THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

THE EFFECT OF MANUAL THERAPY ON POSTURAL CONTROL IN INDIVIDUALS WITH CHRONIC ANKLE INSTABILITY

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with honors in Kinesiology

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ABSTRACT

The Effect of Manual Therapy on Postural Control in Individuals with Chronic Ankle Instability
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Context: Evidence has suggested that manual therapy, consisting of ankle joint mobilization, improves postural control in an elderly population. Investigators have hypothesized that improvement in ankle joint range of motion plays a role in these outcomes. However, the exact mechanisms explaining this phenomenon are unknown. Objective: To profile ankle joint range of motion and functional postural control following a therapeutic manual therapy intervention in chronic ankle instability (CAI) patients. It was hypothesized that manual therapy treatment would increase ankle joint dorsiflexion range of motion (straight knee, bent knee) and reach distances on the Star Excursion Balance Test (SEBT). Design: Pretest-posttest control group true experimental design. Setting: Controlled laboratory environment. Participants: 16 (nine women, seven men) subjects with CAI (age = 22.3 ± 4.7 years, height = 171.9 ± 7.6 cm, mass = 70.3 ± 11.6 kg, BMI = 23.54 ± 3.02) and 16 (nine women, seven men) healthy matched controls (age = 21.2 ± 1.6 years, height = 172.1 ± 8 cm, mass = 67.8 ± 10.6 kg, BMI = 22.84 ± 2.91) volunteered for this research study. No participants to either group presented with a history of previous lower extremity injury. Interventions: The independent variable was the treatment condition (manual therapy or sham treatment) for CAI and control groups. The manual therapy treatment consisted of five different joint mobilization and manipulation techniques that were applied to the joints of the lower leg involved in dorsiflexion. Main Outcome Measures: The dependent variables were ankle joint dorsiflexion range of motion (straight knee, bent knee), and reach distances during the SEBT. Pre- and post-treatment measures were recorded for patients. First post-treatment measures were recorded immediately following the first treatment session and the second post-treatment measures were taken 2 weeks later. The involved and uninvolved ankles of patients were randomized to control for an order effect. Healthy control participants performed the same testing sessions as the chronic ankle instability participants. Averaged maximum reach distances for the single-leg anterior, posterolateral, and posteromedial reach directions of the balance task were normalized to the non-stance leg-length (%MAXD). A repeated measures analysis of variance (ANOVA) was conducted to assess differences among group, treatment and time factors as well as interaction effects. Separate repeated measures ANOVA were calculated to assess within group differences for ankle (treated/untreated) and time as well as the interaction effect. Results: There were no statistically significant differences in factors and interaction effects between groups for ankle joint dorsiflexion range of motion and reach distances during the SEBT. Within group analyses suggested an overall significant difference between straight knee ankle joint dorsiflexion range of motion for the involved versus uninvolved ankle ($P=0.029$) and between the second and third follow-up time periods ($P=0.050$) in CAI patients receiving a true treatment. No other statistically significant differences existed within groups. Conclusion: Our findings suggest a manual therapy technique is no more effective than a sham treatment for improving ankle joint dorsiflexion range of motion and functional postural control in CAI patients or when compared to healthy matched controls. Word Count: 503
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CHAPTER 1: INTRODUCTION

Lateral or inversion ankle sprains are one of the most common injuries sustained among athletes and physically active individuals.\textsuperscript{1-8} Approximately 40-75\% of individuals suffering from lateral ankle sprains usually develop residual problems.\textsuperscript{1} These residual problems include joint laxity, recurrent sprains, swelling and a feeling of weakness or giving way.\textsuperscript{2,3,9} Additional issues that result from ankle sprains involve lower extremity balance and lack of ankle joint range of motion.\textsuperscript{10} The development of residual problems refers to a common disability termed chronic ankle instability (CAI).\textsuperscript{9,11} One of the most common restrictions seen among individuals with chronic ankle instability is limited dorsiflexion which impairs gait and limits overall function.\textsuperscript{16} Amongst the functional deficits seen in CAI individuals, postural control deficits are highly prevalent.\textsuperscript{11}

Manual therapy is commonly used by clinicians as an intervention for acute ankle inversion sprains.\textsuperscript{10} Specifically, passive joint mobilization techniques have been used to improve ankle joint range of motion, functional ability, and pain; which are negatively affected as a result of ankle injury. Whitman et al.\textsuperscript{7} studied the effects of a manual therapy regimen on perceived function in individuals with chronic ankle instability. The findings of Whitman et al.\textsuperscript{7} showed a significant improvement in perceived functional ability following mobilization of the ankle. Specifically, the results demonstrated that participants who had a successful outcome after two or three sessions of manipulation had significant improvements in scores for two reliable outcome questionnaires: the Foot and Ankle Ability Measure (FAAM) and the Lower Extremity Functional Scale.\textsuperscript{7} Although the researchers did not measure ankle joint range of motion post-treatment, it was postulated that the manipulation treatment may have improved mobility of the ankle joints and therefore alleviated impairments that would cause decreased function.\textsuperscript{7}
Another study by Vicenzino et al.\textsuperscript{10} examined the effects of a mobilization treatment on talar glide and dorsiflexion range of motion in individuals with recurrent ankle sprains. Results showed that participants who underwent the manual therapy treatment had significantly improved posterior talar glide and dorsiflexion on the affected side; as well as when compared to the control group who did not receive treatment. These findings are significant because they suggested that a manual therapy treatment program can improve ankle joint mobility, which is one of the most prevalent deficits following recurrent ankle sprain. However, the study only focused on the immediate or short-term effects of a manual therapy treatment on ankle joint motion. Therefore, it is evident that supplementary investigation must be conducted to determine long-term effects of a manual therapy program on ankle mobility.

Other authors have suggested that there are significant balance deficits in people with CAI.\textsuperscript{1-6} Consequently, measures have been taken in efforts to correct deficits in proprioception, specifically postural balance. Previous studies have investigated the effects of a manual therapy regimen applied to the feet and ankles on postural control during quiet standing [eyes open and eyes closed] as well as when performing functional tasks amongst an elderly population.\textsuperscript{12,13} Vaillant et al.\textsuperscript{12} found that mobilization of the feet and ankles had no immediate effect on postural stability in elderly patients.\textsuperscript{12} However, it was postulated that suppression of vision while performing the balance task may have largely compensated for the hypothesized benefits of the manual therapy treatment.\textsuperscript{12} Another study by Vaillant et al.\textsuperscript{13} found that following a manual therapy treatment consisting of foot and ankle mobilization, there was significant improvement in a single-legged balance test and a timed up and go test. It was postulated that the results found may have been due to improvement of somatosensory information to the brain during such tasks. In both studies ankle range of motion was not measured pre- and post-
treatment, which warrants further exploration of whether manual therapy treatments improves postural control.

In order to fully investigate the potential benefits of manual therapy on postural control in people with chronic ankle instability it is necessary to assess a broader patient population that commonly encounters ankle sprains. The primary aim of this study is to investigate the effects of a manual therapy treatment on functional postural control and range of motion in a physically active population. The manual therapy treatment techniques being used have been well defined by a previous study done by Whitman et al. For the purpose of this study, we hypothesized that functional postural control and ankle joint range of motion will improve following treatment in the CAI manual therapy group compared to baseline measures, the sham treatment, and the healthy matched control group.
CHAPTER 2: METHODS

Participants

A total of 32 recreationally active participants were recruited for this research study. Recreationally active was defined as individuals engaging in physical activity with a minimum frequency of three days per week, 30 minutes in duration over a six-month period. The participants consisted of two different groups: sixteen were unilateral chronic ankle instability participants and sixteen were healthy matched controls with no past history of ankle sprain or other lower extremity injury. Each participant was recruited from The Pennsylvania State University student body. Each potential participant completed an informed consent, demographic questionnaire, and a general health screen (Appendix A). Any potential participants that met all of the inclusion criteria (Table 1) and who answered “no” to every component of the exclusion criteria were included in the study. Participant demographics are located in Table 2.

Table 1 Inclusion and Exclusion Criteria

<table>
<thead>
<tr>
<th>Must be able to answer “yes” to these questions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are you recreationally active (defined as individuals engaging in physical activity at least three days per week for 30 minutes over the past six-months)?</td>
</tr>
<tr>
<td>2. Are you between 16 to 35 years old?</td>
</tr>
<tr>
<td>3. Do you have a history of at least one acute ankle sprain that resulted in pain, swelling and loss of function?</td>
</tr>
<tr>
<td>4. Have you experienced at least two episodes of ankle giving way within the past?</td>
</tr>
<tr>
<td>3 Months ☐ 6 months ☐ 12 months ☐</td>
</tr>
<tr>
<td>5. Do you experience stiffness in your sprained ankle?</td>
</tr>
<tr>
<td>6. Do you speak English?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Must be able to answer “no” to these questions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you followed a formal rehabilitation program under supervision of a physical therapist or athletic trainer?</td>
</tr>
<tr>
<td>2. Do you have pain above 3 out of 10?</td>
</tr>
<tr>
<td>3. Have you sustained injury to your back or have a history of back problems?</td>
</tr>
<tr>
<td>4. Have you sustained any further traumatic injury to the lower extremity within the last 6 months?</td>
</tr>
<tr>
<td>5. Have you sustained traumatic injury to the opposite uninvolved leg?</td>
</tr>
<tr>
<td>6. Is there currently any acute swelling present?</td>
</tr>
<tr>
<td>7. Are you diabetic or suffer from peripheral neuropathy?</td>
</tr>
<tr>
<td>8. Have you sustained a concussion within the past six months?</td>
</tr>
</tbody>
</table>
Table 2 Participant Demographics

<table>
<thead>
<tr>
<th></th>
<th>CAI Group</th>
<th>Control Group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>7/9</td>
<td>7/9</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>22.31±4.39</td>
<td>21.13±1.67</td>
<td>0.325</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.94 ± 7.57</td>
<td>172.82 ± 7.55</td>
<td>0.746</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>69.9 ± 11.6</td>
<td>68.3 ± 10.4</td>
<td>0.694</td>
</tr>
<tr>
<td>BMI (kg/m^2)</td>
<td>23.54 ± 3.02</td>
<td>22.84 ± 2.91</td>
<td>0.510</td>
</tr>
<tr>
<td>Treated leg length (cm)</td>
<td>85.88 ± 7.26</td>
<td>87.40 ± 4.04</td>
<td>0.470</td>
</tr>
<tr>
<td>Non-treated leg length (cm)</td>
<td>86.02 ± 7.66</td>
<td>87.19 ± 3.94</td>
<td>0.591</td>
</tr>
</tbody>
</table>

An independent t test was performed to insure no significant differences existed between CAI and control groups.

Values are mean ± SD

The Foot and Ankle Disability Index (FADI) (Appendix A), and FAAM (Appendix A) subjective questionnaires were administered to participants upon enrollment and prior to objective data collection. These were given to CAI and control groups to validate functional ankle performance differences between the groups. Statistical analyses of the responses indicate that a significant difference of perceived functional performance existed between groups. Mean and standard deviations are given in Table 3.

Table 3 Subjective Questionnaire Responses

<table>
<thead>
<tr>
<th></th>
<th>CAI Group</th>
<th>Control Group</th>
<th>P –value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FADI (ADL)</td>
<td>98.44 ± 1.48</td>
<td>104.0 ± 0</td>
<td>0.0007</td>
</tr>
<tr>
<td>FADI (sports scale)</td>
<td>26.63 ± 1.13</td>
<td>32.0 ± 0</td>
<td>0.00004</td>
</tr>
<tr>
<td>FAAM (ADL)</td>
<td>79.94 ± 1.18</td>
<td>84.0 ± 0</td>
<td>0.0017</td>
</tr>
<tr>
<td>FAAM (sports scale)</td>
<td>26.88 ± 1.19</td>
<td>32.0 ± 0</td>
<td>0.0002</td>
</tr>
<tr>
<td>FAAM(ADL) %</td>
<td>95.50 ± 2.15</td>
<td>100.0 ± 0</td>
<td>0.0453</td>
</tr>
<tr>
<td>FAAM (sport) %</td>
<td>88.37 ± 4.72</td>
<td>100.0 ± 0</td>
<td>0.0198</td>
</tr>
<tr>
<td>FAAM Normality Scale</td>
<td>0.375 ± 0.155</td>
<td>0 ± 0</td>
<td>0.0217</td>
</tr>
</tbody>
</table>

An independent t test was performed to insure significant differences existed between CAI and control groups. (ADL signifies activities of daily living)

FAAM normality scale: 0 = normal, 1 = nearly normal, 2 = abnormal, 3 = severely abnormal

Values are mean ± SD
**Questionnaires and Surveys**

The FADI and FAAM are self-report questionnaires used to evaluate physical function in individuals with ankle and foot disorders. The FADI questionnaire is specifically designed for physically active individuals and is used to assess functional limitations related to ankle instability.\(^\text{14}\) It rates the participant’s level of function during activities of daily living (ADL) and sport specific activities using a scale of 0-4; zero being “unable to do” and four being “no difficulty at all”.\(^\text{14}\) The FADI has a total score ranging from 0 to 104 with a lower score indicating greater ankle/foot functional limitations.\(^\text{14}\) Similarly, the FAAM is another self-reported evaluative tool that is used to assess physical function of individuals with musculoskeletal disorders of the foot and ankle. It also consists of various items specific to activities of daily living as well as activities of sport. Like the FADI, the FAAM rates these items on a scale from 0 to 4. However, the two subscales are scored separately with the highest potential score for activities of daily living and sports ranging from 0 to 84 and 0 to 32 respectively.\(^\text{15}\) A higher score represents a higher level of physical function for both the activities of daily living and sports subscales.\(^\text{15}\)

Both the FADI and FAAM have been shown to be reliable and valid. Reliability and validity of both subjective tools have been previously established for clinical applications pertaining to chronic ankle instability.\(^\text{15,16}\) For the FADI, validity was shown when a significant side-to-side difference \((P\leq 0.05)\) was noted between the involved limb and unininvolved limb in CAI participants.\(^\text{14}\) Similarly, for the FAAM test-retest reliability was 0.89 for the activities of daily living section and 0.87 for the Sports subscales.\(^\text{15}\) Based on a 95% confidence interval, it was found that minimal detectable change was ±5.7 and ±−12.3 points for the ADL and Sports
subscales, respectively. Both the ADL and Sports subscales were responsive to changes in ankle function status as well ($P<0.05$)\textsuperscript{15}

**Outcome Measures**

*Ankle Joint Range of Motion*

Ankle joint range of motion was measured using a standard goniometer. The fulcrum of the goniometer was aligned with the lateral malleolus. The stationary arm was aligned with the midline of the lower leg using the head of the fibula as a reference point. The moving arm was aligned parallel to the fifth metatarsal. Measurements of ankle joint dorsiflexion were taken bilaterally in a bent and straight leg position. These measures were taken as a baseline, after treatment in the first session, and in the beginning of the final session. Dorsiflexion in the straight knee position was measured by having the participant lay supine with the knees straight and performing active dorsiflexion ankle motion. The participant was then instructed to sit with his/her legs off the edge of the table so that the knees were bent. In this position the participant actively dorsiflexed the ankle and range of motion measures were recorded. Range of motion was measured in a straight and bent knee position in order to determine whether gastrocnemius inflexibility played a role in ankle motion. See Appendix B for figures depicting proper goniometer alignment and patient positioning during range of motion measures.

*Functional Postural Control*

The Star Excursion Balance Test (SEBT) has been shown to be a reliable measure in assessing dynamic [functional] postural control deficits in people with CAI.\textsuperscript{17} The goal of the SEBT is to reach as far as possible with one leg in each of the eight directions while maintaining
balance upon the opposite leg (Appendix B). The stance leg requires ample ankle, knee, and hip ranges of motion as well as adequate strength, proprioception and neuromuscular control to perform such tasks. The SEBT is best described as a functional screening tool that measures lower extremity reach while challenging the associated limitations of dynamic joint stability. Reliability of the test has been investigated and reported in previous research studies. Reliability estimates, calculated using the intraclass correlation coefficient (ICC) (2/1), ranged from 0.67 to 0.87. More specifically, the ICC for intratester reliability indicated that if measured by the same examiner, the reliability was relatively high. There was an average standard error of measurement that ranged from 1.77 – 3.38 cm. Also, intertester reliability measures ranged from 0.35-0.84 on day one of testing and increased to 0.81-0.93 on day two. Similarly, the intertester standard error of measurement ranged from 3.08-4.96 on day one to 2.27-3.87 cm on day two of testing.

For this study, we have chosen to use only three of the eight reach directions; anterior, posteriolateral, and posteriomedial. According to a study by Hertel et al. these three directions are highly representative of performance in all eight directional components of the test and are reliable in detecting functional deficits related to CAI.

**Manual Therapy**

Manual therapy plays a role in the management of ankle conditions in which joint instability and loss of joint motion are present. Passive joint mobilization, manipulation and mobilization with movement (MWM) techniques are frequently used by physical therapists and athletic trainers as an intervention for ankle inversion sprains. Specifically, these techniques are used to improve dorsiflexion range of motion and posterior talar glide, which are two things
that are effected as a result of recurrent ankle injury. According to the study performed by Whitman et al.\textsuperscript{7} manual therapy may be used in patients who have suffered ankle sprains. The specific techniques used by Whitman et al.\textsuperscript{7} include ankle joint mobilizations, more specifically: proximal tibio-fibular joint mobilization, distal tibio-fibular joint mobilization, rearfoot distraction mobilization and talocrural joint anterior-to-posterior mobilization.

For both the CAI and healthy matched control group, half of the participants ($n = 8$) were randomly assigned to the treatment group, and the other half ($n = 8$) to the sham treatment group. In CAI participants only the involved extremity was treated. For the control participants, the dominant extremity was treated. Extremity dominance was determined by asking the participant which leg he/she felt more comfortable kicking a soccer ball. Participants in the treatment group underwent an approximately 15 minute session of manual therapy treatment, which consisted of grade III/IV mobilizations and manipulation of joints involved in dorsiflexion. Two attempts to produce cavitation with manipulation were allowed. The second attempt was performed if cavitation was not achieved on the first try. Grade III/IV mobilizations were performed as 3 sets of 30 second bouts at each joint. Techniques used in this study included a talocrural joint distraction manipulation, talocrural joint anterior-to-posterior glide mobilization, distal tibiofibular joint anterior-to-posterior glide mobilization, posterior proximal tibiofibular joint manipulation, anterior-to-posterior proximal tibiofibular joint glide mobilization, anterior proximal tibiofibular joint manipulation and posterior-to-anterior proximal tibiofibular joint glide mobilization. (Appendix C). The participants assigned to the sham group underwent an approximately 15 minute session of non-therapeutic treatment consisting of replicating practitioner hand placement and patient positioning with clinically insignificant low velocity, low amplitude oscillation movements.
Experimental Procedures

Recruitment of potential participants was done at The Pennsylvania State University during the spring semester of the 2009-2010 academic year. Before beginning participation in the study, participants were required to read and sign an informed consent form as well as complete the FADI and FAAM questionnaires. After completion of the previously mentioned documents and after being screened for eligibility, eligible participants were then randomized into two subgroups within each group. Participants for CAI and control group were randomized into true treatment and sham treatment subgroups. During the first session, the participant’s demographics were taken which included basic anthropometric measurements of height, weight, BMI and bilateral leg length. Age, sex and leg dominance were also recorded. These measurements were completed by Athletic Training Students (ATSs) under the supervision of a Certified Athletic Trainer (ATC). Leg length was measured by having the participant lay supine and positioning the pelvis in neutral. Using a tape measure, measurement of true leg length was done by measuring from the anterior superior iliac spine to the medial malleolus. All measures were recorded in centimeter units. Leg length was recorded for normalization of reach distances during performance of the SEBT to allow for a standardized comparison among participants.22

Once basic anthropometric measures were recorded and questionnaires completed, ankle joint range of motion measures were taken. The patient was instructed to first lay supine on the table with his/her feet off of the edge. Both the left and right feet were measured by an ATS. The participant was instructed to bring the foot upward toward the body and hold the position while the examiner took dorsiflexion measurements. This was done on both feet in the supine position with the knees straight and was also done with the patient sitting off the edge of the table with the knees bent.
Following ankle joint range of motion assessments participants underwent a 5 minute warm up on the treadmill at a walking speed of 1.2 m/s. After completion of the warm-up session, pretest baselines were taken which included measurements of functional balance performance using the SEBT. Randomization procedures were conducted to prevent order effects. In order to randomize sequence of testing the involved and uninvolved leg as well as SEBT directional excursions, a statistical software program (Minitab, Inc., State College, PA) was used to generate multiple random permutations.

Once the examiner established which stance leg to start with and order of excursions, the participant was given a verbal and visual demonstration of the testing procedure. As recommended by Robinson and Gribble\textsuperscript{23}, the participants were given four practice trials in each of the three directions for each leg. This allowed them to become familiar with the task so that they would perform with proper technique. In order to perform the SEBT, the participant was instructed to stand barefoot in the middle of the star, place both hands on his/her hips and maintain a single leg stance while reaching with the opposite leg as far as possible along the appropriate direction (Appendix B). In order to insure that the foot remained in the same location for each trial, the foot was marked in the position that the participant practiced. The participant was instructed to contact the furthest point possible on the line with a toe-touch using minimal pressure and while maintaining minimal transfer of body weight between their center of mass and reach leg. They were told to utilize whatever strategy they felt necessary to allow them to reach the furthest distance as long as they maintained the appropriate position and balance throughout.

During each reach the examiner marked exactly where the participant touched on the tape using a colored pen (Appendix B figure 7). Three reaches in each direction [anterior,
posterolateral, and posteromedial] were recorded using a standard tape measure. Participants were given 10-15 seconds of rest between each reach attempt for a single direction. A one minute rest interval was given between changing reach directions. Trials were discarded and repeated if a participant did not touch the line with the reach leg while maintaining weight bearing on the stance leg, if they lifted the stance foot from the center grid, lost balance at any point in the trial, removed the hands from the hips, did not maintain initial and return positions for one full second, and if they unloaded too much weight on the touch toe. No verbal cues or communication of encouragement was given to the participants during testing. To avoid intertester variability, the same investigator took all reach measurements. Reach distance was marked and measured from the crosshair at the center of the star to the nearest millimeter.

After baseline measurements of the SEBT were taken the participants underwent their assigned treatment protocol. The examiner brought the participant to a clinician (SJM, GLV) in another room, which was located separate from the laboratory. The examiner was blinded to the treatment protocol assigned to the participant and therefore he/she left the participant with a clinician (SJM, GLV) who performed the treatment. The clinicians (SJM, GLV) were also blinded from the objective data collection. Upon completion of the treatment session, the [participant was returned to the lab where the ATSs remeasured ankle range of motion and SEBT performance.]. The first session was concluded once the post-treatment measurements were obtained.

Participants returned for a second session within 3-4 days. The second session only consisted of treatment intervention. The participant was instructed to report to the Athletic Training Research Laboratory where he/she was given the assigned treatment (manual therapy/sham) for approximately a 15 minute session. During the second session outcome
measures were not taken and the participant was released after treatment. A third follow-up session was scheduled for two weeks after the initial treatment session. During the third session no treatment was given. Participants underwent the initial measures performed during the first session. Ankle dorsiflexion range of motion was measured in the bent and straight leg position on both feet. Functional postural control was measured using reach distances performed on the SEBT.

**Data Analysis**

The independent variable was the treatment condition for CAI and control participants (manual therapy or sham treatment). The dependent variables were ankle joint dorsiflexion range of motion (straight knee, bent knee) and functional postural control. Descriptive statistics were compiled to generate group means and standard deviations. Normality plots for means of the dependent variables were produced and analyzed to assess distribution of the data sets. Normality plots confirmed normal distribution of such measures. A balanced repeated measures analysis of variance (ANOVA) was employed for each response variable examined in this study to compare outcome measure differences between the CAI and control groups receiving true or sham treatments. Specifically, a fixed model factorial treatment design was used where group, treatment, and time served as fixed factors. Interaction effects between these fixed factors were also analyzed. Separate two factor (leg, time) balanced repeated measures ANOVAs and associated interaction effect were calculated to assess bilateral (treated/non-treated) differences within each group (CAI: true treatment, CAI: sham treatment, control: true treatment, control: sham treatment). Where statistical significance was observed, *post hoc* analyses were performed to assess pairwise comparisons for each dependent variable of interest using Tukey’s Honestly
Significant Difference. Statistical significance (alpha level) was set at $P \leq 0.05$ a priori. Residual analyses of the data sets confirmed that the assumptions for ANOVA (normality, constant variance and independence) were appropriately met.
CHAPTER 3: RESULTS

Range of motion outcome measures

No statistically significant findings were observed for straight knee dorsiflexion among the fixed factors (group, treatment, time): (group, \( P = 0.474 \)), (treatment, \( P = 0.129 \)), (time, \( P = 0.528 \)) and interaction effects (group-treatment, \( P = 0.418 \)), (group-time, \( P = 0.506 \)), (treatment-time, \( P = 0.068 \)), (group-treatment-time, \( P = 0.200 \)). Similarly, analyses for bent knee dorsiflexion range of motion yielded no statistically significant findings among the fixed factors; (group, \( P = 0.246 \)), (treatment, \( P = 0.246 \)), (time, \( P = 0.891 \)) and interaction effects (group-treatment, \( P = 0.698 \)), (group-time, \( P = 0.653 \)), (treatment-time, \( P = 0.339 \)), (group-treatment-time, \( P = 0.926 \)).

Within-group analyses indicated an overall statistically significant difference between the involved and uninvolved leg (\( P = 0.029 \)) for straight knee dorsiflexion range of motion and between the second (immediately after treatment) and third (two-week follow-up) time periods (\( P = 0.050 \)) in the CAI group receiving a true treatment. Comparison of the involved and uninvolved leg means (Tables 4 & 5) demonstrate that ironically, the involved leg of the CAI true treatment group reported greater measures of dorsiflexion range of motion at baseline and immediately following initial treatment than at the two-week follow-up compared to the uninvolved leg. A leg-time interaction effect (\( P > 0.05 \)) was statistically insignificant for the CAI true treatment group. There were no statistically significant bilateral differences for the CAI sham (leg, \( P = 0.240 \); time, \( P = 0.825 \)), control treatment (leg, \( P = 0.727 \), time, \( P = 0.995 \)) and control sham (leg, \( P = 0.174 \); time, \( P = 0.973 \)) groups. Furthermore, the interaction (leg-time) effect was statistically insignificant (\( P > 0.05 \)) for all within group analyses. Within-group analyses did not indicate a statistically significant difference between the involved and
uninvolved leg for bent knee dorsiflexion range of motion in CAI treatment (leg, $P = 0.715$; time, $P = 0.913$), CAI sham (leg, $P = 0.111$; time, $P = 0.364$), control treatment (leg, $P = 0.643$, time, $P = 0.789$) and control sham (leg, $P = 0.344$; time, $P = 0.822$) groups. Moreover, the interaction (leg-time) effect was statistically insignificant ($P > 0.05$) for all within-group analyses. Descriptive statistics for dorsiflexion range of motion are provided in Tables 4 and 5.

**Table 4** ROM Descriptive Statistics of Treated Leg (Values are mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>CAI Treatment Group</th>
<th>CAI Sham Group</th>
<th>Control Treatment Group</th>
<th>Control Sham Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight DF 0 (°)</td>
<td>10.75 ± 6.65</td>
<td>2.75 ± 8.08</td>
<td>7.13 ± 6.60</td>
<td>5.88 ± 5.14</td>
</tr>
<tr>
<td>Straight DF 1 (°)</td>
<td>12.88 ± 6.85</td>
<td>6.88 ± 6.10</td>
<td>7.63 ± 6.89</td>
<td>5.88 ± 4.85</td>
</tr>
<tr>
<td>Straight DF 2 (°)</td>
<td>4.25 ± 6.94</td>
<td>8.88 ± 6.29</td>
<td>7.00 ± 6.87</td>
<td>7.13 ± 6.45</td>
</tr>
<tr>
<td>Bent DF 0 (°)</td>
<td>10.63 ± 8.45</td>
<td>6.87 ± 7.18</td>
<td>10.25 ± 7.23</td>
<td>6.13 ± 5.82</td>
</tr>
<tr>
<td>Bent DF 1 (°)</td>
<td>10.50 ± 4.63</td>
<td>8.63 ± 6.74</td>
<td>9.75 ± 7.30</td>
<td>7.62 ± 6.02</td>
</tr>
<tr>
<td>Bent DF 2 (°)</td>
<td>9.75 ± 6.11</td>
<td>12.13 ± 7.49</td>
<td>7.63 ± 7.63</td>
<td>7.38 ± 6.32</td>
</tr>
</tbody>
</table>

Time scale: 0=baseline, 1=immediately after treatment, 2=two week follow-up  DF signifies dorsiflexion ROM

**Table 5** ROM Descriptive Statistics of Non-treated Leg (Values are mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>CAI Treatment Group</th>
<th>CAI Sham Group</th>
<th>Control Treatment Group</th>
<th>Control Sham Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight DF 0 (°)</td>
<td>4.25 ± 5.92</td>
<td>10.88 ± 6.06</td>
<td>6.88 ± 4.97</td>
<td>9.25 ± 4.30</td>
</tr>
<tr>
<td>Straight DF 1(°)</td>
<td>7.00 ± 3.96</td>
<td>7.13 ± 4.22</td>
<td>6.00 ± 4.28</td>
<td>9.00 ± 5.04</td>
</tr>
<tr>
<td>Straight DF 2 (°)</td>
<td>4.87 ± 5.03</td>
<td>7.50 ± 8.93</td>
<td>7.00 ± 6.87</td>
<td>7.13 ± 6.45</td>
</tr>
<tr>
<td>Bent DF (°)</td>
<td>8.88 ± 6.03</td>
<td>12.88 ± 5.00</td>
<td>8.62 ± 8.42</td>
<td>9.25 ± 6.80</td>
</tr>
<tr>
<td>Bent DF 1 (°)</td>
<td>10.50 ± 6.63</td>
<td>10.75 ± 5.15</td>
<td>8.25 ± 8.15</td>
<td>9.88 ± 7.51</td>
</tr>
<tr>
<td>Bent DF 2 (°)</td>
<td>9.50 ± 5.13</td>
<td>13.13 ± 6.81</td>
<td>7.63 ± 7.63</td>
<td>7.38 ± 6.32</td>
</tr>
</tbody>
</table>

Time scale: 0=baseline, 1=immediately after treatment, 2=two week follow-up  DF signifies dorsiflexion ROM
Star Excursion Balance Test outcome measures

No statistically significant findings were observed for the response variables associated with functional postural control among the fixed factors (group, treatment, time) and interaction effects among groups. Specifically, analysis of anterior reach yielded no statistically significant findings among the fixed factors; (group, \( P = 0.930 \)), (treatment, \( P = 0.446 \)), (time, \( P = 0.651 \)) and interaction effects (group-treatment, \( P = 0.160 \)), (group-time, \( P = 0.984 \)), (treatment-time, \( P = 0.866 \)), (group-treatment-time, \( P = 0.972 \)). Analysis for posterolateral reach demonstrated no statistically significant findings among the fixed factors; (group, \( P = 0.320 \)), (treatment, \( P = 0.304 \)), (time, \( P = 0.256 \)) and interaction effects (group-treatment, \( P = 0.139 \)), (group-time, \( P = 0.965 \)), (treatment-time, \( P = 0.963 \)), (group-treatment-time, \( P = 0.886 \)). Finally, analysis of posteromedial reach yielded no statistically significant findings among the fixed factors; (group, \( P = 0.578 \)), (treatment, \( P = 0.257 \)), (time, \( P = 0.292 \)) and interaction effects (group-treatment, \( P = 0.362 \)), (group-time, \( P = 0.997 \)), (treatment-time, \( P = 0.972 \)), (group-treatment-time, \( P = 0.826 \)).

Within group analyses did not indicate a statistically significant difference between the involved and uninvolved leg for the SEBT anterior excursion in the CAI treatment (leg, \( P = 0.902 \), time, \( P = 0.874 \)), CAI sham (leg, \( P = 0.061 \); time, \( P = 0.933 \)), control treatment (leg, \( P = 0.568 \), time, \( P = 0.862 \)) and control sham (leg, \( P = 0.576 \); time, \( P = 0.908 \)) groups. Furthermore, the interaction (leg-time) effect was statistically insignificant (\( P > 0.05 \)) for all within group analyses. No statistically significant differences existed between the involved and uninvolved leg for the SEBT posterolateral excursion in the CAI treatment (leg, \( P = 0.798 \), time, \( P = 0.755 \)), CAI sham (leg, \( P = 0.827 \); time, \( P = 0.192 \)), control treatment (leg, \( P = 0.921 \), time, \( P = 0.686 \)) and control sham (leg, \( P = 0.706 \); time, \( P = 0.174 \)) groups. Moreover, the interaction (leg-time)
effect was statistically insignificant ($P > 0.05$) for all within-group analyses. Bilateral SEBT posteromedial excursions were also insignificant in the CAI treatment (leg, $P = 0.907$, time, $P = 0.719$), CAI sham (leg, $P = 0.605$; time, $P = 0.538$), control treatment (leg, $P = 0.821$, time, $P = 0.787$) and control sham (leg, $P = 0.236$; time, $P = 0.244$) groups. Again, the interaction (leg-time) effect was statistically insignificant ($P > 0.05$) for all within-group analyses. Descriptive statistics for this data set are provided in Tables 6 and 7.
### Table 6 SEBT Reach Excursion Descriptive Statistics of Treated Leg

<table>
<thead>
<tr>
<th>CAI Treatment Group</th>
<th>CAI Sham Group</th>
<th>Control Treatment Group</th>
<th>Control Sham Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant Reach 0 (% MAXD) 85.12 ± 15.71</td>
<td>85.64 ± 5.95</td>
<td>83.67 ± 6.65</td>
<td>88.24 ± 8.13</td>
</tr>
<tr>
<td>Ant Reach 1 (% MAXD) 88.08 ± 14.07</td>
<td>86.72 ± 5.76</td>
<td>85.25 ± 7.40</td>
<td>89.89 ± 7.08</td>
</tr>
<tr>
<td>Ant Reach 2 (% MAXD) 89.05 ± 12.35</td>
<td>86.35 ± 7.55</td>
<td>85.90 ± 7.53</td>
<td>88.92 ± 2.96</td>
</tr>
<tr>
<td>PL Reach 0 (% MAXD) 77.83 ± 20.84</td>
<td>79.30 ± 11.82</td>
<td>86.34 ± 6.13</td>
<td>77.78 ± 10.46</td>
</tr>
<tr>
<td>PL Reach 1 (% MAXD) 82.74 ± 19.36</td>
<td>82.30 ± 12.55</td>
<td>87.12 ± 8.09</td>
<td>82.50 ± 10.42</td>
</tr>
<tr>
<td>PL Reach 2 (% MAXD) 83.24 ± 15.62</td>
<td>85.75 ± 11.07</td>
<td>89.48 ± 7.41</td>
<td>83.27 ± 5.46</td>
</tr>
<tr>
<td>PM Reach 0 (% MAXD) 87.12 ± 20.05</td>
<td>88.17 ± 9.23</td>
<td>92.94 ± 7.78</td>
<td>85.53 ± 10.07</td>
</tr>
<tr>
<td>PM Reach 1 (% MAXD) 91.84 ± 16.29</td>
<td>90.29 ± 11.38</td>
<td>94.64 ± 9.50</td>
<td>90.05 ± 8.55</td>
</tr>
<tr>
<td>PM Reach 2 (% MAXD) 92.90 ± 13.38</td>
<td>91.78 ± 11.84</td>
<td>94.81 ± 9.79</td>
<td>92.10 ± 3.68</td>
</tr>
</tbody>
</table>

Time scale: 0=baseline, 1=immediately after treatment, 2= two week follow-up

Values are mean ± SD

### Table 7 SEBT Reach Excursion Descriptive Statistics of Non-treated Leg

<table>
<thead>
<tr>
<th>CAI Treatment Group</th>
<th>CAI Sham Group</th>
<th>Control Treatment Group</th>
<th>Control Sham Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant Reach 0 (% MAXD) 87.33 ± 13.77</td>
<td>89.89 ± 4.46</td>
<td>86.27 ± 8.11</td>
<td>90.21 ± 7.02</td>
</tr>
<tr>
<td>Ant Reach 1 (% MAXD) 88.37 ± 13.33</td>
<td>89.81 ± 4.56</td>
<td>85.40 ± 6.46</td>
<td>90.24 ± 6.49</td>
</tr>
<tr>
<td>Ant Reach 2 (% MAXD) 88.02 ± 12.48</td>
<td>88.81 ± 5.33</td>
<td>86.67 ± 6.94</td>
<td>89.58 ± 2.85</td>
</tr>
<tr>
<td>PL Reach 0 (% MAXD) 80.66 ± 19.21</td>
<td>78.60 ± 12.76</td>
<td>87.42 ± 7.73</td>
<td>79.22 ± 10.62</td>
</tr>
<tr>
<td>PL Reach 1 (% MAXD) 82.55 ± 18.86</td>
<td>79.35 ± 11.74</td>
<td>87.55 ± 8.45</td>
<td>80.84 ± 11.71</td>
</tr>
<tr>
<td>PL Reach 2 (% MAXD) 84.67 ± 15.14</td>
<td>87.11 ± 11.23</td>
<td>88.60 ± 6.08</td>
<td>86.65 ± 7.18</td>
</tr>
<tr>
<td>PM Reach 0 (% MAXD) 89.49 ± 17.01</td>
<td>89.98 ± 11.23</td>
<td>93.88 ± 6.36</td>
<td>90.79 ± 8.39</td>
</tr>
<tr>
<td>PM Reach 1 (% MAXD) 91.33 ± 16.50</td>
<td>90.30 ± 11.10</td>
<td>93.96 ± 8.48</td>
<td>91.41 ± 8.42</td>
</tr>
<tr>
<td>PM Reach 2 (% MAXD) 92.67 ± 11.97</td>
<td>95.07 ± 12.85</td>
<td>96.28 ± 10.07</td>
<td>93.44 ± 4.70</td>
</tr>
</tbody>
</table>

*Time scale: 0=baseline, 1=immediately after treatment, 2= two week follow-up

Values are mean ± SD
CHAPTER 4: DISCUSSION

Results from this research study suggest that the manual therapy treatment was no more effective than a sham treatment in improving functional postural control in CAI patients as measured by the SEBT and compared with a healthy matched control group. Bilateral comparisons also indicate that the treatment had no significant effects on increasing ankle dorsiflexion range of motion and SEBT reach distances across all conditions. The only statistically significant findings pertinent to this research study include an overall difference between the treated and untreated ankle for straight knee dorsiflexion range of motion and between the second (immediately after treatment) and third (two-week follow-up) time periods in the CAI group receiving a true treatment. Comparison of the involved and uninvolved leg means demonstrate that ironically, the involved leg of the CAI true treatment group reported greater measures of dorsiflexion range of motion at baseline and immediately following initial treatment than at the two-week follow-up compared to the uninvolved leg.

Range of motion

Unexpectedly, the involved ankle of the CAI true treatment group demonstrated a considerably greater measure of straight knee ankle dorsiflexion range of motion compared to the uninvolved/untreated ankle. Potential factors influencing this finding may include altered neural drive of the soft tissue musculature surrounding the ankle joint and leg dominance. Previous studies have shown that range of motion is greater in the dominant side versus the non-dominant side. Consequently, since many of the involved (treated) ankles within the CAI group were of the dominant side we can assume that the involved ankles had greater dorsiflexion range of motion to begin with. Furthermore, we noticed that the involved ankle demonstrated considerably greater range of motion measurements at baseline compared to the uninvolved
ankle. This finding may be explained by an inhibition of the gastrocnemius due to the chronic joint dysfunction (CAI). It has been suggested that pain influences patterns of neuromuscular activation and control. The presence of pain leads to inhibition of muscles that perform synergistic functions to resist unwanted joint movement. This inhibition usually occurs in deep muscles surrounding the involved joint. Therefore, pain and dysfunction due to injury in the CAI patients may have produced an altered afferent sensory input to the central nervous system that resulted in inhibition of muscles, specifically the gastrocnemius, around the affected joint. This inhibition of the gastrocnemius subsequently allowed for greater dorsiflexion range of motion in the involved leg at baseline, which is why we saw a considerable difference compared to the uninvolved.

Further findings when comparing involved (treated) and uninvolved (non-treated) showed that both ankles had a slight increase in straight knee dorsiflexion range of motion. A likely explanation for this observation is viscoelastic changes in connective tissue that allowed for greater range of motion in both legs. Studies have shown short term (within 90 minutes) increases in range of motion after stretching due to viscoelastic behavior. During stretching, there are changes in the mechanical properties of the muscle-tendon unit that result in gains in joint range of motion. The dynamic 5 minute warm up on the treadmill and performing the SEBT excursions may have caused a low–level stretch to the gastrocnemius which in turn would cause viscoelastic changes to the muscle. Therefore, we can attribute the increased range of motion from baseline measures to post-baseline measures in the treated and non-treated ankles of the CAI group to the stretching of the gastrocnemius during the dynamic warm up and balance task. However, the effect that stretching has on the mechanical viscoelastic properties of a muscle appear to rapidly disappear and therefore only have short term effects on range of
motion. Since we measured range of motion immediately following the treatment session, there were still viscoelastic gains present that affected the dorsiflexion measures in both ankles.

Longitudinally, straight knee dorsiflexion range of motion was drastically less during the two-week post-treatment session compared to immediately after treatment in the involved ankle of the CAI group. A probable explanation for this may be that the problems associated with the abnormal joint mechanics in individuals with CAI may result in afferent sensory input to the central nervous system that causes facilitation of the gastrocnemius and therefore allowing it to resist active dorsiflexion. In other words, the manual therapy treatment increased the stiffness produced at the ankle joint by the gastrocnemius. It is probable that the manual therapy treatment uninhibited the gastrocnemius and allowed it to function more normally to produce functional joint stability and increased joint stiffness which will limit active range of motion. Therefore, according to this theory, losing active dorsiflexion range of motion may be a positive finding. However, this theory does not explain bent knee dorsiflexion range of motion findings. Theoretically, the treatment selectively inhibited the gastrocnemius but not the soleus which accounts for no differences in bent knee ankle dorsiflexion. Overall, the manual therapy treatment accompanied by two weeks of walking may have helped reprogram the motor control of the ankle.

The observed trends for the treated ankle of the involved leg and the true treatment CAI group paralleled those trends of the parallel uninvolved leg in that there was an immediate increase in ankle dorsiflexion range of motion following baseline with a noticeable decrement in that range of motion in the two week follow up. More specifically, the treated ankle in the CAI true treatment group more closely mirrored the straight knee dorsiflexion range of motion of the uninvolved leg. Potentially, the manual therapy treatment reestablished correct function in the
involved ankle of the CAI group.

*Functional Postural Control*

The findings of this study suggest that there were no significant differences in functional postural control between groups, within-groups or over times. The SEBT was used to assess functional postural control and challenges specific neuromuscular control patterns in order to maintain a stable base of support while reaching. The challenge of having to maintain a stable base of support while testing their limits of stability requires coordinated muscle activity throughout the trunk and lower extremities. Each participant utilized different strategies in order to attain the furthest possible reach. Depending on how much they flexed the knee or the hip, variable stress could be put on the muscles of the trunk and lower extremities that are important for postural control.

It is highly reasonable to assume that fatigue may have hindered reach performance during the balance task. Although the participants were allotted rest between trials, they had to perform multiple reaches in three different directions on each leg. Gribble et al. found that the presence of fatigue increased significantly in CAI patients due to a disruption of normal muscle activation. To allow for the greatest maintenance of dynamic postural control while performing the SEBT there is heavy dependence on optimal knee and hip flexion. When fatigue sets in, participants are less able to utilize these strategies which results in not being able to achieve a maximum reach distance. One study found that postural control performance was altered by onset of fatigue in healthy controls as well. It is evident that when repeatedly performing the SEBT, fatigue was induced on the musculature of the knee and hip, therefore disrupting muscle activation and resulting in diminished task performance.
In a previous study,\textsuperscript{1} it was suggested that a jump-landing task was the best assessment task for detecting postural control deficiencies because it is a more stressful test of dynamic stability. Therefore, it can be questioned whether the SEBT is a dynamic enough task to differentiate true deficits in dynamic postural control in individuals with CAI. When analyzing the patient position while performing the SEBT, we noted that the foot was in a relatively stable position. Participants began in a single leg position with a relatively stable base of support. It is known that the ankle is most “unstable” while in a plantarflexed/inversion position. Perhaps if the participants were instructed to perform the SEBT excursion with the ankle in a plantarflexed position (on tip-toe) this would have placed a greater challenge on the sensorimotor system and made it a more dynamic task. However, further investigation may warrant using a more dynamic task that involves changing the base of support and regaining balance.

McKeon et al.\textsuperscript{28} discussed constraints that limit the sensorimotor system during dynamic tasks, such as task difficulty, and how these constraints can be decreased with a progressive balance training program. Their findings showed significant improvements in the PM and PL SEBT reach excursions following a 4-week balance training program that emphasized dynamic stabilization following landings tasks.\textsuperscript{28} These findings indicate that implementation of a balance training program will help improve dynamic postural control in CAI patients. We can therefore assume that a combination of manual therapy and balance training would show more positive changes in functional postural control because it would enhance overall sensorimotor function that is necessary for dynamic postural stability.

All in all, the fact that no group differences in the SEBT were noted demonstrates that the decrease in straight knee dorsiflexion range of motion was not a hindrance to functional postural
control for patients. However, further research is warranted to investigate whether further manual
therapy mobilization treatment would improve functional postural control by increasing reach
distances as measured by the SEBT. Also, implementation of more treatment sessions could
improve arthrokinematics of the ankle joint and therefore improve range of motion in CAI
patients.

Limitations

There were many limitations during this study that may have hindered some results. With
regard to ankle joint range of motion one of the greatest limitations was that we only had the
participants perform active motion. Active range of motion has significant limitations: you must
rely on the individual to achieve maximum range of motion where the amount of force
maintained at end range is not controlled. Ideally, range of motion should be measured passively
to insure that minimal EMG (muscle activity) is present. Also, passive range of motion allows
for measures to be taken at an end range point that is maintained with the same amount of force
for each subject. During passive range of motion you are able to control the amount of force you
place on the joint whereas with active range of motion this is limited since the participant may
not have been able to hold the foot long enough in the desired position. Furthermore, intertester
variance may have played a role in differing measurements. Since there were two different
examiners there may have been some variability in range of motion measurements. Finally, there
were two different clinicians performing the treatment whose technique and expertise may have
been different. This may account for differences noted between participants, depending on which
clinician treated them.
CHAPTER 5: CONCLUSION

In conclusion, the findings of this study suggest that a manual therapy technique is no more effective than a sham treatment for improving ankle joint dorsiflexion range of motion and functional postural control in CAI patients when compared to healthy matched controls. Although there was an overall difference between the treated and untreated ankle during straight knee dorsiflexion range of motion in the CAI treatment group, this cannot be attributed to arthrokineamic changes from the manual therapy treatment itself. However, it is plausible that the manual therapy treatment played a role in the facilitation of the gastrocnemius muscle since the treated ankle in the CAI true treatment group more closely mirrored the straight knee dorsiflexion range of motion of the uninvolved leg after two treatment sessions. Further research is warranted on the efficacy of this treatment on ankle joint range of motion as well as dynamic postural control.
REFERENCES:


LITERATURE REVIEW

The purpose of this paper is to evaluate the effect that chronic ankle instability has on postural control, as well as to whether the use of manual therapy, specifically ankle joint mobilization techniques, will improve static and dynamic balance in individuals with chronic ankle instability.

BACKGROUND

CHRONIC ANKLE INSTABILITY

Lateral or inversion ankle sprains are one of the most common injuries sustained among athletes and physically active individuals.\(^1\)\(^-\)\(^8\) Approximately 40-75% of individuals suffering from lateral ankle sprain usually develop residual symptoms.\(^1\) These residual symptoms include joint laxity, recurrent sprain, swelling, and a feeling of weakness or giving way.\(^2,3,9\) Additional problems that result from ankle sprains involve proprioceptive deficits of the ankle, lack of ankle dorsiflexion, and reduced posterior glide of the talus in the mortise.\(^10\) The development of residual giving way symptoms refer to a common disability termed chronic ankle instability (CAI).\(^9,11\) The term chronic ankle instability can be divided into two categories of instability referred to as functional and mechanical instability.\(^1\)

Functional ankle instability can be defined as impaired proprioception, strength, and postural and neuromuscular control leading to giving way episodes.\(^1,2,11\) Mechanical instability is defined as ankle movement beyond its physiological limit of motion and is often referred to as “laxity” of the ankle.\(^11\) Mechanical instability is thought to be associated with laxity of the ankle due to damage of the ligamentous tissues that support the ankle joint. Contributing factors associated with mechanical instability include arthokinematic restrictions, degenerative changes, and synovial changes.\(^11\) Although functional instability can occur without mechanical instability and mechanical instability can occur without functional instability, CAI usually occurs due to a
combination of both.\textsuperscript{11} Gribble et al.\textsuperscript{4} describe CAI as “altered mechanical joint stability due to repeated disruptions to ankle integrity with resultant perceived and observed deficits in neuromuscular control” which describes the relationship between functional and mechanical instability. This paper will focus mainly on deficits of postural and neuromuscular control and arthokinematic restrictions of the ankle and how the integration of manual therapy into a rehabilitation program will affect these deficits commonly seen in individuals with CAI.

\textit{POSTURAL CONTROL}

Impaired postural control is common in individuals with both acute and repetitive ankle sprains.\textsuperscript{11} Functional deficits associated with postural control are evident in people with CAI. The postural control deficits seen with CAI are often due to a combination of impaired neuromuscular control and proprioception.\textsuperscript{11} Postural control is classified as either static or dynamic.\textsuperscript{4} Static postural control [or balance] is attempting to maintain center of mass over a base of support with minimal movement.\textsuperscript{4} Dynamic control is attempting to maintain balance over a moving base of support.\textsuperscript{2,4} Transitioning from a dynamic to a static state can be described as when the base of support is moving or when an external perturbation or force is applied to the body.\textsuperscript{6}

A systematic review by Riemann\textsuperscript{29} provided a clear perspective on the association between chronic ankle instability and postural control. One study in the review suggested that alterations in postural control may be due to deficits in afferent input arising from mechanoreceptors within the ankle ligaments and capsule. In addition to the disruption of mechanoreceptors within the ankle, other components of the postural control system may also become impaired in individuals with CAI. These components include, strength, mechanical
stability, and range of motion deficits. The postural control system is responsible for maintaining postural equilibrium during all motor activities of the body. Although the role of mechanoreceptors in postural control has been highly studied, many studies have shown no differences in balance between normal individuals and individuals with CAI. Riemann suggests that several biomechanical and physiological characteristics appear to be altered in CAI patients. Decreased ankle joint stability, due to excessive joint laxity, requires significant ankle muscle co-activation to maintain the joint in optimal alignment. To help compensate for ankle muscle weakness (that is prevalent in CAI patients) corrective action at the hip is heavily relied on during postural demands. Additionally, many individuals with CAI present with altered ankle range of motion (ROM) which may influence the execution of motor strategies concerned with maintaining balance. Further research must be done to investigate the potential source of postural deficits in CAI individuals.

In a study by Ross et al. static and dynamic postural stability were examined and compared in people with CAI. The main objective of the study was to determine if there was a significant difference in mean sway between individuals with CAI and those without during a single-leg stance. However, it is speculated that static components of single-leg balance do not adequately challenge the postural control system. Therefore, this study also compared stabilization times between CAI and stable individuals during a single-leg jump landing procedure. The subject population consisted of 14 subjects with chronic ankle instability and 14 subjects with no history of ankle sprain injury. Subjects were required to perform a single leg balance task and instructed to remain motionless for 20 seconds. Three trials were completed and then they were instructed to perform a jump landing test where they jumped 50% of their vertical height and had to land on a single leg, stabilize themselves and maintain in a static position for
20 seconds. Results indicated that mean sway in both the anterior/posterior (A/P) and medial/lateral (M/L) directions were not significantly different between groups during the static single leg balance test. Whereas, in the jump-landing task the CAI subjects took significantly longer to stabilize in the frontal and sagittal planes of motion compared with the stable ankle group. These results suggest that the CAI groups center of pressure excursions were not significantly different from the stable ankle group’s and that ankle strength may have compensated for proprioceptive deficits, which caused the mean sway between each group to be similar in the single leg balance test. Consequently, during the jump-landing task Ross suggest that the jump and stabilization test may challenge ankle joint stability at a more clinically relevant level and the inability for the CAI group to stabilize as quickly as the stable ankle group is due to insufficient muscle strength or neuromuscular control. Further research must be done to explore the relationship between time to stabilization (TTS) and landing strategies in order to effectively assess specific instability of the ankle that is causing it.

A recent study by Brown et al. used tibial nerve stimulation as a perturbation to test for dynamic balance deficits between individuals with CAI and those with stable ankles. The subject population consisted of 20 recreational athletes with CAI and 20 recreational athletes with stable ankles. Balance deficits were observed for each subject during static and dynamic tests. The static test consisted of three trials of standing motionless with both feet on a force plate with hands on hips looking straight ahead. Next, the subjects were instructed to stand in the same position and the tibial nerve was stimulated using stimulating electrodes for approximately 5-10 seconds. There were no statistical differences between groups in individuals with CAI during the stable double-leg stance. After perturbation, using tibial nerve stimulation, subjects with CAI took much longer to return to a stable stance in the A/P direction. Brown concluded that the
significant difference in TTS in subjects with CAI after perturbation indicates that CAI affects the sensorimotor system by limiting its ability to generate new patterns of movement needed to control posture and regain stability after an external perturbation. Limitations of this study include the ease of the balance tasks used. A double leg stance does not necessarily challenge the postural system and therefore incorporation of perhaps a single leg stance may have changed the results. Although tibial stimulation is considered a perturbation that is testing dynamic postural control, its validity is not well known and therefore other dynamic tasks should be studied to compare dynamic control between groups.

Hiller et al. compared sensorimotor control of ankle movement during quiet stance and after inversion perturbation in chronically unstable ankles with stable controls. The study included 21 female dancers. Ten subjects had no history of ankle injury, six had unilateral CAI, and 5 had bilateral CAI. Movement control was measured during single leg stance in two foot positions, flat and demi-point. Then, the subjects underwent perturbation in the same two positions as the single leg stance. During the perturbation test, perturbation time, or the time it took for the ankle to return to baseline oscillation after sudden inversion, was measured and compared between groups. Results showed that in all conditions except the baseline oscillation with the foot flat (single leg stance) more subjects with CAI failed to complete the test condition. The results suggest that differences in sensorimotor control exist between the functionally unstable and control groups. Overall, it is evident from these findings that sensorimotor control is altered in functionally unstable ankles. This deficit in sensorimotor control may be a result of deficits in movement detection or peroneal muscle response. This study indicates that sensorimotor deficits exist in individuals with CAI, however further research must be done to explore the cause of these postural impairments and to develop possible rehabilitation guidelines.
Although static balance is essential to daily living, dynamic balance is more functional and is much more likely to be impaired following ankle injury. Wilkstrom et al.\textsuperscript{2} express a critical need to quantify dynamic postural stability after an ankle sprain in efforts to allow clinicians to investigate the effects of CAI during dynamic tasks. A recent study by Noronha et al.\textsuperscript{31} investigated the relationship between postural control and functional ankle instability during a dynamic hop-landing task. They included 60 volunteers and classified them according to the Cumberland Ankle Instability Tool as having unstable or stable ankles. The Cumberland Ankle Instability Tool is a questionnaire that is used for measuring severity of functional ankle instability. It is a self-administered questionnaire that consists of 9 questions relating to the subjects’ perception of ankle stability during various activities. The landing task involved the subject standing on one foot on a step for approximately 3 seconds, then hopping down onto a force plate and regaining postural stability after landing.\textsuperscript{31} The outcome measures included TTS after landing for inversion and dorsiflexion, as well as measuring movement in the frontal plane for the hip and ankle, the variability on inversion movement prior to hopping and ground reaction force. They observed that there was a significant difference in performance of the landing task between groups. When measuring TTS for inversion, the instability group took significantly longer than the control group. Also, the inversion variability measure taken prior to the hop was greater in the CAI group than in the control.

These findings suggest that individuals with CAI have a disruption of somatosensory receptors that result in decreased sensorimotor function. This delay and deficit in sensory motor response may disrupt postural equilibrium and the ability to maintain it during different balance tasks. It is possible that the deficits seen in the CAI group are more localized to the joint ankle itself. This warrants for further research on ankle joint arthrokinematics and the possibility of
limited joint motion playing a role in dynamic postural control deficits.

Detection of dynamic postural control has been studied in efforts to determine the effects that CAI has on dynamic tasks that are especially prevalent amongst physically active individuals. Wilkstrom and colleagues\(^1\) examined which combination of landing techniques and analysis would be the most effective at detecting differences in dynamic stability between subjects with CAI and healthy subjects. Fifty-eight subjects, half with CAI and half with stable ankles participated in the study. The subjects underwent two different landing protocols: a step down and a jump task. Time to stabilization was measured for each technique in multiple directions including A/P, M/L and vertical directions.\(^1\) Results showed that the jump protocol was most effective in detecting differences in dynamic stability between healthy and CAI groups.\(^1\) With the jump task showing promising effects on measuring ankle stability, further research should incorporate this task as an outcome measure following some type of training or treatment protocol that may help improve proprioceptive deficits in CAI patients.

A subsequent study by the same group\(^2\) incorporated the reliable jump protocol from the prior study and examined whether an index for dynamic postural stability could differentiate between individuals with CAI and those without it. Wilkstrom\(^2\) hypothesized that subjects with CAI would have a higher overall dynamic postural stability index (DPSI) and higher scores on anterior/posterior and vertical direction components. This study consisted of 108 subjects (54 stable and 54 unstable ankles). Subjects were instructed to jump with both legs from a 70cm platform onto a single leg on a force plate. The calculated DPSI scores and directional instability indices showed that the subjects with CAI had higher scores in all components. Although these studies were able to detect differences in dynamic balance in CAI subjects compared to healthy subjects, one must take into account that not all individuals partake in activities that require
jumping and landing.

Postural response of the lower extremity musculature following perturbation has been heavily studied. Brunt and colleagues\textsuperscript{32} investigated postural responses of healthy and functionally unstable people after a perturbation was applied. This study focused on examining stability in the frontal plane as opposed to the sagittal plane. Ten healthy volunteers and five people with recent ankle sprains participated in the study. Subjects were placed on a platform that applied a rotational perturbation in the frontal plane. Investigators were able to examine postural sway by placing surface electrodes over the peroneus longus (PL) and tibialis anterior (TA) and using EMG readings as data. The data suggested that patients with recurrent ankle sprain use a modified postural response following perturbation in order to compensate for instability due to injury. Although these findings suggest that postural response is altered in individuals suffering from ankle instability, further research is recommended using a more dynamic method in efforts to further assess the effects of ligamentous ankle injury on ankle instability.

Furthermore, Hiller\textsuperscript{9} compared balance and recovery from perturbation in subjects who had no history of ankle sprain and in subjects with unilateral or bilateral functional ankle instability. The study used 61 participants who ranged from having a sedentary lifestyle to being an athlete at high level of recreational sport. Participants who were highly trained in dance or gymnastics were excluded in order to ensure that being balance trained would not mask deficits in postural stability that may be present in subjects with CAI. Inversion and eversion ROM as well as ankle joint laxity was measured before the procedure. Each subject was instructed to stand on one foot with eyes closed followed by standing on demi-point for 5 seconds. Results showed significant difference in time to recover for the ankle instability group as compared to
the stable group. Results indicated that during single leg balance, people with ankle instability showed a change from ankle control to postural control at the hip. Furthermore, the longer recovery time after perturbation indicates that functional ankle instability may be the result of a lack of effective control during inversion movement. It can be concluded that people with functional ankle instability, whether balance trained or not, are less able to recover from inversion perturbation, as well as to balance on demi-point and one leg with eyes shut than are people who do not suffer from unstable ankles.

After careful review of the literature it is evident that individuals with CAI suffer from postural control deficits. Postural control or balance problems following ankle injury is very prominent and may be due to decreased joint mobility and strength deficits. Alterations in joint mobility following ankle injury commonly results in impairments of ankle dorsiflexion range of motion. With the incorporation of specific rehabilitation tools, ankle dorsiflexion ROM may be restored. Manual therapy, specifically of the ankle joint, is a treatment intervention that has been heavily studied for its effects on restoring normal ankle joint arthokinematics and motion.

**MANUAL THERAPY**

Passive joint mobilization and mobilization with movement (MWM) techniques are frequently used by physiotherapists and athletic trainers as an intervention for acute ankle inversion sprains. Specifically, these techniques are used to improve dorsiflexion range of motion and posterior talar glide, which are two things that are effected as a result of ankle injury. The inability to dorsiflex is often a complication of ankle injury and has been implicated as a risk factor for recurrent ankle sprain. Restriction of dorsiflexion is commonly seen among individuals with chronic ankle instability and is known to limit gait and many other functional
activities.\textsuperscript{21}

Dorsiflexion ROM can be limited due to various reasons including tightness in the triceps surae muscles, capsular/soft tissue restrictions, loss of posterior glide of the talus in the ankle mortise, and loss of additional motions at other joints of the ankle.\textsuperscript{8} The most common cause of dorsiflexion deficits in individuals with CAI is due to a reduction in posterior glide of the talus.\textsuperscript{8,10} It is suggested that because the talus lacks muscular attachment, it is susceptible to anteriorly subluxing following a disruption to the ligaments that attach to it, which is usually after an inversion ankle sprain.\textsuperscript{8,10} Following an inversion ankle sprain the anterior talofibular ligament (ATF) is usually injured which causes the talus to subluxate anteriorly.\textsuperscript{8} The talus remains in this anterior position until it is returned to its normal position.\textsuperscript{8,10} Additionally, findings suggest that reduced posterior talar glide may foreshadow dorsiflexion ROM deficits, since posterior talar glide is an accessory motion component of ankle dorsiflexion.\textsuperscript{10}

A study by Denegar et al.\textsuperscript{8} investigated the effects of lateral ankle sprain on dorsiflexion ROM, posterior talar glide and joint laxity. Twenty athletes with a history of lateral ankle sprain were used in this study. Both injured and uninjured ankles of each subject were compared for measures of joint laxity, dorsiflexion ROM and posterior talar glide. Results indicated that laxity was greater in the injured ankle and that posterior talar glide was significantly reduced in injured ankles. Dorsiflexion ROM measures were similar between injured and uninjured ankles. It was discussed that dorsiflexion can be almost completely restored by stretching the gastrocnemius-soleus complex. However, the results of this study suggest that although these rehabilitation exercises do restore significant dorsiflexion following ankle injury, normal talocrural joint arthrokinematics have not been restored due to the reduced posterior talar glide of the injured ankles. Therefore, treatment of restricted talocrural arthrokinematics found in unstable ankles
should be considered in efforts to regain complete dorsiflexion motion.

Since ankle dorsiflexion may be due to an anteriorly positioned talus that resulted from ankle sprain injury, it can be assumed that using ankle joint mobilization techniques will improve the arthrokinematics associated with dorsiflexion ROM in CAI individuals. Therefore, ankle joint mobilizations are used to restore the talus to its normal position and may positively influence deficits in functional tasks such as postural control that is found in people with chronic ankle instability.

A recent systematic review evaluated the effectiveness of exercise therapy and manual mobilization of the ankle in acute ankle sprains and in patients with functional ankle instability. With regards manual therapy, they reviewed four studies that specifically showed the effects of manual mobilization of the ankle. Green et al. compared manual mobilization in patients with acute ankle injury. The intervention consisted of 3 sessions of anterior-posterior mobilization of the talus. They found a positive effect on dorsiflexion ROM during the first 3 treatment sessions. Also, Pellow and Brantingham studied the effect of a mortise separation adjustment. The results showed a positive effect on dorsiflexion, pain and function score outcomes up to one month follow-up. This review showed that manual mobilization has an initial effect on dorsiflexion ROM. However, these findings are very limited in that they did not give sufficient insight on functional outcomes that resulted from these techniques.

A recent study by Vicenzino et al. aimed to prove that both weight bearing and non-weight bearing MWM treatment techniques of the talocrural joint improve posterior talar glide as a means of improving dorsiflexion. They hypothesized that a deficit in posterior talar glide and dorsiflexion ROM would be present in people with recurrent ankle sprain and that both MWM treatment techniques would result in improved dorsiflexion and posterior talar glide.
subjects used in this study included 8 males and 8 females with a history of recurrent lateral ankle sprain and deficits in posterior talar glide. A within-subject procedure was used in which subjects underwent weight bearing and non-weightbearing MWM treatments. The non-weightbearing treatment consisted of a posterior talar glide technique which was used to assess posterior glide of the talus in relation to the ankle mortise. The weight bearing technique consisted of a weight bearing lunge with the foot and lower extremity in a standard position. While performing the lunge, the subject was observed to determine when maximum dorsiflexion was attained. The results showed that the use of MWM treatment techniques improved posterior talar glide and dorsiflexion immediately after application in subjects with CAI. All in all, improving dorsiflexion ROM has important implications for full restoration of function following injury. Further research must be done in efforts to evaluate the long term effects of these mobilization techniques on functional ability in individuals with CAI.

Two studies investigated the effects of a thrust manipulation on ROM at the ankle joint in patients with a history of ankle injury. Anderson et al. aimed to determine whether a single high-velocity, low-amplitude (HVLA) thrust manipulation to the talocrural joint would alter ankle ROM in patients with recurrent ankle injury. Manipulation, or HVLA techniques involve a sudden force or thrust that may produce cavitation of a synovial joint. Fifty two male and female volunteers with a history of lateral ligament injury were randomly assigned into either an experimental group who received HVLA thrust or a control group that received no treatment. The HVLA thrust treatment was applied to 26 subjects and consisted of a single caudal thrust with the subject in a supine position. The results showed no significant changes in dorsiflexion ROM between the manipulated ankles and the untreated ankles. A thorough discussion included the suggestion that manipulation may influence ankle proprioception and
stability rather than range of motion. Proprioception is often the first step in rehabilitation following ankle sprain, and assessing proprioception and stability following manipulation treatment may yield more applicable conclusions.

The study conducted by Whitman et al. developed a clinical prediction rule (CPR) to identify patients with sustained ankle injuries who would likely benefit from manual therapy. The treatment program consisted of four components: ankle thrust and non-thrust manipulation, mobility exercises, advice to maintain usual activity within the limits of pain, and instruction in the use of ice and elevation. The thrust technique used included a rearfoot distraction and a proximal tibiofibular posterior-to-anterior thrust manipulation. The non-thrust techniques included an anterior-to-posterior talocrural technique, lateral glide/eversion rearfoot technique and a distal tibiofibular technique. The non-thrust treatments included five 30 second sessions of grade III or IV manipulations. Of the 85 patients used in the study, 64 experienced a successful outcome. The results of this study demonstrated that distal tibiofibular hypomobility responded to manual therapy and exercise; with an improvement in posterior talar glide and dorsiflexion seen as well. Thrust manipulation techniques may have effects on subjects by alleviating biomechanical impairments such as improving position and mobility of the talus and fibular head. This study helped develop a CPR that may provide clinicians with variables that predict which patients benefit from manual therapy and exercise following ankle injury.

Although both studies presented above showed variable effects of manipulation techniques on improving dorsiflexion and joint mobility, further research must be done on joint manipulation to determine if thrust manipulation techniques are more beneficial than mobilization techniques as a rehabilitation tool for individuals with ankle instability. One study by Eisenhart et al. evaluated an osteopathic manipulative treatment (OMT) for patients with
acute ankle injuries. Subjects with unilateral ankle sprain participated and either received manipulation or no treatment. Patients in the manipulation group had significant improvement in edema and pain and a trend toward increased ROM immediately following OMT intervention sessions. A follow-up revealed that ROM significantly improved in the subjects that received OMT in addition to the standard RICE therapy. Many limitations of this study were found and suggest that further investigation be done in efforts to determine long-term outcomes of this type of treatment on ankle injury.

Few studies have been completed showing how manual therapy techniques for the ankle effect functional tasks such as postural control/balance. Postural control is a complex system that involves various sensory and motor components. However, two very recent studies have looked at the effect of ankle mobilization and manipulation on postural control and balance performance in elderly adults. Vaillant et al. aimed to investigate the effect of a therapeutic manipulation of the feet and ankles on postural control during quiet standing. It was proposed that manipulation of somatosensory information from cutaneous, muscles, tendon and joint receptors have an effect on postural control. Seventeen elderly adults participated in the study and were instructed to stand barefoot on a force platform with moving as little as possible. The intervention treatment included massage techniques involving friction and glide force pressure of the plantar sole as well as mobilization techniques involving the mortise, subtalar, midtarsal, tarsometatarsal, intermetatarsal and metatarsophalangeal joints. The subjects’ ability to maintain a stable upright posture was evaluated both pre-treatment and post-treatment while also undergoing changes in the availability of visual information. Results found that the massage and mobilization of the feet and ankles had no immediate effect on postural stability.

A subsequent study by Vaillant et al. also evaluated the effect that massage and
mobilization of the feet and ankles have on balance performance in elderly patients. It is known that decrease in dorsiflexion ROM is associated with normal aging and that reduced ankle range of motion is seen in elderly adults who fall frequently. Consequently, sufficient ROM of the ankle and metatarsophalangeal joints are important biomechanical components that allow for normal balance and movement, both of which are essential to activities of daily living. Included in the study were healthy individuals over the age of 65 with the ability to walk at least 10 meters. Functional tests used were a one leg balance test, a lateral reach test and a timed-up and go test (TUG). The mobilization technique used involved all of the joints of the foot and ankle and their designated motions. Each manipulation was performed three times per foot and a total of 20 minutes of massage and mobilization treatment was done. Results showed a statistically significant improvement for the one leg balance test and TUG test, whereas the lateral reach test did not show much improvement. The improved performances observed in the study could be a result of enhanced somatosensory information to the ascending pathways that effects the kinesthetic senses of the body. However, such improvements may also be related to mechanical effects of the ankle and feet joints themselves. In this study, changes of joint ROM were not measured and should be explored further since other studies have shown the importance of ROM of the feet and ankle joints with regard to balance performance.

It is evident that ankle joint mobilizations positively affect posterior talar glide and ankle dorsiflexion ROM. It has also been shown that ankle joint motion is an important factor in postural stability. However, further research must be done in to find how ankle mobilization techniques affect balance and postural stability in younger physically active individuals with history of ankle instability. However, with enough evidence that shows the positive effects that manual therapy of the ankle joint has on dorsiflexion range of motion and talar glide, it is
probable that further examination of these same manual therapy techniques will show promising effects on postural stability.

CONCLUSION

After review of the literature pertaining to chronic ankle instability and the effects that CAI have on postural control and balance it is evident that there is a great correlation. Also, the effects of manual therapy, specifically ankle joint mobilization techniques, have been studied. There seems to be a positive effect on ankle mobilization on ankle range of motion and joint mobility, especially posterior talar glide. There is still question as to whether manual therapy has a positive effect on postural stability in young athletic individuals. There is still a lot of research that needs to be done regarding the effect that ankle mobilization techniques have on postural control and balance. Specifically, future research needs to aim towards a population of people with chronic ankle instability.
ADDITIONAL REFERENCES


APPENDIX A

Demographic Questionnaire

Subject: _________________________

Height (cm): ______________________

Weight (kg): ______________________

BMI (kg/m²): ______________________

Leg Length (cm)

Involved Leg: ______________________ R L

Uninvolved Leg: _____________________ R L

Leg Dominance: R L
Foot and Ankle Disability Index (FADI) Scoring

FADI ADL Scale

26 questions, each worth a maximum of 4 points (Total of 104 points possible)

Points assigned as follows:

4 – No difficulty at all

3 – Slight difficulty

2 – Moderate difficulty

1 – Extreme difficulty

0 – Unable to do

FADI Sports Scale

8 questions, each worth a maximum of 4 points (Total of 32 points possible)

Points assigned as with FADI ADL scale

Scoring:

1) Have patient answer every question in relation to their condition within the last week
2) Add up scores for each section. Assign points as outlined above. Each section has a separate score.
3) Raw score or percentage score can be used for analysis
# Foot and Ankle Disability Index (FADI)

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)**.

<table>
<thead>
<tr>
<th>Activity</th>
<th>No difficulty at all</th>
<th>Slight difficulty</th>
<th>Moderate difficulty</th>
<th>Extreme difficulty</th>
<th>Unable to do</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking on even ground</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking on even ground without shoes</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking up hills</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking down hills</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Going up stairs</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Going down stairs</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking on uneven ground</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Stepping up and down curbs</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Squatting</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Sleeping</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Coming up on your toes</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking initially</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking 5 minutes or less</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking approximately 10 minutes</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Walking 15 minutes or greater</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
</tbody>
</table>

1999 FADI Interim 1/2
Because of your **foot and ankle** how much difficulty do you have with:

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

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

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

**FADI Sports Scale**

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

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

1999 FADI Interim 2/2
Foot and Ankle Ability Measure (FAAM)

Please answer *every question* with *one response* that most closely describes to 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).

<table>
<thead>
<tr>
<th>Activity</th>
<th>No difficulty</th>
<th>Slight difficulty</th>
<th>Moderate difficulty</th>
<th>Extreme difficulty</th>
<th>Unable to do</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on even ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on even ground without shoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking up hills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking down hills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Going up stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Going down stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking on uneven ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stepping up and down curbs</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squatting</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coming up on your toes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking initially</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Walking 5 minutes or less</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Walking approximately 10 minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Walking 15 minutes or greater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Because of your foot and ankle how much difficulty do you have with:

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

How would you rate your current level of function during your 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 %
FAAM Sports Scale

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

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

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?

□□□□□ □%  

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

□ Normal □ Nearly normal □ Abnormal □ Severely abnormal
Title of Project: The Effect of Manual Therapy on Postural Control in Individuals with Chronic Ankle Instability

Principal Investigator: Sayers John Miller, PhD, PT, ATC

Advisor: Nicole M McBrier, PhD, ATC

Other Investigator(s): Giampietro L Vairo, MS, ATC

Research Assistant(s): Jennifer A Crespo and Christina A Shields

Screening Checklist: Chronic Ankle Instability Patients

Participant Identification Number:_________________________________________

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

1. If you are under 18 years old, do you have parental permission to participate in this study? Yes No

2. Are you recreationally active (defined as individuals engaging in physical activity at least three days per week for 30 minutes over the past six-months)? Yes No

3. Are you between 16 to 35 years old? Yes No

4. Do you have a history of at least one acute ankle sprain that resulted in pain, swelling and loss of function? Yes No

5. Have you experienced at least two episodes of ankle giving way within the past? 3 Months □ 6 months □ 12 months □ None □

6. Do you experience stiffness in your sprained ankle? Yes No

7. Do you speak English? Yes No
As a general health screen, you must be able to answer ‘NO’ to the following questions.

8. Have you followed a formal rehabilitation program under supervision of a physical therapist or athletic trainer?  
   Yes  No

9. Do you have pain above 3 out of 10?  
   Yes  No

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

11. Have you sustained any further traumatic injury to the lower extremity within the last 6 months?  
    Yes  No

12. Have you sustained traumatic injury to the opposite uninvolved leg?  
    Yes  No

13. Is there currently any acute swelling present?  
    Yes  No

14. Are you diabetic or suffer from peripheral neuropathy?  
    Yes  No

15. Have you sustained a concussion within the past six months?  
    Yes  No
Title of Project: The Effect of Manual Therapy on Postural Control in Individuals with Chronic Ankle Instability

Principal Investigator: Sayers John Miller, PhD, PT, ATC

Advisor: Nicole M McBrier, PhD, ATC

Other Investigator(s): Giampietro L Vairo, MS, ATC

Research Assistant(s): Jennifer A Crespo and Christina A Shields

Screening Checklist: Control Patients

Participant Identification Number: 

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

1. Are you recreationally active (defined as individuals engaging in physical activity at least three days per week for 30 minutes over the past six-months)? Yes No

2. Are you between 16 to 35 years old? Yes No

3. Do you speak English? Yes No

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

4. Have you sustained traumatic injury to any joint on either of your legs? Yes No

5. Are you diabetic or suffer from peripheral neuropathy? Yes No

6. Have you sustained a concussion within the past six months? Yes No
APPENDIX B

ROM

Figure 1 Goniometer placement for straight knee DF

Figure 2 Goniometer placement for bent knee DF

Figure 3 Straight knee DF

Figure 4 Bent knee DF
Star Excursion Balance Test

Figure 5 SEBT Foot position

Figure 6 SEBT Hand position

Figure 7 Marking of excursion
Figure 8 SEBT Anterior direction

Figure 9 SEBT Posterolateral direction

Figure 10 SEBT Posteromedial direction
### DESCRIPTION OF MOBILIZATION/MANIPULATION TECHNIQUES

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description of Technique</th>
<th>Illustration</th>
</tr>
</thead>
</table>
| Lateral glides and eversion mobilization/manipulation | **Talocrural joint lateral glide:**  
- Grasp the malleolus just proximal to talocrural joint with your left index finger, thumb, and web space, and use your forearm to stabilize the patient’s leg against the table  
- Place your right thenar eminence on the talus just distal to malleolus and grasp the rearfoot  
- Use your body to impart a mobilizing force through your right arm and thenar eminence to the medial talus  
**Subtalar joint lateral glide:**  
- Shift your left hand/forearm distally and grasp the talus with your left index finger, thumb, and web space  
- Place your right thenar eminence on the patient’s medial calcaneus and grasp the rearfoot  
- Use your body to impart a mobilizing force through your right arm and thenar eminence to the medial calcaneus | ![Image](image1) |
| Proximal tibiofibular joint thrust mobilization/manipulation | **Place your second metacarpophalangeal (MCP) joint in the popliteal fossa, then pull the soft tissue laterally until your MCP is firmly stabilized behind the fibular head**  
- Use your right hand to grasp the foot and ankle as demonstrated  
- Externally rotate the leg and flex the knee to the restrictive barrier (you should feel firm pressure from the fibular head over the palmar aspect of your MCP)  
- Once at the restrictive barrier, apply a high-velocity, low-amplitude thrust through the tibia (direct the patient’s heel towards the ipsilateral buttock) | ![Image](image2) |
| Distal tibiofibular joint mobilization/manipulation (AP mobilization/manipulation to the distal fibula) | **Place the distal leg at the edge of the table. Use your leg to stabilize the foot (and move the ankle into progressive dorsiflexion)**  
- Grasp and stabilize the distal tibia with one hand  
- Place your thenar eminence over the lateral malleolus and use your body to impart an anterior-to-posterior-directed mobilizing force (through your arm and thenar eminence) | ![Image](image3) |
| Rearfoot distraction thrust mobilization/manipulation | **Grasp the dorsum of the patient’s foot with interlaced fingers**  
- Provide firm pressure with both thumbs in the middle of the plantar surface of the forefoot  
- Engage the restrictive barrier by dorsiflexing the ankle and applying long axis distraction  
- Pronate and dorsiflex the foot to fine-tune the barrier  
- Apply a high-velocity, low-amplitude thrust in a caudal direction  
**Tip:**  
- For some patients, it may also help to internally rotate the hip a bit when positioning the patient for this technique. This will decrease the amount of motion that will be created at the hip as you perform the distraction | ![Image](image4) |
| Talocrural joint anterior-to-posterior mobilization/manipulation | **Use your left hand to firmly stabilize the lower leg at the malleoli**  
- Grasp the anterior, medial, and lateral talus with your right hand  
- Apply an anterior-to-posterior oscillatory mobilization force to the talus  
**Tips:**  
- You may need to adjust the amount of supination/pronation to optimize the technique  
- Use your thigh to help stabilize the foot and to progressively increase the amount of ankle dorsiflexion as range of motion improves. As you gradually increase dorsiflexion, your angle of glide should move to follow the plane of the joint (it will aim more inferiorty and create a bit of distraction with the anterior-to-posterior force) | ![Image](image5) |
| Alternate method of talocrural joint anterior-to-posterior mobilization/manipulation | **The clinician grasps and supports the arch of the foot and applies a stabilizing force (anterior-to-posterior-directed force) over the anterior talus**  
- A padded belt is placed over the patient’s distal posterior tibia and fibula and around the clinician’s buttock region  
- The patient is guided into dorsiflexion of the involved ankle while, simultaneously, the clinician produces a posterior-to-anterior-directed force to the distal leg by pushing/moving backwards and pulling on the belt  
- The forces and direction of motion and stabilization should be adjusted until the patient experiences a pain-free motion of ankle dorsiflexion | ![Image](image6) |
## ANKLE EXERCISE

<table>
<thead>
<tr>
<th>Component</th>
<th>Procedure</th>
<th>Duration and Frequency</th>
<th>Comments or Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles tendon stretch, non-weight bearing with the knee extended</td>
<td>Use a towel to pull foot toward your face while you keep your knee straight</td>
<td>Pain-free stretch for 30 seconds; perform 3 repetitions; repeat twice daily</td>
<td>Keep your leg in an elevated position</td>
</tr>
<tr>
<td>Achilles tendon stretch, weight bearing</td>
<td>In standing, lean forward while keeping your heel on the floor and your knee straight. Lean forward until you feel a stretch in the calf and/or Achilles region</td>
<td>Pain-free stretch for 30 seconds; perform 3 repetitions; repeat twice daily</td>
<td>Do not allow your heel to rise, keep toes pointed towards the wall</td>
</tr>
<tr>
<td>Alphabet exercises</td>
<td>Move ankle in multiple planes of motion by “drawing” all of the letters of alphabet (lower case and upper case)</td>
<td>Repeat twice daily</td>
<td></td>
</tr>
<tr>
<td>Ankle eversion self-mobilization</td>
<td>Stabilize your leg with your arm as shown. Your stabilizing hand should wrap around the very end of your leg, just above your ankle. Use your other hand to grasp the back part of your foot and push towards the floor</td>
<td>Perform in an on-off fashion 30 times, repeat 3 times</td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion self-mobilization</td>
<td>The foot/ankle you are stretching should be placed behind the other as shown. Make sure that your foot is pointed straight forward. Bring your knee forward while “driving” the heel down and back. Keep your heel in contact with the floor at all times. You should feel a stretch deep in the back part of the ankle. If you feel a “pinch” in front of the ankle, your therapist will help you to adjust your foot position to minimize the “pinch” and maximize the stretch</td>
<td>Perform in an on-off fashion 30 times, repeat 3 times</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D

Informed Consent Form for Biomedical Research
The Pennsylvania State University
CHRONIC ANKLE INSTABILITY PARTICIPANTS
(18-35 years old)

Title of Project: The Effect of Manual Therapy on Postural Control in Individuals with Chronic Ankle Instability

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

Advisor: Nicole M McBrier, PhD, ATC
Assistant Professor of Kinesiology
Department of Kinesiology
146 Recreation Building
University Park PA 16802
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814-863-9732

Other Investigator(s): Giampietro L Vairo, MS, ATC
PhD Candidate in Kinesiology
Department of Kinesiology
146 Recreation Building
University Park PA 16802
glv103@psu.edu
814-865-2725

Research Assistant(s): Jennifer A Crespo
Schreyer Honors College Undergraduate Students
Department of Kinesiology
146 Recreation Building
University Park PA 16802
Jac5208@psu.edu
814-865-4303

Christina A Shields
Undergraduate Student
Department of Kinesiology
146 Recreation Building
University Park PA 16802
Cas5148@psu.edu
814-865-4303
1. **Purpose of the study:** The purpose of this research is to study the effects of a manual therapy treatment on dynamic and static balance in people with chronic ankle instability. A total of 32 people between the ages of 16-35 years old will be taking part in this study. Sixteen people are in the manual therapy treatment group and 16 will be in the sham treatment control group.

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 16-35 years old. You have also have chronic ankle instability, history of at least one acute ankle sprain, at least two episodes of ankle giving way within the past 3 months, and are not currently in a rehabilitation program.

3. **Procedures to be followed:** If you chose to participate in this research study, you will be asked to perform the following procedures:

   **Procedures**

   A. We will begin the study by asking you to complete two subjective analyses questionnaires which will determine the severity of your chronic ankle instability condition. These self reports are used to evaluate and assess functional limitations that result from chronic ankle instability. These questionnaires will help us understand how you would personally describe your ankle during activities of daily living or during athletic tasks such as running. The results of these questionnaires will help us assess how you feel before and after treatment. You will need to repeat these questionnaires during the third session.

   B. We will measure ankle range of motion using a measuring tool. This test will be performed by either the primary or co-investigators.

   C. 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 maintaining 45 degrees of knee flexion and 30 degrees of hip flexion of the non-stance leg. Measures of balance will be taken using a force platform which is hooked up to a computer.

   D. You will be asked to perform another single-leg balance task called the Star Excursion Balance Test. For the Start Excursion Balance Test you stand in place on one leg in the middle of the star and reach as far as possible with your other leg in eight different directions: front, same-side diagonal front, same-side, same-side diagonal back, back, opposite-side diagonal back, opposite-side, opposite-side diagonal front. You will be given four (4) practice trials and complete three (3) testing trials. You will be given a five (5) minute rest period between the practice and test trials. A picture of the Star Excursion Balance Test is below.

   ![Star Excursion Balance Test Diagram](image)

   **Left Limb Stance**

   Opposite-side
   Diagonal Front

   Opposite
   Side

   Opposite-side
   Diagonal Back

   Same-side
   Diagonal Back

   **Right Limb Stance**

   Same-side
   Diagonal Front

   Opposite-side
   Diagonal Front

   Opposite
   Side

   Opposite-side
   Diagonal Back

   Same-side
   Diagonal Back
E. After you’re done with testing procedures A through D you have finished the baseline testing of your first session. You will then undergo a treatment session and be asked to perform testing procedures A through D again. You will be asked to come back to the Athletic Training Research Laboratory in three (3) days to complete a second session comprised of treatment only. After completing the second session you will report back once more after 2 weeks and will perform testing procedures A through D. After completing the third session your participation in the research study is done.

4. **Discomforts and risks:** The discomforts and risks with participation in this type of research study are minimal. The tests used are within expected ranges for physically active people. 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 possible 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 chronic ankle instability symptoms. We will take every possible effort to watch for and help prevent against any discomforts and risks.

5. **Benefits:** There is no direct benefit to you from participating in this research study. The benefits to society include recognizing potential advantages from using manual therapy techniques on balance performance in patients suffering from chronic ankle instability.

6. **Duration/time of the procedures and study:** The first two (2) treatment sessions are at least three (3) days apart and last about one hour each. The third session of testing will be performed two weeks are the initial treatment session and will last about thirty minutes. All testing takes place in the Athletic Training Research Laboratory in 21E Recreation Building on Penn State’s University Park Campus.

7. **Alternative procedures that could be utilized:** There are no known alternative procedures used to answer the research questions of this study.

8. **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.

9. **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 those who wish to seek additional assistance includes the following:

Penn State University Health Services
10. 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.

11. 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 testing procedures the investigators listed on this informed consent form 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 John 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.

12. 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
Title of Project: The Effect of Manual Therapy on Postural Control in Individuals with Chronic Ankle Instability

Principal Investigator: Sayers John Miller, PhD, PT, ATC
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Other Investigator(s): Giampietro L Vairo, MS, ATC
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1. **Purpose of the study:** The purpose of this research is to study the effects of a manual therapy treatment on dynamic and static balance in people with chronic ankle instability. A total of 32 people between the ages of 16-35 years old will be taking part in this study. Sixteen people are in the manual therapy treatment group and 16 will be in the sham treatment control group.

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 16-35 years old. You have also have chronic ankle instability, history of at least one acute ankle sprain, at least two episodes of ankle giving way within the past 3 months, and are not currently in a rehabilitation program.

3. **Procedures to be followed:** If you chose to participate in this research study, you will be asked to perform the following procedures:

**Procedures**

A. We will begin the study by asking you to complete two subjective analyses questionnaires which will determine the severity of your chronic ankle instability condition. These self reports are used to evaluate and assess functional limitations that result from chronic ankle instability. These questionnaires will help us understand how you would personally describe your ankle during activities of daily living or during athletic tasks such as running. The results of these questionnaires will help us assess how you feel before and after treatment. You will need to repeat these questionnaires during the third session.

B. We will measure ankle dorsiflexion range of motion using a goniometer. This test will be performed by either the primary or co-investigators.

C. 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 maintaining 45 degrees of knee flexion and 30 degrees of hip flexion of the non-stance leg. Measures of balance will be taken using a force platform which is hooked up to a computer.

D. You will be asked to perform another single-leg balance task called the Star Excursion Balance Test. For the Star Excursion Balance Test you stand in place on one leg in the middle of the star and reach as far as possible with your other leg in eight different directions: front, same-side diagonal front, same-side, same-side diagonal back, back, opposite-side diagonal back, opposite-side, opposite-side diagonal front. You will be given four (4) practice trials and complete three (3) testing trials. You will be given a five (5) minute rest period between the practice and test trials. A picture of the Star Excursion Balance Test is below.
E. After you’re done with testing procedures A through D you have finished the baseline testing of your first session. You will then undergo a treatment session and be asked to perform testing procedures A through D again. You will be asked to come back to the Athletic Training Research Laboratory in three (3) days to complete a second session comprised of treatment only. After completing the second session you will report back once more after 2 weeks and will perform testing procedures A through D. After completing the third session your participation in the research study is done.

4. Discomforts and risks: The discomforts and risks with participation in this type of research study are minimal. The tests used are within expected ranges for physically active people. 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 possible 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 chronic ankle instability symptoms. We will take every possible effort to watch for and help prevent against any discomforts and risks.

5. Benefits: There is no direct benefit to you from participating in this research study. The benefits to society include recognizing potential advantages from using manual therapy techniques on balance performance in patients suffering from chronic ankle instability.

6. Duration/time of the procedures and study: The first two (2) treatment sessions are at least three (3) days apart and last about one hour each. The third session of testing will be performed two weeks are the initial treatment session and will last about thirty minutes. All testing takes place in the Athletic Training Research Laboratory in 21E Recreation Building on Penn State’s University Park Campus.

7. Alternative procedures that could be utilized: There are no known alternative procedures used to answer the research questions of this study.

8. 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.

9. Right to ask questions: Please contact Giampietro “John” L Vairo at 814-865-2725 or 412-225-5276 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 those who wish to seek additional assistance includes the following:

Penn State University Health Services
10. 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.

11. 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 testing procedures the investigators listed on this informed consent form 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 Giampietro “John” L Vairo immediately at 814-865-2725 or 412-225-5276. If you cannot reach John please leave him a voicemail and contact your doctor.

If you are a Penn State student and cannot reach John or your doctor (Wayne J Sebastianelli or Paul S Sherbondy) 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 John or your doctor please leave them voicemails and contact your private medical provider.

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12. 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.

13. Protected health information: Health information about you will be collected because you are a part of this research study. The privacy law, Health Insurance Portability & Accountability Act (HIPAA), protects your health information. The privacy law requires you to sign an authorization in order for researchers to be able to use or disclose your protected health information for research purposes in this study. The required HIPAA authorization form is attached to the end of this document. Please read and sign the HIPAA authorization form.

14. Payment for participation: You have the potential to earn a total of $50.00 for your participation in this research study. A one-time payment of $50.00 in the form of a check is made immediately following the single laboratory testing session you attend.

15. Sponsor: The Pennsylvania Athletic Trainers’ Society, Inc. has no financial interest in this research study. No individuals from the Pennsylvania Athletic Trainers’ Society, Inc. will be present during your recruitment or testing session nor will they be involved in the analysis or your results.
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
ACADEMIC VITA of Jennifer A. Crespo

Jennifer A. Crespo
235 S. Buckhout St. Apt. B6
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Education:
Bachelor of Science Degree in Kinesiology, Penn State University, Spring 2010
Honors in Kinesiology
Thesis Title: The Effect of Manual Therapy on Postural Control in Individuals with Chronic Ankle Instability
Thesis Supervisor: Dr. Nicole McBrier and Sayers John Miller, III

Related Experience:
Student Athletic Trainer for different Division I athletic teams
Supervisor: Dr. Lauren Kramer
Fall 2007 to Spring 2010

New York Giants Rookie Mini Camp Intern
Supervisor: Ronnie Barnes
May 8, 2009 – May 10, 2009

First Responder- Penn State Sports Camps
Supervisor: John Vairo
Summer 2009

Physical Therapy Aide at Sports Care Institute of America
Supervisor: Jim Neilan
Summer 2008

Awards:
Bunton Waller Fellowship (Fall 2006- present)
Dean’s List (Fall 2006, Spring 2007, Fall 2007, Spring 2008, Fall 2008, Spring 2009, Fall 2009)
Phi Eta Sigma National Honors Society

Presentations/Activities:
Penn State Dance Marathon Operations committee member (Fall 08- Spring 09)
Volunteer Athletic Training Student for Penn State Dance Marathon
Pennsylvania Athletic Trainers’ Society Student Symposium conference attendee
Penn State Athletic Training Club member