapter 3

Results

<u>FAAM Survey:</u>

No significant differences existed in the pre-intervention scores between the manipulation and tape group for the ADL or Sports Subscales of the FAAM (see Table 3). The post-intervention FAAM scores were significantly higher than the pre-intervention scores for the manipulation and tape groups on both the ADL and Sport Subscales (see Table 3). Descriptive statistics for the FAAM scores for the stiff ankle are included in Table 2.

Table 2. Pre-Test and Post-Test FAAM Scores

	M Pre	M Post	T Pre	T Post
FAAM ADL	93.09±6.35	95.90±3.87	96.11±5.15	97.70±2.92
FAAM Sport	80.11±12.58	87.25±13.64	83.42±15.88	90.31±11.75

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
N=14 for each group

Table 3. Significance of FAAM Score Between and Within Participant Differences

	Pre by Group P-Value	Pre vs Post M P-Value	Pre vs Post T P-Value
FAAM ADL	0.179	0.007*	0.036*
FAAM Sport	0.548	0.016*	0.005*

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
* denotes statistical significance for P-Value<0.05
N=14 for each group

<u>Dorsiflexion Range of Motion:</u>

Residual analyses of the data confirmed it met the assumptions for ANOVA. The three factors compared in our analysis were group (stiff or healthy ankle), intervention (manipulation or tape), and time (pre- or post-test). No statistically significant three-way interactions were found.

Tukey's HSD post-hoc pairwise comparisons revealed a few significant differences. With the stiff and healthy ankle groups combined, DF ROM of the manipulation group pre-intervention was significantly less than the tape group post-intervention [SCI: (0.201,4.895)]. With the manipulation and tape groups combined, the stiff ankles pre-intervention had significantly less DF than the healthy ankles pre-intervention [SCI: (0.6887, 5.383)] and the healthy ankles post-intervention [SCI: (0.8851, 5.579)]. The stiff ankle of the manipulation had significantly less DF than the healthy ankle of the manipulation group [SCI: (0.3137, 4.323)] and the healthy ankle of the tape group [SCI: (1.7601, 6.454)]. The DF of the manipulation group was significantly less than the DF of the tape group with the stiff and healthy ankles combined [SCI: (0.4500, 2.973)]. The stiff ankles had significantly less DF than the healthy ankles with the manipulation and tape group combined [SCI: (1.135, 3.657)]. No other pairwise comparisons were statistically significant. Descriptive statistics for DF ROM are presented in Table 4.

Table 4. Dorsiflexion Range of Motion

	Stiff M	**Healthy M**	**Stiff T**	**Healthy T**
DF ROM Pre	7.80±3.96	11.04±3.82	9.83±2.63	12.67±2.90
DF ROM Post	9.33±3.60	11.42±3.73	11.25±3.25	12.68±2.75

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
N=14 for each group

<u>Static Postural Control:</u>

Single-Legged Quiet Stance Eyes Opened Trials:

Very few participants had difficulty with the 30 second eyes open static balance trials. On both the stiff and healthy leg in the manipulation group, one person fell during one trial before treatment, but none of the participants fell during the post-treatment data collection. In the tape group, one person fell on their stiff leg during one trial of pre-treatment data collection, but no participants fell during the post-treatment collection and none fell on their healthy leg pre- or post-intervention. Every participant was able to complete the 10 second eyes opened trials.

Residual analyses of the data confirmed it met the assumptions for ANOVA. No significant three-way interactions were observed for the COP or TTB measures of the 30 or 10 second trials. Tukey's HSD post-hoc pairwise comparisons revealed that the manipulation group has a significantly lower TTB mean minima than the tape group [SCI: (0.010, 0.082)] in the 30 second eyes opened trials. No other significant pairwise comparisons existed in the 30 second or 10 second trials. Eyes opened 30 second trial descriptive statistics are presented in Table 5 and eyes opened 10 second trial descriptive statistics are presented in Table 6.

Table 5. Single-Legged Quiet Stance Eyes Opened 30 Second Trials

Measure	Stiff M	Healthy M	Stiff T	Healthy T
COP Path Length Pre	141.5±44.7	139.9±30.0	142.7±37.7	136.0±40.5
COP Path Length Post	138.2±41.3	135.7±28.2	138.3±33.6	135.8±33.8
COP Path/Area Pre	13.55±3.58	12.88±2.89	11.94±3.65	11.70±4.25
COP Path/Area Post	15.26±6.42	13.33±3.49	13.32±5.30	12.31±3.90
COP Avg Velocity Pre	4.72±1.49	4.67±1.00	4.75±1.26	4.53±1.35
COP Avg Velocity Post	4.61±1.37	4.52±0.94	4.61±1.12	4.53±1.13
TTB Mean Min Pre	0.373±0.080	0.371±0.118	0.416±0.076	0.408±0.103
TTB Mean Min Post	0.378±0.112	0.361±0.112	0.435±0.073	0.408±0.075
TTB Mean Min SD Pre	0.179±0.042	0.163±0.036	0.176±0.031	0.173±0.057
TTB Mean Min SD Post	0.168±0.039	0.163±0.033	0.177±0.027	0.165±0.047

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
N=14 for each group

Table 6.Single-Legged Quiet Stance Eyes Opened 10 Second Trials

Measure	Stiff M	Healthy M	Stiff T	Healthy T
COP Path Length Pre	42.04±12.56	39.99±7.89	44.87±11.06	41.50±8.85
COP Path Length Post	43.27±12.79	43.65±12.14	40.18±8.04	39.94±9.97
COP Path/Area Pre	6.67±1.38	6.91±1.12	6.61±1.42	7.02±1.63
COP Path/Area Post	7.15±1.43	6.89±1.39	6.67±1.63	5.58±1.91
COP Avg Velocity Pre	4.21±1.26	4.00±0.79	4.49±1.11	4.15±0.88
COP Avg Velocity Post	4.33±1.28	4.44±1.25	4.02±0.80	4.42±2.02
TTB Mean Min Pre	0.383±0.126	0.338±0.162	0.423±0.114	0.405±0.127
TTB Mean Min Post	0.202±0.651	0.405±0.107	0.443±0.065	0.443±0.090
TTB Mean Min SD Pre	0.183±0.040	0.168±0.047	0.172±0.038	0.159±0.047
TTB Mean Min SD Post	0.171±0.052	0.170±0.045	0.162±0.041	0.167±0.044

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
N=14 for each group

Single-Legged Quiet Stance Eyes Closed Trials:

The majority of participants were unable to complete the 30 second eyes closed trials. On the stiff leg in the manipulation group, only three people balanced for 30 seconds during the 3 trails pre- and post-intervention. Six participants were unable to complete any of the 30 second trials. On the healthy leg in the manipulation group, four of the participants were able to complete all 3 trials pre- and post-intervention. Eight of the participants fell during all of the 30 second trials, or only had one trial where they were able to balance the entire 30 seconds. On the stiff leg in the taping group, only 2 people were able to balance the full 30 seconds for all 6 trials. Four participants fell during all 6 trials. On the healthy leg in the taping group, 3 people were able to balance for the full 30 seconds for all 6 trials. Four of the participants fell during all 6 trials. The COP velocity and TTB measures are not sensitive to time, so no data was excluded for these measures. Center of pressure path length and path/area are sensitive to time, so the participants who did not complete a full trial were excluded for these measures. The data sets for the manipulation and taping groups were uneven after the participants who fell were excluded, so t-test were used for the COP path length and path/area measures to prevent the exclusion of valid data. The majority of participants were able to complete the 10 second eyes closed trials. One participant in the manipulation group fell during all three trials on their healthy leg pre-intervention, so all of his data was excluded. An outlier of the taping group was excluded to make even groups for the ANOVA test.

Residual analyses of the data confirmed it met the assumptions for ANOVA. No significant three-way interactions were observed for the COP or TTB measures of the 30 or 10 second trials. The COP path/area was significantly different between the stiff manipulation group pre- and post-intervention with a paired t-test ($p=0.038$). The COP path/area of the manipulation group post-intervention was significantly different than the tape group post-intervention with a two-sample t-test ($p=0.004$). No other significant differences were observed in the 30 second eyes closed trials. Tukey's HSD post-hoc pairwise comparisons revealed that the TTB mean minima SD of the stiff ankle post-intervention was significantly less than the healthy ankle post-intervention when the manipulation and tape groups were combined [SCI: (-0.0462, -0.00291)]. The TTB mean minima SD of the stiff ankle in the tape group was significantly less than the healthy ankle of the manipulation group [SCI: (-.0438, -.0005)]. The TTB mean minima SD of the stiff group was significantly lower than the healthy group when the manipulation and tape groups were combined [SCI: (-.0256, -.0024)]. No statistically significant differences existed in the 10 second eyes closed trials. The descriptive statistics of the eyes closed 30 second trials are presented in Table 7 and the descriptive statistics of the eyes closed 10 second trials are presented in Table 8.

Table 7. Single-Legged Quiet Stance Eyes Closed 30 Second Trials

Measure	Stiff M	Healthy M	Stiff T	Healthy T
COP Path Length Pre**	233.8±52.6	255.8±38.1	256.4±78.1	238.6±28.1
COP Path Length Post**	255.2±50.1	279.4±49.9	248.2±60.4	242.3±64.6
COP Path/Area Pre**	9.36±1.95	10.23±1.51	9.32±1.89	10.56±1.20
COP Path/Area Post**	11.07±1.74	11.66±2.37	7.47±0.37	9.98±1.60
COP Avg Velocity Pre*	8.68±2.77	8.44±1.08	8.44±2.17	9.16±2.48
COP Avg Velocity Post*	9.03±2.02	9.07±1.79	9.23±4.16	8.83±2.18
TTB Mean Min Pre*	0.284±0.075	0.277±0.072	0.300±0.066	0.326±0.071
TTB Mean Min Post*	0.274±0.073	0.263±0.093	0.305±0.056	0.293±0.075
TTB Mean Min SD Pre*	0.152±0.051	0.135±0.021	0.137±0.023	0.150±0.022
TTB Mean Min SD Post*	0.123±0.026	0.128±0.044	0.144±0.022	0.134±0.025

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
**N=6 for M groups and N=5 for T groups; *N=14 for each group

Table 8. Single-Legged Quiet Stance Eyes Closed 10 Second Trials

Measure	Stiff M	Healthy M	Stiff T	Healthy T
COP Path Length Pre	91.71±29.30	89.82±23.21	82.22±17.96	81.94±19.63
COP Path Length Post	88.52±31.74	89.10±25.20	79.03±22.97	85.48±21.66
COP Path/Area Pre	4.37±0.68	4.73±1.31	4.47±0.99	4.56±1.16
COP Path/Area Post	4.93±0.69	4.82±0.61	4.16±0.86	4.76±1.58
COP Avg Velocity Pre	8.38±1.33	8.98±2.32	8.22±1.79	8.19±1.96
COP Avg Velocity Post	8.85±3.17	8.91±2.52	7.90±2.30	8.13±2.20
TTB Mean Min Pre	0.257±0.089	0.247±0.108	0.303±0.087	0.296±0.073
TTB Mean Min Post	0.293±0.072	0.265±0.093	0.319±0.079	0.297±0.050
TTB Mean Min SD Pre	0.123±0.029	0.121±0.026	0.131±0.024	0.126±0.044
TTB Mean Min SD Post	0.130±0.032	0.116±0.026	0.150±0.032	0.115±0.030

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
N=13 for each group

<u>Dynamic Postural Control:</u>

Repetitive Sub-Maximal Squatting:

Residual analyses of the data confirmed it met the assumptions for ANOVA. No significant three-way interactions were observed for the COP or TTB measures. Tukey's HSD post-hoc pairwise comparisons revealed that the TTB mean minima of the tape group post-intervention was significantly higher than the TTB mean minima of the manipulation group pre-intervention when the stiff and healthy ankles were combined [SCI: (0.0015, 0.1112)]. With the stiff and healthy ankles combined, the TTB mean minima of the tape group post-intervention was also significantly higher than the TTB mean minima of the manipulation group post-intervention [SCI: (0.0077, 0.1174)]. The TTB mean minima was significantly higher for the stiff ankle in the tape group than the stiff ankle of the manipulation group [SCI: (0.0047, 0.1145)] and the healthy ankle of the manipulation group [SCI: (-0.1137, -0.0039)]. The TTB mean minima were significantly lower for the manipulation group than the tape group with the stiff and healthy ankles combined [SCI: (0.0206, 0.0796)]. No other statistically significant differences existed in the squatting task. The descriptive statistics for the squatting task are presented in Table 9.

Table 9. Repetitive Sub-Maximal Squatting Task

Measure	Stiff M	Healthy M	Stiff T	Healthy T
Squat Depth Max Pre	15.95±6.56	19.55±6.16	19.73±7.95	21.37±7.24
Squat Depth Max Post	18.44±6.52	19.84±5.81	19.96±9.02	22.54±10.53
COP Path Length Pre	91.42±20.89	98.34±19.96	91.25±17.39	98.87±25.61
COP Path Length Post	97.91±23.00	99.39±21.46	89.94±16.37	89.51±16.91
COP Path/Area Pre	4.86±0.85	4.45±0.79	4.46±0.82	4.91±1.28
COP Path/Area Post	4.94±0.91	4.53±0.69	4.61±1.14	4.59±0.98
COP Avg Velocity Pre	9.14±2.09	9.84±1.99	9.11±1.75	9.89±2.56
COP Avg Velocity Post	9.79±2.30	9.94±2.15	9.00±1.64	8.94±1.69
TTB Mean Min Pre	0.289±0.091	0.285±0.088	0.333±0.080	0.316±0.078
TTB Mean Min Post	0.278±0.062	0.283±0.097	0.352±0.055	0.334±0.070
TTB Mean Min SD Pre	0.142±0.036	0.140±0.036	0.146±0.034	0.147±0.040
TTB Mean Min SD Post	0.148±0.030	0.130±0.025	0.142±0.028	0.147±0.021

M=Manipulation Group; T=Tape Group; Pre=Pre-intervention Score; Post=Post-intervention Score
Values are Mean±Standard Deviation
N=14 for each group

Chapter 4

Discussion

The purpose of this study was to compare the effects of an ankle and lower leg mobilization intervention with a placebo taping technique on ankle DF ROM and static and dynamic postural control in individuals with a lack of ankle DF ROM. It was hypothesized that the group that received the joint mobilization intervention would demonstrate significant improvements in ankle DF ROM and static and dynamic postural control compared to the taping group. The findings of our study were not able to robustly support this hypothesis.

FAAM Survey:

The FAAM survey was administered before and after the interventions, and the scores were significantly higher on the ADL and sport subscales after the interventions. These differences existed in both the manipulation and taping intervention groups, which was unexpected especially in the tape group because it was considered a placebo control treatment. The improvement in the manipulation group was interesting as well because the manipulation did not significantly improve static or dynamic balance ability or DF ROM. There appeared to be an improvement in DF ROM in the manipulation group. Although insignificant statistically, the improved mobility may have been perceived by the participants who frequently noted that their treated ankle had improved functioning. The FAAM survey is a subjective measure, so the change seen in the taping group could be a result of a placebo effect, based on their positive expectation of the treatment. Bialosky et al[26] found that there was an increase in pain perception in participants who received spinal manipulation treatment with a negative expectation in the instructional set they received, but people with a positive expectation in the instructional set had a decrease in pain perception following spinal manipulation treatment. This effect may correspond with the perceived improvement in ankle functioning in the taping group because the physical therapist explained the taping technique with a positive expectation.

Dorsiflexion Range of Motion:

The most robust statistical analysis that compared DF ROM changes in this study was not statistically significant. Most importantly, the DF ROM in the stiff ankle before the ankle mobilization was not significantly different than the DF ROM after the intervention, which was unexpected. This finding is contrary to some literature, but when taking the time of the intervention into account it agrees with other literature. Hoch et al[9] found that a two-week joint mobilization intervention improved weight-bearing DF in individuals with CAI. In patients who had ankle fractures, improvements in DF were seen after 5 weeks of subtalar and talocrural joint mobilizations.[14] The intervention in this study only included two sessions of ankle mobilizations within one week, so it is possible that a longer duration intervention would have improved DF ROM. Cosby et al[11] found that multiple treatment sessions of talocrural joint mobilization has been seen to increase DF ROM, but only one treatment session is not enough to improve DF. The findings of these studies suggest that a longer treatment would have been more likely to elicit an improvement in DF.

Contrary to the previous studies mentioned, Reid et al[12] found that DF was increased immediately after treatment with talocrural joint mobilization in patients with limited DF following an ankle sprain that occurred within the past two years. The results in this study may differ because other injuries such as ankle fractures were included, which may require more mobilization sessions than an ankle sprain. There was not a limit on how recent the ankle injury was either, so it is possible that DF ROM is harder to correct with talocrural joint mobilizations when it has been left untreated for longer than two years. Further research should be conducted to determine the number of ankle mobilization sessions needed to improve DF ROM in these different cases.

An interesting component of the DF data is that the DF of the stiff ankle in the manipulation group before the intervention was significantly less than the pre- and post-DF of the healthy ankle in the taping group. However, the DF of the stiff ankle in the manipulation group after the intervention was not significantly different than the pre- and post-DF of the healthy ankle in the taping group. The mean DF ROM in the stiff ankle of the manipulation group did increase after the intervention, and although it was not enough to produce a statistically significant change between pre- and post-measures within the stiff manipulation group, it was enough to make the stiff manipulated ankle DF ROM not statistically significant than the healthy taping group. This suggests that the manipulation intervention may have caused the ankle DF to be closer to the ROM of the healthy and tape intervention ankles. Unfortunately, the random assignment of participants with one ankle stiffer than the other resulted in statistically significant different DF measures at baseline between the mobilization and taping groups. The lack of equivalence between the groups may have made it difficult to demonstrate significant changes in ROM after the mobilization intervention. It is possible that a larger sample size or a longer intervention period may have caused significant improvements in DF ROM. Additional statistical analysis exploring differences in relative change (percent difference) between the intervention groups may also reveal differences between the interventions.

Static Postural Control:

No statistically significant interactions were found in static postural control measures in this study. Pairwise comparisons confirmed initial differences between the randomly assigned groups again. Although postural control was hypothesized to be impaired in the participants' leg with the stiff ankle, it was not surprising that the difference did not exist. There is a body of literature that suggests a correlation exists between DF deficits and dynamic balance[4-6], however there are no reports of a correlation between impaired DF ROM and static postural control COP measures. A number of studies have found that people with chronic ankle instability have static postural control deficits, and that a number of people with CAI have limited DF[4,22], but the direct correlation between DF and static postural control has not been reported. Basnett et al[4] believe that the DF impairment does not correlate with the static balance at all, so the results of this study do complement the findings of Basnett et al. It is possible that static balance tasks do not require enough DF ROM to engage the limitation and alter balance mechanics.

The eyes open trials with both 30 second and 10 second duration did not show any statistically significant differences of interest. The only significant difference was the 30 second TTB mean minima measures between all of the participants in the manipulation group and taping group. This finding suggests that the intervention groups were different at baseline. This baseline difference may have impacted the results because absolute measures were used in the analysis, rather than percentage change. The insignificant results in the eyes open static postural control trials agrees with a number of studies though that have found that postural deficits do not appear until the visual component of postural control is taken away.[17,21,22] McKeon and Hertel[22] completed a study where they did not find any postural control deficits in CAI participants during 10 second eyes opened trials, but they did find postural control deficits in the participants during the 10 second eyes closed trials.

The 30- and 10-second eyes closed trials in the study did not reveal any significant differences between the comparative factors. It was expected that the eyes closed trials would present a postural control deficit because deficits are much easier to find when the visual cue is eliminated.[21] The insignificance of the path length and average velocity COP measures agrees with a variety of literature because these measures have been found to be less reliable for postural control deficits in CAI participants.[10,17,20] The more sensitive measure for postural control deficits has been the TTB measurement.[10,17,20] Hertel and Olmsted-Kramer found that TTB measures detect postural control deficits in people with CAI that the more traditional COP measures do not, with only one COP measurement revealing postural control deficits and 5 TTB measurements revealing deficits in their study with CAI participants. This study did not reveal any statistically significant differences in the TTB measurements. These findings are contrary to previous literature. It is possible that TTB differences were not found in this study because the participants were not required to have CAI, and it may be that CAI, and not limited DF, causes more postural control impairments. Also, we included participants based upon having one stiff ankle but did not correlate this stiffness with previous injury or symptoms as would be present in an individual with CAI. We provided the intervention to the stiff ankle, and in several cases this ankle did not correlate with previous injury or symptoms. Correlating stiffness, injury history, and symptoms may provide a more appropriate inclusion criterion that will better position a study to reveal the true effects of an ankle and lower leg joint mobilization treatment.

The only significant differences of interest found with the eyes closed trials were in the path/area COP measures for the 30 second eyes closed trials. The path/area of the stiff manipulation group was significantly different before and after the intervention, and the post-intervention path/area measurements were significantly different for the stiff manipulation and stiff taping groups. This statistics would show that the manipulation did cause an increase in postural control on the leg with the stiff ankle, and that it caused a bigger increase than the taping intervention. However, these measures may not be as valid because only 7 participants from the manipulation group were included, and 5 participants from the taping group because the other participants were unable to complete at least one of the three 30 second eyes closed trials for one of the conditions, and therefore their data was excluded. It seems unlikely that this measure is valid because the TTB measures have been found to be more sensitive in detecting postural control deficits[10,17,20], and since the TTB measures were insignificant it is not likely that a COP measure would be valid.

Dynamic Postural Control:

No statistically significant differences of interest were found in the dynamic postural control testing. This contradicts the majority of literature. Deficits in ankle DF ROM have been found to be highly correlated with decreased dynamic postural control using the SEBT.[4-6,17] The anterior reach direction of the SEBT is especially impacted by limited DF.[4-6,17] However, this study did not show that dynamic balance was diminished on the leg with a stiff ankle when compared to the leg with the healthy ankle. It is possible that the repeated squat test used in this study was not challenging enough or was not a big enough perturbation to produce a dynamic balance deficit. The SEBT includes a series of reaching tasks in a single-legged stance[17], so the reaching component may present a challenge that is severe enough to expose a deficit in dynamic postural control.

Contradicting literature exists on the effect of joint mobilization on dynamic postural control. One study found that a two week joint mobilization intervention improved DF ROM and the reach distance in all direction using the SEBT in people with CAI.[9] Our study does not complement these results because there was no significant difference observed in any of the dynamic balance measures for the stiff ankles of the manipulation group after the intervention. It is possible that the increase in dynamic balance ability was not obtained because the dynamic balance test was not challenging enough or the intervention was not long enough to cause improvement, compared to the 2 week intervention in the study mentioned. Also in our study there was not a significant improvement in DF following the intervention, which may be needed to cause the increase in dynamic postural control ability. Another study found that 2 sessions of joint mobilization increased DF ROM, but it did not improve any SEBT reach distances.[10] Our study agrees with this study in that the dynamic balance was not improved following the joint mobilization, however it is possible that an increase in dynamic balance was not observed in either of these studies because the participants only received two sessions of mobilization. The study that produced an improvement in dynamic postural control had a 2 week joint mobilization intervention[9], which may be the amount of treatment time needed to cause an increase in dynamic postural control.

Limitations:

A number of limitations were present in this study that may have impacted the results. During the static postural control tests, several participants had difficulty completing the 30 seconds eyes open trials and especially eyes closed trials. The results were analyzed for the velocity and TTB for the time that they were able to maintain balance, so including the trials where people fell might have caused the results to be less accurate. Theoretically COP velocity and TTB measures should not be significantly affected by trials of different time lengths, unlike COP path length and path/area measures. Another issue that was found when analyzing the results is there appeared to be a difference in pre-intervention DF and balance ability between the manipulation and taping groups, although the participants were randomly assigned which intervention they received. Absolute measures of ROM and postural control were used in the analysis rather than relative change measures. This likely impacted the statistical significance of the results between the groups since these differences were not accounted for during the data collection or analysis.

Another major limitation is that the eligibility screening did not include a component to make sure the participant's stiff ankle was the same as their symptomatic ankle. Because this criterion did not exist, there were 6 participants who had a healthy ankle treated because it was stiffer than their symptomatic ankle. This suggests that their healthy ankle is not stiff, but rather their symptomatic ankle is hypermobile due to their previous injury. This could have impacted our results because their symptomatic ankle was grouped in with the healthy ankles, and their healthy ankle was grouped with the stiff ankles, which could have skewed the postural control results for each group. Alburquerque-Sendin[27] found that performing talocrural joint manipulation in healthy participants does not improve their postural stability. This may attribute to the inconclusive results for the manipulation group because there were a few healthy ankles that were manipulated and likely did have any improvement in postural control.

Lastly, there was one limitation found during the manipulation intervention sessions. Cavitation of the talocrural joint with rearfoot distraction technique was not attained in all cases. This may indicate the source of limited DF DF was a result of the posterior calf myofascial tissues rather than the talocrural joint. This would impact the results because joint mobilization would not affect these tissues, and therefore no improvement in DF or postural control would be observed in these cases.

Chapter 5

Conclusion

This research study demonstrated that 2 sessions of an ankle and lower leg mobilization intervention does not have significant effects on DF ROM or static and dynamic postural control. This finding may have clinical implications, suggesting that a longer duration of ankle mobilization may needed to improve DF and postural control or ankle mobilization may only be effective for certain populations. It is possible that limited DF from certain injuries does not respond to ankle mobilization. Further research is needed to determine the responses of different populations to ankle mobilization. Additional research could possibly determine a rule for clinicians to help them determine what type of treatment would be most beneficial for individuals with ankle stiffness.

Chapter 6

Literature Review

A variety of ankle injuries have been found to cause deficits in DF ROM, and these deficits can cause a number of issues in daily functioning.[3,4,8,28] Some treatments that improve DF ROM have been investigated. One common treatment that has been found to be effective is talocrural joint manipulation.[4,8-16] However, there is limited research on the effects of this treatment on dynamic postural control using different types of tests, and how the dynamic postural control results relate to static postural control. Furthering the knowledge in this area of study will provide more evidence-based reasoning for administering talocrural joint mobilization in the clinical setting, which will improve the rehabilitation of ankle injuries. The purpose of this literature review is to investigate the causes of limited DF ROM and the impairments that result from decreased DF. The literature review will also examine the efficacy of techniques for evaluating static and dynamic balance, and explore the suggested results of ankle mobilization for individuals with limited DF ROM.

Limited Ankle Dorsiflexion Range of Motion:

Ankle DF ROM can be impacted by a number of factors. Deficits in ankle DF occur frequently after a variety of lower extremity injuries[19], and it is especially common after lower extremity injuries that require prolonged immobilization.[13] Hertel[18] found that college level dance students with a history of lower extremity injuries had significantly less DF ROM than those who were not injured. Deficits in ankle DF can persist following ankle sprains even when rehabilitation programs addressed the issue.[4] This is extremely common in individuals with chronic ankle instability (CAI), or those who suffer from recurrent ankle sprains.[4,8] Another injury that often results in decreased DF ROM is a fracture of the ankle or distal leg.[3] It is believed that the lack of DF ROM following an ankle or lower extremity injury may be a result of altered arthokinematics, such as a lack of posterior talar glide on the calcaneus.[8] Reduced DF ROM can also be a result of the calf muscle-tendon unit being tighter than normal, or even just from inherent ankle stiffness.[29]

An easy and reliable way to evaluate DF ROM is using the weight-bearing lunge test (WBLT), which measures how far the tibia can move over the rear foot during weight-bearing.[19] There is a very high correlation in this test between degrees of DF and the maximum lunge distance.[19] A lot of research studies have used asymmetries in maximum lunge distance using the WBLT to identify people with DF impairments.[19] In order to determine a valid asymmetry distance to use for categorizing participants as having a DF impairment, Hoch and McKeon[19] performed a study to identify how much asymmetry exists in healthy people. Hoch and McKeon[19] used the knee-to-wall principle by Vicenzio et al[8] for the WBLT, which is a very effective method of the WBLT. The knee-to-wall principle consists of a tape measure secured to the floor coming out from a wall.[8] The participant puts their test foot parallel to the tape measure and lunges to try to touch the anterior surface of their knee to the wall, without their heel coming off of the ground.[8] The participant is allowed to put their hands on the wall and their opposite foot behind the test foot to help them balance.[8] The participant's foot is progressed a centimeter further from the wall each time they are able to perform the task properly.[8] Once they cannot touch the wall with their knee, they are moved back up to the centimeter mark and moved by millimeter increments to find their maximum lunge distance to the nearest millimeter.[8]

Hoch and McKeon[19] used this principle and found that healthy individuals can have up to 1.5 centimeters of lunge distance asymmetry, so they suggest using a 2 centimeter asymmetry to determine participants with impairments in ankle DF. Using this principle, each centimeter further away from the wall is equal to about 3.6 degrees of DF, so this is also a relevant test to use clinically.[19]

Impairments with Limited Dorsiflexion:

Limited DF ROM has been found to cause numerous other impairments in people, so it is an important factor to address in clinical settings. A lack of DF has been found to decrease dynamic balance control.[4] Also, the CAI population has been found to have deficits in static postural control, and people with CAI commonly have a lack of DF[4], so the deficit in DF ROM may impact static postural control as well. The impairment in DF ROM also impacts the mechanics of a lot of movements, including jogging, squatting, and stepping.[4] These changes in balance ability and altered mechanics cause people with a lack of DF to be at a high risk of re-injury as well.[4]

Limited DF ROM puts people at a risk for sustaining recurring ankle sprains and injuries at the knee joint.[4] Malliaras[29] found that reduced DF may be a risk for patellar tendon injuries, because a significant number of volleyball players with limited DF were found to experience patellar tendinopathy. Another knee injury that limited DF ROM can cause is anterior cruciate ligaments (ACL) injuries.[30] Limited DF is a risk factor for ACL injuries because landing a jump with less DF will decrease knee flexion, and therefore increase the ground reaction forces experienced at the knee.[30] Decreased DF also leads to more valgus knee displacement during landing and squatting, which is another risk factor for ACL injuries.[30] Lastly, a lack of DF can also cause an increased risk of osteoarthritis in the ankle.[11]

Static Postural Control:

Static postural control refers to a person's ability to maintain their balance while staying stationary. Postural control depends on proprioceptive information, vestibular information, and visual cues.[21] The most common way to assess static postural control is by having a participant stand on one leg and balance on a force plate with their arms in a fixed position, such as on their hips.[20-23] The force plate is then used to track the center of pressure (COP) of the person's foot, and the common variables from the force plate used to determine postural control are the amplitude and variability of COP, including the excursion length and velocity of the COP excursions, as well as time to boundary measures (TTB).[20,23] A participant is considered to have poorer postural control when they have a larger COP path length and higher COP mean velocity.[31] TTB measures are calculated based on the estimate of the time it would take for the COP to reach the boundary of the base of support, if the COP continued on its trajectory at the same instantaneous velocity.[20] This indicates when the person would lose their balance because if the COP of their foot goes outside of the boundary of their base of support, then they would not be able to maintain their balance and would fall.[20] Therefore, a smaller TTB measure means it will take less time for the individual to lose their balance, meaning they have poorer postural control.[20]

Obtaining three ten second trials of single leg stance (SLS) on a force plate is common for assessing postural control.[20-22] However, longer trials can also be used to challenge postural control more.[21] It is also important to include trials with both eyes open and eyes closed. In the trials with eyes open, the participant should have fixed point to focus on straight ahead.[20] The eyes closed trials are included because it will take out the visual cues and determine the participants postural control ability using just proprioceptive and vestibular information.[21] This will help to determine their true balance ability. Linens et al[32] found that when using force plate measures to determine if an individual has poor balance due to an unstable ankle, the criteria values should be greater than 1.56 cm/s for the COP resultant velocity, less than 3.78 seconds for the anterior to posterior TTB standard deviation, and less than 1.56 seconds for the medial to lateral TTB standard deviation.

These methods of assessing static postural control have been found to be effective in finding postural control impairments in numerous populations, including people who have suffered an ankle sprain and those with CAI.[22,23] It is believed that deficits in static postural control will also be found in people with limited DF ROM because a lack of DF ROM may result in a disruption in the transmission of afferent information from the sensorimotor system.[10,33] The decreased DF impacts how the foot sits on the surface of the ground, which may impact the proprioceptive information the person is receiving from their foot.[34] This would have a very large impact on balance because proprioception is a crucial factor in postural control ability.[34] It is important to maintain good postural control because poor balance can increase the risk of sustaining injuries substantially.

Dynamic Postural Control:

Dynamic postural control refers to a person's ability to remain balanced as they transition from a dynamic to a static state.[35] Maintaining dynamic balance depends on sensory information, like postural control, but it also includes feed-forward and feedback postural reactions and memories of muscular activity and joint movements used to maintain balance in previous personal experiences.[21,34] A common way to measure dynamic postural control is by using the SEBT.[5,9,10,17] The SEBT contains a series of reaching tasks in various directions, where you are in a single leg stance, then lunge and reach as far as you can on a piece of tape.[17] The reach directions for the test include anterior, posterior-medial, and posterior lateral.[17] Deficits in ankle DF ROM have been found to impact dynamic balance functioning because a lack of DF is correlated with the composite score of the SEBT, as well as the anterior and posterior-lateral reach direction.[4] Hoch et al[5] found that the amount of DF from the WBLT is significantly related to the reach distance of the SEBT in the anterior reach direction. It has been found that people with deficits in DF ROM have a decrease in anterior reach distance on the SEBT if they have CAI and if they do not have CAI, so the DF ROM is the main factor that influences dynamic balance stability.[4,6]

Another test used for testing dynamic balance is the single-leg hop stabilization test on a force plate.[18] The measurements from the force plate are used to determine how long it took the participant to stabilize their balance.[18] It has been found that people with functional ankle instability took a longer time to stabilize themselves after a single leg jump landing than those with stable ankles.[36] Since limited DF is a big contributing factor to functional ankle instability[18], the lack of DF likely plays a role in the increase in the amount of time it took people with functional ankle instability to stabilize themselves.

Both the SEBT and the single-leg hop stabilization test have been used in countless research studies to determine dynamic postural control ability. The aim of this study was to use another form of functional movement that has not been used previously to test dynamic balance stability. A single leg squat test was chosen because it has been shown that a single leg squat does involve dynamic balance ability[18], making this a good functional movement to test for postural control. Hertel[18] found that there was an improvement in single leg squat performance following the implementation of a balance training program in collegiate women volleyball athletes, showing that dynamic balance stability is involved in squatting. Limited DF has been found to impact the mechanics of squatting[4], so determining the effects of DF on balance stability during squatting is important for understanding the changes in mechanics. Also, physical therapists commonly use a single leg to assess the functional ability of the lower leg.[37] Determining the effects of limited DF on postural control during squatting could further validate the use of a single leg squat test by physical therapists. Therefore, using a single leg squat to test dynamic postural stability will be beneficial for numerous reasons.

Joint Mobilization:

It has been proven that spinal manipulation can influence proprioception, as well as decrease pain.[38] Since proprioception is a very large component of postural control, researchers began to believe that such a treatment could be used to improve postural control.[34,38] These treatments have recently been applied to peripheral joints as well because spinal manipulation has proven to be so effective.[4,34,38] Lopez-Rodriguez et al[34] found that mobilization of the talocrural joint immediately resulted in an altered load pattern of the foot during standing which they believe causes proprioceptive effects. Mobilization of the talocrural joint is not only used to increase proprioception, but it is used to improve ankle DF ROM as well, which is believed to impact postural control.[4]

Talocrural joint mobilization has been found to be effective in increasing DF ROM following a number of injuries. Hoch and McKeon[10] observed that joint mobilization treatment increased DF ROM in individuals with CAI. It has been shown that ankle DF ROM can be improved with talocrural joint mobilization following acute, sub-acute, and recurring ankle sprains, with a decrease in pain in the ankle.[8,15,16] Reid et al[12] discovered that DF ROM was increased immediately after one bout of talocrural joint mobilization in patients experiencing limited DF following an ankle sprain. Talocrural joint mobilization has also been proven to increase ankle DF ROM after prolonged immobilization following an injury, including ankle fractures and distal leg fractures.[3,13,14] Cosby et al[11] found that DF was improved following multiple sessions of talocrural joint mobilization treatments, but that one treatment was ineffective in improving DF ROM, so it is likely that using multiple treatment sessions would be the most effective method in improving DF range of motion.

Talocrural joint mobilization also has been seen to improve balance. Hoch et al[9] found that after a two-week talocrural joint mobilization treatment, the reach distance was improved for all directions on the SEBT for people with CAI. Hoch and McKeon[10] observed that the TTB was significantly decreased in the anterior-posterior direction during quiet SLS following a talocrural joint mobilization treatment in people with CAI. However, Alburquerque-Sendin et al[27] did not see any changes in postural control in healthy participants following talocrural joint mobilization using COP force plate measurements. Therefore it is likely that talocrural joint mobilization is only effective in individuals who have sustained an injury.

Appendix A

Recruitment Flyer

PENNSTATE

1855

Athletic Training Research Laboratory

Research Volunteers Needed

*Have you had an **ankle sprain**, and your **ankle is still stiff** from it?*
If so, you may be interested in participating in our research study.

Measurements: Ankle joint range of motion, balance and functional tests to measure ankle joint mobility and dynamic balance.

Purpose: Study the effects of a taping technique and manual therapy treatment on ankle range of motion and balance.

Time requirement: Two (2) 60 minute sessions for postural control testing and two 15 minute sessions for treatment. Your first testing session will also include a treatment session. All sessions will be in the Athletic Training Research Laboratory in 21D&E Recreation Building over one (1) week.

Requirements:
• Men and women ages 18 – 40 years old
• Good general health
• Experiences stiffness in ankle
• No current lower limb injuries, low back and leg pain or concussion symptoms

Dr. Sayers John Miller, Dr. John Vairo, and Jaclyn Fissinger
Department of Kinesiology

For more information, contact Jaclyn Fissinger at
Jmf5579@psu.edu or 215-589-3895

Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895	Stiff Ankle Study Jaclyn Fissinger Jmf5579@psu.edu 215-589-3895

Appendix B

Recruitment Script

Title of Project:	The Effect of Joint Mobilization to the Ankle and Lower Leg on Static and Dynamic Postural Control Measures
Principal Investigator:	Sayers John Miller, PhD, PT, ATC
Co-Investigators:	Giampietro L Vairo, MS, ATC and Jaclyn Fissinger

Script: Patients with limited dorsiflexion (18 – 40 years old)

Hello, my name is Jaclyn Fissinger and I work with the Athletic Training Research Laboratory at Penn State. I am currently looking for research volunteers and was wondering if you would be interested in participating or at least hearing more about this study. I am looking for a group of participants who are 18 to 40 years old, have been experiencing ankle stiffness since an ankle sprain, and not undergoing a formal rehabilitation program. Participants in this research study should be in good general health, without any current lower limb injuries. If you are undergoing physical therapy or sports rehabilitation under the supervision of a physical therapist or athletic trainer you will not be eligible to participate. I will be examining ankle performance and the effect of a taping technique and manual therapy treatments on balance and functional performance in patients with limited ankle dorsiflexion, or ankle stiffness. If you are interested in participating, you would be required to come to the Athletic Training Research Lab in 21D&E Recreation Building for two 60 minutes data collection sessions, and one additional 15 minute treatment session. During the first visit you will be asked to perform two balancing exercises and a functional test. You will also undergo your initial treatment. During the next week you will come in for your second treatment session. The final visit will be a repeat of the balancing tests and functional test, one week after your first visit. As a participant we will be happy to provide you with your specific measurement results. If you have any questions or need to get in touch with me for any reason, my phone number is 215-589-3895 and my e-mail is jmf5579@psu.edu. Thank you.

Appendix C

Recruitment Email

PENNSTATE

1855

Title of Project:	The Effect of Joint Mobilization to the Ankle and Lower Leg on Static and Dynamic Postural Control Measures
Principal Investigator:	Sayers John Miller, PhD, PT, ATC
Co-Investigators:	Giampietro L Vairo, MS, ATC and Jaclyn Fissinger
E-mail script:	Patients with limited dorsiflexion (18 – 40 years old)

Hello, my name is Jaclyn Fissinger and I work with the Athletic Training Research Laboratory at Penn State. I am currently looking for research volunteers who are 18 to 40 years old, that have been experiencing ankle stiffness since an ankle sprain and not undergoing a formal rehabilitation program. Participants in this research study should be in good general health, without any current lower limb injuries. I will be examining ankle performance and the effect of a taping technique and manual therapy treatments on balance, range of motion and functional performance, in patients with limited ankle dorsiflexion, or ankle stiffness. If you are interested in participating, you would be required to come to the Athletic Training Research Lab in 39 Recreation Building for two 60 minute data collection sections, and one 15 minute treatment session. As a participant we will be happy to provide you with your specific measurement results. If you are interested in participating or would like more information, my phone number is 215-589-3895 and my e-mail is jmf5579@psu.edu. Thank you.

Appendix D

Participant Eligibility Screening

PENNSTATE

1855

Title of Project:	The Effect of Joint Mobilization to the Ankle and Lower Leg on Static and Dynamic Postural Control Measures
Principal Investigator:	Sayers John Miller, PhD, PT, ATC
Other Investigator(s):	Giampietro L Vairo, MS, ATC and Jaclyn Fissinger
Screening Checklist:	Patients with limited ankle dorsiflexion (18-40 years old)

Participant Identification Number: ____

As a general health screen, you must be able to answer 'YES' to the following questions.

1. Are you between 18 to 40 years old? **Yes** **No**
2. Do you have a one ankle that it stiffer (has less range of motion) than the other? **Yes** **No**
3. Are you recreationally active? **Yes** **No**
4. Do you speak English? **Yes** **No**

As a general health screen, you must be able to answer 'NO' to the following questions.

5. Are you currently in a formal rehabilitation program for a low back or lower extremity injury? **Yes** **No**
6. Do you have pain above 2 out of 10? **Yes** **No**

7. Have you sustained injury to your back or have a history of back problems? **Yes** **No**

8. Have you sustained a significant injury to either lower extremity within the last 6 months that required formal treatment or kept you from participating in normal activities? **Yes** **No**

9. Have you had an ankle sprain in the last 6 months? **Yes** **No**

10. Are you diabetic? **Yes** **No**

11. Have you sustained a concussion within the past six months? **Yes** **No**

12. Do you have neurological deficits in your legs (e.g. numbness, tingling, weakness) **Yes** **No**

Appendix E

Participant Informed Consent Form

Informed Consent Form for Biomedical Research
The Pennsylvania State University
ANKLE STIFFNESS PARTICIPANTS
(18-40 years old)

ORP OFFICE USE ONLY
DO NOT REMOVE OR MODIFY
IRB# 44316
The Pennsylvania State University
Institutional Review Board
Office for Research Protections
Approval Date: 11/14/2013 DJG
Expiration Date: 11/13/2014 DJG

Title of Project: The Effect of Joint Mobilization to the Ankle and Lower Leg on Static and Dynamic Postural Control Measures.

Principal Investigator:
Sayers John Miller, PhD, PT, ATC
Assistant Professor of Kinesiology
Department of Kinesiology
146 Recreation Building
University Park PA 16802
sjm221@psu.edu; 814-865-6782

Co-Investigators:
Giampietro L. Vairo, MS, ATC
Instructor of Kinesiology
PhD Candidate in Kinesiology
Department of Kinesiology
146 Recreation Building
University Park PA 16802
glv103@psu.edu; 814-865-2725

Jaclyn Fissinger
Undergraduate Schreyer Honors College Student
Department of Kinesiology
146 Recreation Building
University Park PA 16802
jmf5579@psu.edu; 215-589-3895

1. **Purpose of the study:** Ankle stiffness is a common problem after an ankle sprain. The purpose of this research is to compare the effects of manual therapy treatments and a taping technique of on ankle joint mobility and balance in people with one stiff ankle. A total of 60 people between the ages of 18-40 years old will be taking part in this study. Half of the participants will undergo manual therapy treatments to their ankle and lower leg while the

other half will have a taping technique applied to their leg. Both groups will undergo range of motion and balance testing.

2. **Criteria for inclusion of participants:** You are being invited to participate in this research study because you are healthy, physically active and between the ages of 18-40 years old. You also have one ankle that doesn't bend as far as the other.

3. **Procedures to be followed:** If you choose to participate in this research study, you will be asked to perform the following procedures over the course of three sessions:

Procedures

A. We will begin the study by asking you to complete one subjective questionnaire which will identify any functional limitations you may have related to your ankle stiffness. The results of the questionnaire will help us assess how you feel about your functional abilities before and after treatment. You will need to repeat these questionnaires during the final session.

B. During the first and last sessions, we will measure ankle range of motion using a simple squatting task. You will be asked to stand facing a wall and then bend your ankle as far as you can without your heel coming off the floor. How far you are able to bend your ankle will be measured using a tape measure. We will also measure your leg length using a measuring tape during the first session.

C. During the first and last sessions, you will be asked to perform a single leg balance stance task. You will be standing on one leg barefoot while maintaining balance for a ten second trial with eyes open and then eyes closed. You will be instructed to stand as still as possible with their arms crossed over their chest while keeping your other leg off the ground. A force plate you will be standing on will record measures of balance through an attached computer.

D. During the first and last sessions, you will be asked to stand on one leg barefoot on the force plate with your hands on your hips and your other leg held off the ground. From this position, you will be asked to squat down as far as you can without your heel coming off the ground. The distance you squat will be measured using a measuring tape and the force plate you will be standing on will record measures of balance through an attached computer.

E. During the first and last sessions, you will be asked to stand on one leg barefoot on the force plate with your hands on your hips and your other leg held off the ground. From this position, you will be asked to squat down and up three consecutive times without your heel coming off the ground. The force plate you will be standing on will record measures of balance through an attached computer.

F. Immediately after the balance testing during the first session, you will undergo either 15 minutes of manual therapy to your ankle and lower leg or application of therapeutic tape. Three days after your initial testing and treatment session, you will be asked to return for a second manual therapy or taping session.

G. Your last session will occur one week after your first session and will be comprised of the balance testing outlines in C, D and E above.

H. All three sessions will be performed in the Athletic Training Research Laboratory in 39 Recreation Building on Penn State's University Park Campus.

4. **Discomforts and risks:** The discomforts and risks associated with participation in this type of research study are minimal. The tests used require movements within expected ranges for physically active people. The manual therapy and taping treatments used in this study are commonly used in physical therapy clinics and the individual applying the treatments is a licensed physical therapist with 30 years of experience. To lessen the chance of injury, you will also be shown how to properly perform every task in the experiment. Possible discomfort may consist of post-mobilization soreness associated with ankle mobilization treatments as well as delayed onset muscle soreness 48 to 72 hours following testing. As with any research study, it is possible that unknown harmful effects may happen. However, the chance for injury in this type of research study is minimal and includes muscle strains, ligament sprains, or aggravation of previously experienced ankle symptoms. We will take every possible effort to watch for and help prevent potential causes of discomfort and risk.

5. **Benefits:** The treatments applied in this study may result in improved ankle mobility and balance in your lower extremity. The results of this study may help guide the selection of treatment techniques for stiff ankles.

6. **Duration/time of the procedures and study:** The first session will last approximately 1 hour and 15 minutes. The treatment session will occur 3 days after the first session and will last 15 minutes. The final testing session will occur one week after the first session and will last about one hour. All testing will take place in the Athletic Training Research Laboratory in 39 Recreation Building on Penn State's University Park Campus.

7. **Statement of confidentiality:** Your participation in this research study is strictly confidential. All research records from your participation in this study will be kept confidential similar to medical records at your doctor's office or hospital. All records will be secured in locked file cabinets at the Athletic Training Research Laboratory. A unique case number will indicate your identity on research records. In the event of any publication resulting from this research study, no personally identifiable information will be disclosed. Penn State's Office for Research Protections, the Institutional Review Board and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this research study. Penn State policy requires that research records be kept for a minimum period of three years at the end of the study. Three years following the end of this research study all records will be appropriately destroyed.

8. **Right to ask questions:** Please contact Sayers John Miller at (814) 865-6782 with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact Penn State University's Office for Research Protections at (814) 865-1775. The Office for Research Protections cannot answer questions about research procedures. Questions about research procedures can be answered by the research team. Referral information for Penn State students who wish to seek additional assistance includes the following:

Penn State University Health Services
Student Health Center
University Park PA 16802
814-863-0774

If you are not a Penn State student, please contact your Primary Care Physician for additional assistance.

9. **Voluntary participation:** Your decision to be in this research study is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this research study will not involve penalty or loss of benefits you would receive otherwise. You may be removed from this research study by investigators in the event you cannot complete the testing procedures.

10. **Injury Clause:** In the unlikely event you become injured as a result of your participation in this research study, medical care is available. If you become injured during the treatment or testing procedures the investigators listed on this informed consent form we will provide you with appropriate first aid care and instruct you on proper steps for follow-up care. If you were to experience any unexpected pain or discomfort from participating in this research study after leaving the Athletic Training Research Laboratory please contact Sayers John Miller immediately at (814) 865-6782. If you cannot reach Dr. Miller please leave him a voicemail and contact your doctor.

    If you are a Penn State student and cannot reach Dr. Miller or your doctor please leave them voicemails and contact Penn State University Health Services at:

    Student Health Center,
    University Park PA 16802
    814-863-0774

    If you are not a Penn State student and cannot reach Dr. Miller or your doctor please leave them voicemails and contact your private medical provider.

    It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

11. **Abnormal Test Results:** In the event that abnormal test results are obtained, you will be made aware of the results in three days and recommended to contact your private medical provider for follow-up consultation.

You must be 18 years of age or older to take part in this research study. If you are under the age of 18 years old, your parent or legal guardian must also agree to your participation in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent form for your records.

____ ____________________

Participant Signature Date

____ ____________________

Person Obtaining Consent Date

Appendix F

Functional Foot and Ankle Ability Measure

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale

Please Answer **every question** with **one 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" (N/A).

	No Difficulty	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Standing	□	□	□	□	□	□
Walking on even Ground	□	□	□	□	□	□
Walking on even ground without shoes	□	□	□	□	□	□
Walking up hills	□	□	□	□	□	□
Walking down hills	□	□	□	□	□	□
Going up stairs	□	□	□	□	□	□
Going down stairs	□	□	□	□	□	□
Walking on uneven ground	□	□	□	□	□	□
Stepping up and down curbs	□	□	□	□	□	□
Squatting	□	□	□	□	□	□
Coming up on your toes	□	□	□	□	□	□
Walking initially	□	□	□	□	□	□
Walking 5 minutes or less	□	□	□	□	□	□
Walking approximately 10 minutes	□	□	□	□	□	□
Walking 15 minutes or greater	□	□	□	□	□	□

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale
Page 2

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

	No Difficulty at all	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Home responsibilities	□	□	□	□	□	□
Activities of daily living	□	□	□	□	□	□
Personal care	□	□	□	□	□	□
Light to moderate work (standing, walking)	□	□	□	□	□	□
Heavy work (push/pulling, climbing, carrying)	□	□	□	□	□	□
Recreational activities	□	□	□	□	□	□

How would you rate your current level of function during you usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities.

__ __ __ . 0 %

Martin, R; Irrgang, J; Burdett, R; Conti, S; VanSwearingen, J: Evidence of Validity for the Foot and Ankle Ability Measure. Foot and Ankle International. Vol.26, No.11: 968-983, 2005.

Foot and Ankle Ability Measure (FAAM)
Sports Subscale

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

	No Difficulty at all	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Running	□	□	□	□	□	□
Jumping	□	□	□	□	□	□
Landing	□	□	□	□	□	□
Starting and stopping quickly	□	□	□	□	□	□
Cutting/lateral Movements	□	□	□	□	□	□
Ability to perform Activity with your Normal technique	□	□	□	□	□	□
Ability to participate In your desired sport As long as you like	□	□	□	□	□	□

How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?

__ __ __ . 0%

Overall, how would you rate your current level of function?

□ Normal □ Nearly Normal □ Abnormal □ Severely Abnormal

Appendix G

IRB Approval Letter

PENNSTATE

Vice President for Research
Office for Research Protections

The Pennsylvania State University
The 330 Building, Suite 205
University Park, PA 16802-3301

(814) 865-1775
Fax: (814) 863-8699
www.research.psu.edu/orp/

Date: November 14, 2013

From: David Goldstein, Compliance Coordinator

To: Sayers J. Miller, III

Subject: Results of Review of Proposal - Expedited **(IRB #43086)**
Approval Expiration Date: November 13, 2014
"The Effect of Joint Mobilization to the Ankle and Lower Leg on Static and Dynamic Postural Control Measures"

The Institutional Review Board (IRB) has reviewed and approved your proposal for use of human participants in your research. By accepting this decision, you agree to obtain prior approval from the IRB for any changes to your study. Unanticipated participant events that are encountered during the conduct of this research must be reported in a timely fashion.

The dated, IRB-approved informed consent/assents to be used when enrolling participants for this research can be accessed by navigating to and logging into PRAMS (www.prams.psu.edu) . Once there, please click on the documents button in order to access said documents. Participants must receive a copy of the approved informed consent form to keep for their records.

Participants must receive a **copy** of the approved informed consent form to keep for their records.

If signed consent is obtained, the principal investigator is expected to maintain the original signed consent forms along with the IRB research records for this research at least three (3) years after termination of IRB approval. For projects that involve protected health information (PHI) and are regulated by HIPAA, records are to be maintained for six (6) years. The principal investigator must determine and adhere to additional requirements established by the FDA and any outside sponsors.

If this study will extend beyond the above noted approval expiration date, the principal investigator must submit a completed Continuing Progress Report to the Office for Research Protections (ORP) to request renewed approval for this research.

On behalf of the IRB and the University, thank you for your efforts to conduct your research in compliance with the federal regulations that have been established for the protection of human participants.

Please Note: The ORP encourages you to subscribe to the ORP listserv for protocol and research-related information. Send a blank email to: L-ORP-Research-L-subscribe-request@lists.psu.edu

DG/dg
cc: Jaclyn M. Fissinger
Giampietro L. Vairo

REFERENCES

1. Polzer H, Kanz KG, Prall WC, et al. Diagnosis and treatment of acute ankle injuries: development of an evidence-based algorithm. *Orthopedic Review.* 2012;4(1):22-32.
2. Wolfe MW, Uhl TL, Mattacola CG, McCluskey LC. Management of ankle sprains. *American Family Physician.* 2001;63(1):93-105.
3. Kramer PG. Restoration of dorsi flexion after injuries to the distal leg and ankle. *Journal of Orthopaedic & Sports Physical Therapy.* 1980;1(3):159-164.
4. Basnett CR, Hanish MJ, Wheeler TJ, et al. Ankle dorsiflexion range of motion influences dynamic balance in individuals with chronic ankle instabilty. *International Journal of Sports Physical Therapy.* 2013;8(2):121-128.
5. Hoch MC, Staton GS, McKeon PO. Dorsiflexion range of motion significantly influences dynamic balance. *Journal of Science and Medicine in Sport.* 2011;14(1):90-92.
6. Hoch MC, Staton GS, Medina McKeon JM, Mattacola CG, McKeon PO. Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. *Journal of Science and Medicine in Sport.* 2012;15(6):574-579.
7. Denegar CR, Hertel J, Fonseca J. The effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. *The Journal of Orthopaedic and Sports Physical Therapy.* 2002;32(4):166-173.
8. Vicenzino B, Branjerdporn M, Teys P, Jordan K. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. *Journal of Orthopaedic & Sports Physical Therapy.* 2006;36(7):464-471.
9. Hoch MC, Andreatta RD, Mullineaux DR, et al. Two-Week joint mobilization intervention improves self-reported function, range of motion, and dynamic balance in those with chronic ankle instability. *Journal of Orthopaedic Research.* 2012;30(11):1798-1804.
10. Hoch MC, McKeon PO. Joint mobilization improves spatiotemporal postural control and range of motion in those with chronic ankle instability. *Journal of Orthopaedic Research.* 2011;29(3):326-332.
11. Cosby NL, Koroch M, Grindstaff TL, Parente W, Hertel J. Immediate effects of anterior to posterior talocrural joint mobilizations following acute lateral ankle sprain. *Journal of Manual & Manipulative Therapy.* 2011;19(2):76-83.
12. Reid A, Birmingham TB, Alcock G. Efficacy of mobilization with movement for patients with limited dorsiflexion after ankle sprain: a crossover trial. *Physiotherapy Canada.* 2008;59(3):166-172.
13. Landrum EL, Kelln BM, Parente W, Ingersoll CD, Hertel J. Immediate effects of anterior-to-posterior talocrural joint mobilization after prolonged ankle mobilization: a preliminary study. *The Journal of Manual & Manipulative Therapy.* 2008;16(2):100-105.
14. Wilson FM. Manual therapy versus traditional exercises in mobilisation of the ankle post-ankle fracture: a pilot study. *New Zealand Journal of Physiotherapy.* 1991;19:11-16.
15. Green T, Refshauge K, Crosbie J, Adams R. A randomized controlled trial of a passive accessory joint mobilization on acute ankle inversion sprains. *Journal of Physical Therapy.* 2001;81(4):984-994.

16. Collins N, Teys P, Vicenzino B. The initial effects of a Mulligan's mobilization with movement technique on dorsiflexion and pain in subacute ankle sprains. *Manual Therapy.* 2004;9(2):77-82.
17. McKeon PO, Ingersoll CD, Kerrigan DC, Saliba E, Bennett BC, Hertel J. Balance training improves function and postural control in those with chronic ankle instability. *Medicine & Science in Sports & Exercise.* 2008;40(10):1810-1819.
18. Hertel J. Functional instability following lateral ankle sprain. *Sports Medicine.* 2000;29(5):361-371.
19. Hoch MC, McKeon PO. Normative range of weight-bearing lunge test performance asymmetry in healthy adults. *Manual Therapy.* 2011;16:516-519.
20. Hertel J, Olmsted-Kramer LC. Deficits in time-to-boundary measures of postural control with chronic ankle instability. *Gait & Posture.* 2007;25:33-39.
21. Verhagen E, Bobbert M, Inklaar M, et al. The effect of a balance training programme on centre of pressure excursion in one-leg stance. *Clinical Biomechanics.* 2005;20:1094-1100.
22. McKeon PO, Hertel J. Spatiotemporal postural control deficits are present in those with chronic ankle instability. *BMC Musculoskeletal Disorders.* 2008;9(76).
23. Hertel J, Buckley WE, Denegar CR. Serial testing of postural control after acute lateral ankle sprain. *Journal of Athletic Training.* 2001;36(4):363-368.
24. Whitman JM, Cleland JA, Mintken P, et al. Predicting short-term response to thrust and nonthrust manipulation and exercise in patients post inversion ankle sprain. *Journal of Orthopaedic & Sports Physical Therapy.* 2009;39(3):188-200.
25. !!! INVALID CITATION !!!
26. Bialosky JE, Bishop MD, Robinson ME, Barabas JA, George SZ. The influence of expectation on spinal manipulation induced hypoalgesia: An experimental study in normal subjects. *BMC Musculoskeletal Disorders.* 2008;9(19).
27. Alburquerque-Sendin F, Fernandez-de-las-Penas C, Santos-del-Rey M, Martin-Vallejo FJ. Immediate effects of bilateral manipulation of talocrural joints on standing stability in healthy subjects. *Manual Therapy.* 2009;14:75-80.
28. Ellis H. Disabilities after tibial shaft fractures. *The Journal of Bone and Joint Surgery.* 1958;40B(2):190-197.
29. Malliaras P, Cook JL, P K. Reduced ankle DF range may increase the risk of patellar tendon injury among volleyball players. *Journal of Science and Medicine in Sport.* 2006;9:304-309.
30. Fong C, Blackburn JT, Norcross MF, McGrath M, Padua DA. Ankle-Dorsiflexion range of motion and landing biomechanics. *Journal of Athletic Training.* 2011;46(1):5-10.
31. Ruhe A, Fejer R, Walker B. Center of pressure excursion as a measure of balance performance in patients with non-specific low back pain compared to healthy controls: a systematic review of literature. *European Spine Journal.* 2011;20(3):358-368.
32. Linens SW, Ross SE, Arnold BL, Gayle R, Pidcoe P. Postural-stability tests that identify individuals with chronic ankle instability. *Journal of Athletic Training.* 2014;49(1):15-23.
33. Hertel J. Funtional anatomy, pathomechanics, and pathophysiology of lateral ankle instabilty. *Journal of Athletic Training.* 2002;37(4):364-375.
34. Lopez-Rodriguez S, De-Las-Penas CF, Alburquerque-Sendin F, Rodriguez-Blanco C, Palomeque-del-Cerro L. Immediate effects of manipulation of the talocrural joint on stabilometry and baropodometry in patients with ankle sprain. *Journal of Manipulative and Physiological Therapeutics.* 2007;30(3):186-192.

35. Wikstrom EA, Tillman MD, Smith AN, Borsa PA. A new force-plate tecnology measure of dynamic postural stability: the dynamic postural stability index. *Journal of Athletic Training.* 2005;40(4):305-309.
36. Ross SE, Guskiewicz KM. Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. *Clinical Journal of Sport Medicine.* 2004;14(6):332-338.
37. Weeks BK, Carty CP, Horan SA. Kinematic predictors of single-leg squat performance: a comparison of experienced physiotherapists and student physiotherapists. *BMC Musculoskeletal Disorders.* 2012;13(207).
38. Palmgren PJ, Sandstrom PJ, Lundqvist FJ, Heikkila H. Improvement after chiropractic care in cervicocephalic kinesthetic sensibility and subjective pain intensity in patients with nontraumatic chronic neck pain. *Journal of Manipulative and Physiological Therapeutics.* 2006;29(2):100-106.

ACADEMIC VITA

Jaclyn Marie Fissinger

Current Address | Tel: 215-589-3895 | **Permanent Address**
325 South Garner Street | Email: jmf5579@psu.edu | 67 Stonybrook Dr.
State College, PA 16801 | Levittown, PA 19055

Education

Penn State University, University Park *Intended Graduation: May 2014*
-Schreyer Honors College and College of Health and Human Development
-B.S. candidate in Kinesiology with Biology Minor

Academic Honors

-Dean's List *Fall and Spring: 2010-2013*
-Schreyer Academic Excellence Scholarship *2010-2014*
-Honors Coursework *2010- Present*

Clinical Work Experience

Internship at Penn State University Health Services Physical Therapy Clinic *Spring 2013*
-Recording patient information, obtaining patient condition since previous visit, implementing treatment plans, charting progress, applying ice or heat packs, and setting up equipment
-Equipment set-up includes: Ultrasound, electric stimulation, arm bike, N/K table, Total Gym, and pulley system equipment
Volunteer at Penn State University Health Services Physical Therapy Clinic *Fall 2012-Fall 2013*
-Volunteered 3 hours a week to assist physical therapists in patient treatment and to clean the facility
Volunteer at St. Mary's Medical Center *Summer 2013*
-Volunteered 3 hours a week to assist physical therapists in patient treatment and bring the patients to the physical therapy gym from their rooms
Volunteer at Arden Courts *Summer 2013*
-Volunteered 10 hours a week, on average, to assist the physical therapist in patient treatment by administering the exercise routine

Other Work Experience

Sesame Place in Culinary Operations *Summers from 2007-2012*
-Assistant Manager (2011-2012): oversaw the restaurant in its daily operation including ordering, dealing with customer needs, and assigning employee tasks
-Supervisor (2008-2010): helped the assistant manager to oversee the employees, assign tasks, and deal with costumer needs
-Employee (2007): cashier, cooked and prepared food, served customers, and cleaned
Healthcare Services Group *Summer 2013*
-Made copies and scanned documents into the electronic filing system, in order to convert the human resources department to a fully electronic system

Social Activities

Schreyer Honors College Student Council ***Member*** *2012-Present/* ***Secretary*** *2011-2013*
-Social Committee: help plan and decorate for social events such as a semi-formal and coffee-house
-Service Committee: Participation in for Relay for Life including fundraising, coordination of decorations and organization of date auction to benefit the Susan G. Komen Foundation
-Recruitment Committee: Tours for prospective students, and hosted stay over prospective students
-Homecoming: helped build the float for the Honors College
Schreyer THON Organization ***Member*** *2010-Present/* ***Meeting Minutes Chair*** *2011-2012*
-Participated in planning fundraisers benefitting the Four Diamonds Fund, which raises money to fight pediatric cancer