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THE EFFECTS OF MANUAL THERAPY AND BALANCE TRAINING ON PERFORMANCE OUTCOMES IN INDIVIDUALS WITH CHRONIC ANKLE INSTABILITY

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ABSTRACT

THE EFFECTS OF MANUAL THERAPY AND BALANCE TRAINING ON PERFORMANCE OUTCOMES IN INDIVIDUALS WITH CHRONIC ANKLE INSTABILITY

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Objective: To determine if a combination of manual therapy and balance training improves performance outcomes in chronic ankle instability (CAI) participants when compared to respective stand-alone treatments. We hypothesized that the combination would yield greater improvements compared to stand-alone treatments. **Design and Settings:** A pretest-posttest experimental design conducted in a laboratory setting. The manual therapy (MT) group received Maitland's grade III/IV ankle mobilizations and high-velocity, low-amplitude thrust manipulation treatments administered three times over one week. The balance training (BT) group performed hop-to-stabilization activities and single-leg stance exercises three times a week over four weeks. The manual therapy and balance training (MTBT) underwent multimodal interventions that paralleled parameters described for the MT and BT groups. Data was collected at baseline and four weeks following treatment. **Subjects:** Eighteen (10 men, 8 women) CAI participants were randomly assigned to a group: MT (23.5 ± 1.8 years, 1.8 ± 0.1 m, 71.2 ± 11.7 kg), BT (20.7 ± 1.8 years, 1.8 ± 0.1 m, 76.4 ± 10.1 kg), MTBT (20.5 ± 1.7 years, 1.7 ± 0.1 m, 72.3 ± 8.3 kg). **Measurements:** Passive and active dorsiflexion range of motion (ROM) using standard goniometry; center of pressure path length and average velocity during a static balance task using a force platform; modified Star Excursion Balance Test (SEBT) reach distances; and crossover hop test distances. Order of testing was randomized to prevent order effects. **Results:** Dorsiflexion ROM was significant at baseline {passive (°): [MT|39.0 ± 6.8, BT|39.5 ± 3.6, MTBT|49.2 ± 8.5, $P = 0.000$]; active (°): [MT|34.8 ± 5.7, BT|37.3 ± 3.1, MTBT|44.2 ± 8.2, $P = 0.000$]} and post-treatment: {passive (°): [MT|43.3 ± 5.6, BT|40.8 ± 5.7, MTBT|53.3 ±11.2, $P = 0.000$]; active (°): [MT|40.8 ± 5.2, BT|37.3 ± 5.4, MTBT|51.0 ± 11.9, $P = 0.000$]} for the involved leg. Eyes-closed static balance was significant at baseline {path length (cm): [MT|79.1 ± 14.3, BT|70.6 ± 14.5, MTBT|67.0 ± 12.2, $P = 0.026$]; average velocity (cm/s): [MT|7.9 ± 1.4, BT|7.1 ± 1.4, MTBT |6.7 ± 1.2, $P = 0.026$]} and post-treatment: {path length (cm): [MT|70.2 ± 14.3, BT|64.5 ± 11.8, MTBT|65.4 ± 17.7, $P = 0.026$]; average velocity (cm/s): [MT|7.0 ± 0.7, BT|6.4 ± 1.2, MTBT|6.5 ± 1.8, $P = 0.026$]} for the involved leg. **Conclusions:** Post hoc baseline measures suggest heterogeneity among groups, which may underpin the lack of statistical significance for our comparisons. However, trends were observed indicating a therapeutic effect that may suggest clinical significance. **Word Count:** 400.

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CHAPTER 1: INTRODUCTION

Ankle sprains are among the most common musculoskeletal injuries and have a high recurrence rate.[1] In addition, chronic ankle instability (CAI) is often defined as having a history of one or more ankle sprains as well as multiple episodes of the ankle "giving way."[2] It has been reported that the incidence of developing CAI after a lateral ankle sprain is between 31% and 40%.[3] This condition has been associated with impairments such as poor arthrokinematics, reduced dorsiflexion (DF), and decreased postural control.[4] Previous investigators have studied the effectiveness of various independent rehabilitative interventions, such as manual therapy and balance training to improve these impairments, which could have clinical significance when treating those with CAI. For instance, Hoch et al[4] found patients suffering from CAI demonstrated improved postural control after a manual therapy treatment. Furthermore, McKeon et al[2] reported CAI patients displayed improved perceived function as well as dynamic and static balance following a balance training program, which complements similar noted trends in the literature.[1,5-7] In addition, the results of various research studies have shown a reduction in the recurrence of lateral ankle sprains following balance training programs.[1,5-7] Both McGuine et al[1] and Mohammadi et al[7] reported that the incidence of ankle sprains was significantly lower in a balance training intervention group compared to a control group. Therefore, balance training may be clinically effective in improving function in CAI individuals and aiding in preventing further injuries. However, there is limited evidence on the effects of multimodal treatment, such as combining manual therapy and balance training, on performance outcomes in CAI patients. Therefore, the purpose of this clinical research study was to investigate if a combination of joint mobilizations to the associated shank and foot segment joints, and balance training exercises were beneficial in improving the functional performance of individuals with CAI. These benefits include improvements in subjective reports of ankle joint health-related quality of life, DF range of motion (ROM), balance, and lower extremity functionality. Based on previous findings,[2,4] we hypothesized that the multimodal regimen would elicit greater improvements in path length and average velocity for static

balance, reach distance for dynamic balance, and hop distance for the crossover hop compared to the manual therapy or balance training treatments alone.

CHAPTER 2: MATERIALS AND METHODS

Experimental Design & Setting:

This study was completed in the Athletic Training and Sports Medicine Research Laboratory at The Pennsylvania State University. A pretest-posttest true experimental design was utilized for this investigation. Eighteen participants volunteered for this research study. Before enrolling in the research study, all participants provided written informed consent per Institutional Review Board guidelines. All participants were randomly assigned to one of three treatment groups: manual therapy (MT), balance training (BT), or manual therapy and balance training (MTBT) based on random permutations generated by statistical software (Minitab 16, Minitab Inc., State College, PA). Dependent variables of interest included: ankle DF ROM via standard goniometry; dynamic balance as measured by the Star Excursion Balance Test (SEBT); static balance via center of pressure excursion measurements using a force platform; functional performance using a crossover hop for distance test. Comparisons were being made among groups and between the involved and uninvolved leg. The sequence of testing leg and battery of tests were randomized as previously described to prevent order effects.

Participants:

Eighteen participants were enrolled in this study and six participants were included in each of the three groups. A screening questionnaire was used to determine if the participants met all of the necessary inclusion criteria. Before data collection began, all individuals walked for five minutes on a treadmill at 1.2 m/s for the purposes of a dynamic warm-up.

Table 2.1: Participant Demographics and Anthropometrics

	MT Group	BT Group	MTBT Group	P-Value
Participants	6	6	6	
Sex (Male/Female)	4/2	4/2	2/4	
Age (Years)	23.5 ± 1.8	20.7 ± 1.8	20.5 ± 1.7	0.262
Height (m)	1.8 ± 0.1	1.8 ± 0.1	1.7 ± 0.1	0.758
Mass (kg)	71.2 ± 11.7	76.4 ± 10.1	72.3 ± 8.3	0.650
BMI (kg/m^2)	23.0 ± 2.7	24.8 ± 4.2	24.2 ± 1.8	0.601
LL Involved (cm)	90.8 ± 5.2	92.1 ± 5.2	91.4 ± 5.5	0.921
LL Uninvolved (cm)	90.3 ± 5.0	91.88 ± 5.4	91.4 ± 5.3	0.874

Values are Mean ± Standard Deviation; a one-way analysis of variance was conducted to ensure no statistically significant differences existed among groups for demographic and anthropometric measures ($P < 0.05$)

Inclusion Criteria:

The criteria for inclusion was:

- Between the ages of 16 and 35 years old
- Recreationally active
- Positive for Chronic Ankle Instability based on the Foot and Ankle Disability Index and Foot and Ankle Ability Measure
- Minimal to no pain
- History of at least one acute ankle sprain that resulted in pain, swelling, and loss of function
- Have at least 2 episodes of giving way within the past 3 months
- Not currently in a rehabilitation program
- English speaking
- Minimum of eighth grade literacy

Exclusion Criteria:

The criteria for exclusion was:

- Back problems
- Diabetes or neurological deficits present
- Injury to the lower extremity within past 6 months
- History of concussion
- Acute swelling present
- Pregnant at time of enrollment

Treatment Interventions:

The participants received different interventions based on the group to which they were randomly assigned. Treatment was completed over the course of four weeks and all treatment sessions were conducted at 72-hour intervals. Before the intervention was implemented, participants' baseline data was recorded for straight-leg and bent-leg DF ROM, dynamic balance using the SEBT, static balance using a force plate, and functional performance using the crossover hop test.

Manual therapy has been shown to be beneficial in improving ankle ROM.[8] In this study, participants in the MT group were asked to report to the laboratory three times a week for the initial week alone. They received three separate 15-minute manual therapy sessions, which consisted of Maitland's grade III/IV mobilizations and high-velocity low-amplitude thrust manipulations of shank segment joints involved in ankle DF. Two attempts were permitted to produce cavitation with manipulation. A second attempt was performed if cavitation was not achieved on the first. Maitland's grade III/IV mobilizations were performed as three sets of 30-second bouts at each joint. Specific manual therapy techniques used in this study included a talocrural joint distraction manipulation (Figure 2.1), talocrural joint anterior-to-posterior glide mobilization (Figure 2.2), distal tibiofibular joint anterior-to-posterior glide mobilization (Figure 2.3), posterior proximal tibiofibular joint manipulation, anterior-to-posterior proximal tibiofibular joint glide mobilization (Figure 2.4), anterior proximal tibiofibular joint manipulation, posterior-to-anterior proximal tibiofibular joint glide mobilization (Figure 2.5), and subtalar joint distraction manipulation and mobilization (Figure 2.6).

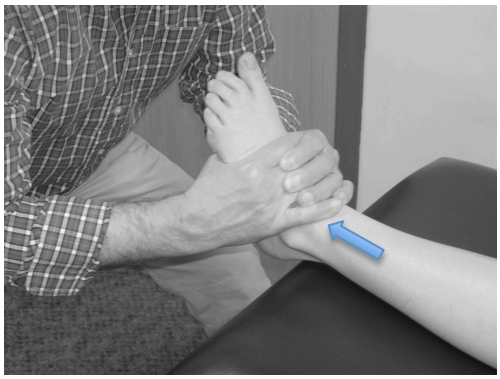


Figure 2.1: Talocrural Joint Distraction Manipulation

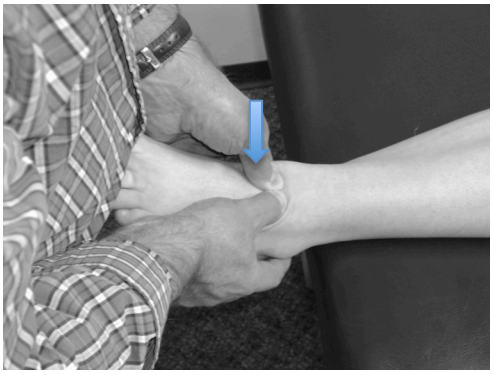


Figure 2.2: Talocrural Joint Anterior-to-Posterior Glide Mobilization

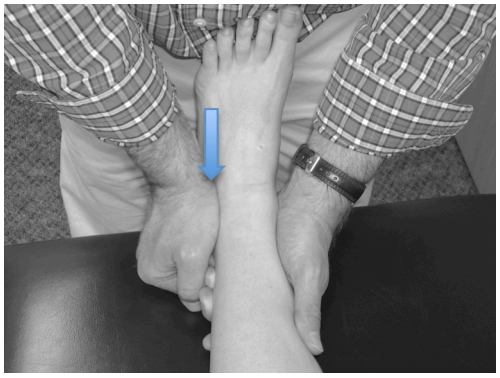


Figure 2.3: Distal Tibiofibular Joint Anterior-to-Posterior Glide Mobilization

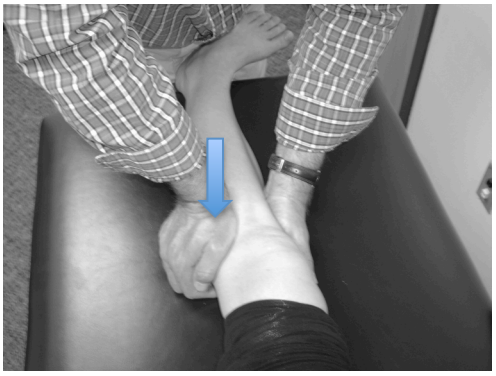


Figure 2.4: Anterior-to-Posterior Proximal Tibiofibular Joint Glide Mobilization

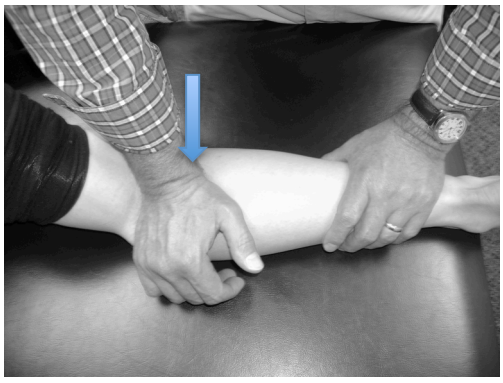


Figure 2.5:Posterior-to-Anterior Proximal Tibiofibular Joint Glide Mobilization

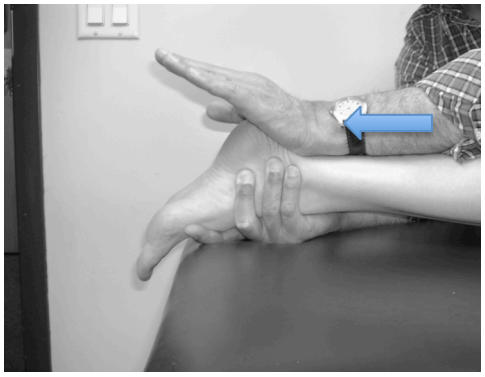


Figure 2.6: Subtalar Joint Distraction Manipulation and Mobilization

Participants in the BT group were asked to report to the laboratory three times a week for four weeks to complete the balance-training program. Sessions lasted approximately 15 minutes. The balance training program used by McKeon et al[2] was used in this study with slight modifications (Appendix H). The program consisted of single-leg hops to stabilization (Figure 2.7 and Figure 2.8), hop to stabilization and reach (Figure 2.9), and single-leg stance activities (Figure 2.10). The single-leg stance activities were adjusted to involve the BOSU (BOSU Balance Trainer, BOSU Fitness, LLC, San Diego, CA) balance trainer. The progression on the BOSU was double-leg (eyes open, eyes closed), single-leg (eyes open, eyes closed), single-leg squat (eyes open, eyes closed), single-leg balance and reach, single-leg squat with diagonal reach, and single-leg balance with ball toss (light weight, and heavy weight). Participants were able to advance to the next level when they were able to complete three sets without error. Errors included: touching down with non-stance leg, excessive trunk motion, removing arms from hips, excessive knee motion, bracing non-stance leg against stance leg, and not reaching 45° of knee bend during squatting activities. Other balance activities followed the procedures outlined by McKeon et al.[2] Post-treatment measures were taken three days after their final treatment session.

Figure 2.7: Hop-to-Stabilization Start Position

Figure 2.8: Hop-to-Stabilization Finish Position

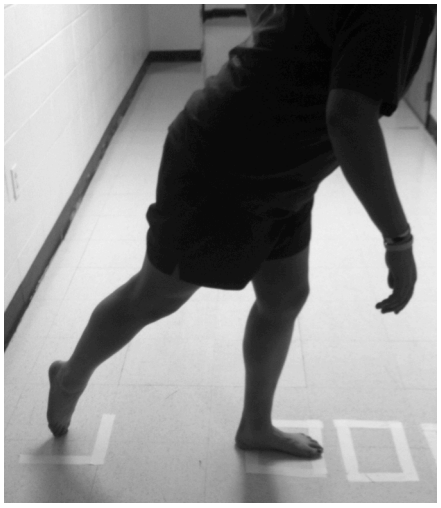


Figure 2.9: Hop-to-Stabilization and Reach Finish Position

Figure 2.10: BOSU Single-Leg Balance

Participants assigned to the MTBT group were asked to report to the laboratory three times a week for four weeks. During the first week, participants completed both the manual therapy intervention and the balance-training program. For the remaining three weeks, the participants completed only the balance training program. Post-treatment measures were taken three days after their final treatment session.

Outcome Measures:

During the first session, participants were asked to complete the Foot and Ankle Disability Index (FADI) (Appendix F) and the Foot and Ankle Ability Measure (FAAM) (Appendix G) questionnaires. All questionnaires were completed under the supervision of the researcher.

Foot and Ankle Disability Index:

The FADI is a self-report outcome survey that was designed to assess functional deficiencies that are present due to foot and ankle conditions.[9] It consists of 33 questions about a person's ability to perform different functional activities. Hale and Hertel[10] examined the reliability and sensitivity of the FADI in individuals with CAI. Based on their results, Hale and Hertel[10] recommend the use of the FADI in studies involving individuals with CAI because the FADI appears to be a reliable and sensitive survey in

detecting functional deficits in those with CAI. In addition, the survey appears to show a difference between healthy individuals and those affected with CAI as well as a difference pre- and post-rehabilitation for individuals with CAI. Based on this evidence, the FADI was used in this study as a survey to assess functional limitations in individuals with CAI.

Foot and Ankle Ability Measure:

The FAAM is a self-report outcome survey that was designed to assess physical function in individuals with foot and ankle conditions.[11] It consists of 31 questions about a person's ability to perform different functional activities that are divided into Activities of Daily Living and Sports subscales. Different studies have shown that the FAAM is an effective tool in assessing the functionality of individuals suffering from various foot and ankle conditions.[11,12] Martin et al[11] developed the FAAM and then investigated its reliability. In their study, they found that the FAAM is a reliable, valid, and responsive measure. Significant differences were reported in individuals with CAI compared to healthy individuals. Similarly, Carcia et al[12] reported that both the ADL and sports subscale scores were significantly lower in individuals suffering from CAI. Both studies[11,12] recommend the use of the FAAM in studies investigating individuals with a foot and ankle condition. Based on this evidence, the FAAM was used in this study as a survey to assess functional limitations in individuals with CAI.

Range of Motion:

Dorsiflexion ROM was measured using a standard manual goniometer. The fulcrum of the goniometer was aligned with the lateral malleolus. The movable arm was positioned parallel to the fifth metatarsal and the stationary arm was aligned with the lower leg. Participants were positioned in a supine position on the table in order to measure straight-leg DF ROM (Figure 2.11 and Figure 2.12). Participants were in a seated position with legs off the table in order to measure bent-leg DF ROM (Figure 2. Active and passive DF ROM were measured in both described positions. Previous literature has reported that standard manual goniometry measurements for ankle DF have high interrater[13-15] and high intrarater[14,16,17] reliability.

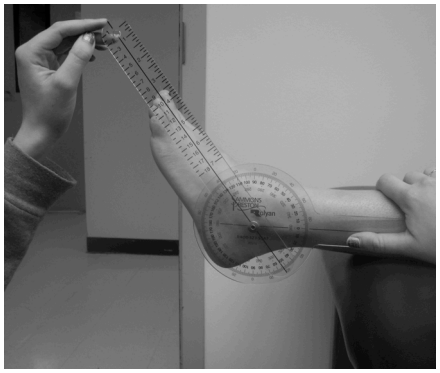


Figure 2.11: Knee-Straight DF ROM Initial Alignment

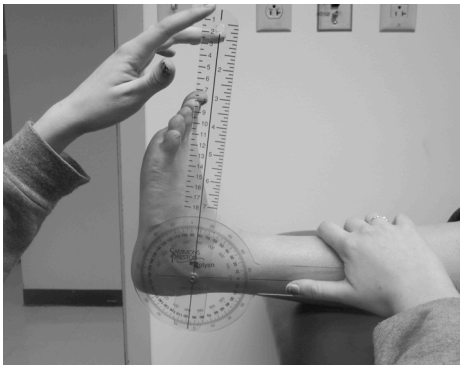


Figure 2.12: Knee-Straight DF ROM Final Alignment

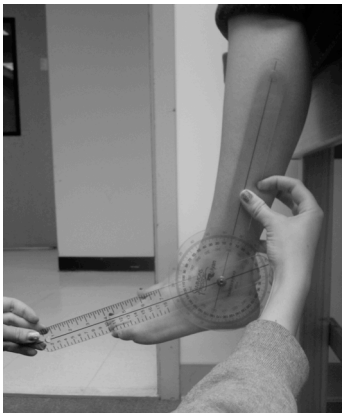


Figure 2.13: Bent-Knee DF ROM Initial Alignment

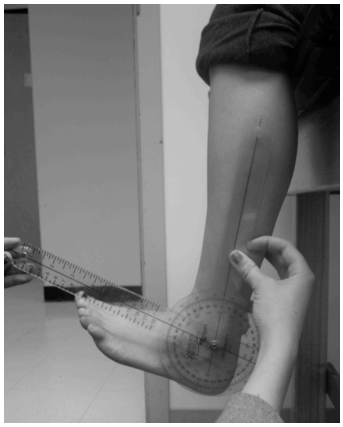


Figure 2.14: Bent-Knee DF ROM Final Alignment

Static Balance:

Static balance was measured using a quiet single-leg balance task. Center of pressure data was collected using an AccuSway force platform (AMTI Corp., Watertown, MA), which was controlled using Balance Clinic computer software (AMTI Corp., Watertown, MA). Participants were asked to stand barefoot on one leg while maintaining balance for a ten-second period. The stance foot was placed in the same position on the force plate for each trial.[18] They were instructed to stand as still as possible with hands on hips and non-stance leg bent 45 degrees with the hip flexed 30 degrees and not touching the stance leg. Three practice trials and three test trials were conducted with eyes-open and eyes-closed for both legs. Thirty-second rest periods separated each trial and a one minute rest period separated practice and test trials. For eyes-open trials, participants were asked to focus on a reference point at eye-level, 10 feet from the force platform. If the participant touched the ground with the non-stance leg during the trial or moved out of the testing position, the trial was thrown out and repeated. This method of testing center of pressure excursion measures has been shown to be reliable and valid in previous research studies.[19,20]

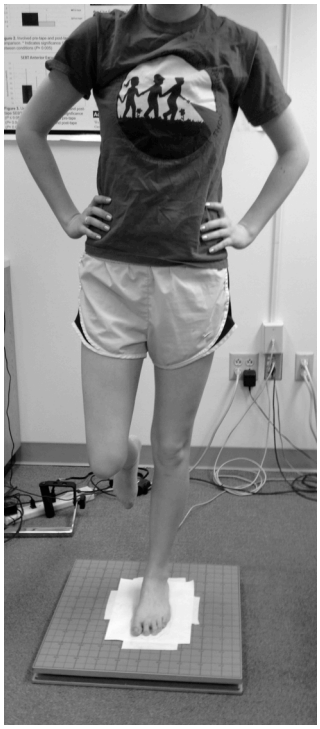


Figure 2.15: Static Balance Position

Dynamic Balance:

The SEBT has been previously shown to be a reliable test for dynamic balance.[21,22] Another benefit of the SEBT is that it has been shown to be effective in screening for functional deficits in various musculoskeletal conditions. Olmsted et al[23] investigated differences in performance on the SEBT between the unaffected leg of an individual with unilateral CAI, the affected leg of an individual with CAI, and individuals without CAI. When standing on their injured leg, individuals with CAI had a significant decrease in the distance they could reach compared to when standing on their uninjured leg as well as compared to individuals without CAI. This finding suggests that the SEBT is a good test to detect functional deficits in individuals with CAI and, therefore, was

determined to be useful in this study for detecting changes in function before and after manual therapy and balance training for individuals with CAI.

The participant was instructed to stand at the center of an outlined floor grid with eight lines extending at 45° angles from the center of the grid. The participant was asked to reach as far as possible with the non-stance leg in the anterior direction (Figure 2.16) without shifting their weight. The researcher measured the distance reached from the toes of the stance leg to the toes of the reach leg for the anterior direction and from the heel of the stance leg to the toes of the reach leg for the posterior directions. The participant was given three practice trials with 15 second rest period between trials followed by a one minute rest period before measured trials began. The participant was then required to perform three measured trials with a 15 second rest period between trials. Trials were discarded and repeated if the participant did not touch the line with the reach leg, transferred weight to the reach leg, removed hands from hips, or did not maintain initial and return positions for at least one second. The same testing protocol was used for the posterolateral (PL) (Figure 2.17) and posteromedial (PM) (Figure 2.18) directions as recommended by Robinson and Gribble.[24] Order of the directions was randomized using statistical software. The average of the three reaches was calculated and normalized by using the non-stance leg length in order to provide a standard comparison among participants.[25]

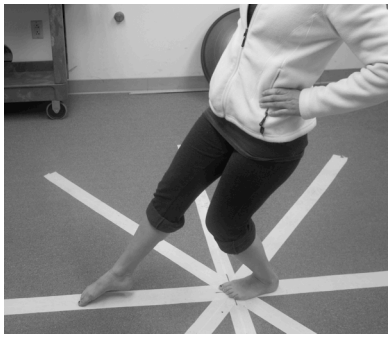


Figure 2.16: Anterior Direction for the SEBT

Figure 2.17: Posterolateral Direction for the SEBT

Figure 2.18: Posteromedial Direction for the SEBT

Crossover Hop for Distance:

The crossover hop is a functional test that has been shown to have high measurement reliability and high intra-tester reliability.[26,27] Moreover, previous studies have shown that individuals with CAI displayed decreased performance on the crossover hop test compared to healthy individuals.[28] An area that was 20 centimeters wide by 900 centimeters long was marked with tape on the floor. Participants were instructed to stand on one leg with the lateral portion of the foot in line with the contralateral edge of the course.[27] They were instructed to try to cover as much distance as possible by completing three consecutive hops, crossing over the thick line with each hop (Figure 2.19). Trials were discarded and repeated if the participant touched the ground with the non-stance leg, paused in the middle of the three hops, or didn't hold the landing position for at least two seconds. The researcher measured the distance covered from the heel in the start position to the heel in the landing position. One practice trial followed by three measured trials were completed with a minute of rest between each trial. The average of the three trials was calculated and normalized by using the stance-leg length in order to provide a standard comparison among participants.

Figure 2.19: Progression of Crossover Hop

Data Analysis:

Descriptive statistics, such as group means and standard deviations, were calculated for each dependent variable. Analysis of variance (ANOVA) was computed using a general linear model to compare dependent variable means among the conditions. Inspection of the standardized residuals was conducted to verify that the data met the necessary assumptions for ANOVA. An a priori alpha level of $P < 0.05$ was used to denote statistical significance. When applicable, Tukey's honestly significant difference (HSD) was used as a post-hoc test for pairwise comparisons. A 95% simultaneous confidence interval was used to determine statistical significance among the pairwise comparisons.

CHAPTER 3: RESULTS

FADI and FAAM:

Residual analyses for these data met the assumptions for ANOVA. No significant differences were observed in the FADI questionnaire score for factors (Group: P-value = 0.320; Time: P-value = 0.266; Group-Time Interaction: P-value = 0.728) among the conditions. Furthermore, no significant differences were observed in the FAAM questionnaire score for factors (Group: P-value = 0.350; Time: P-value = 0.174; Group-Time Interaction: P-value = 0.800) among the conditions. Descriptive statistics for the total FADI and FAAM scores for the involved ankle are listed in Table 3.1.

Table 3.1: Descriptive Statistics for FADI and FAAM Questionnaires of the Involved Ankle

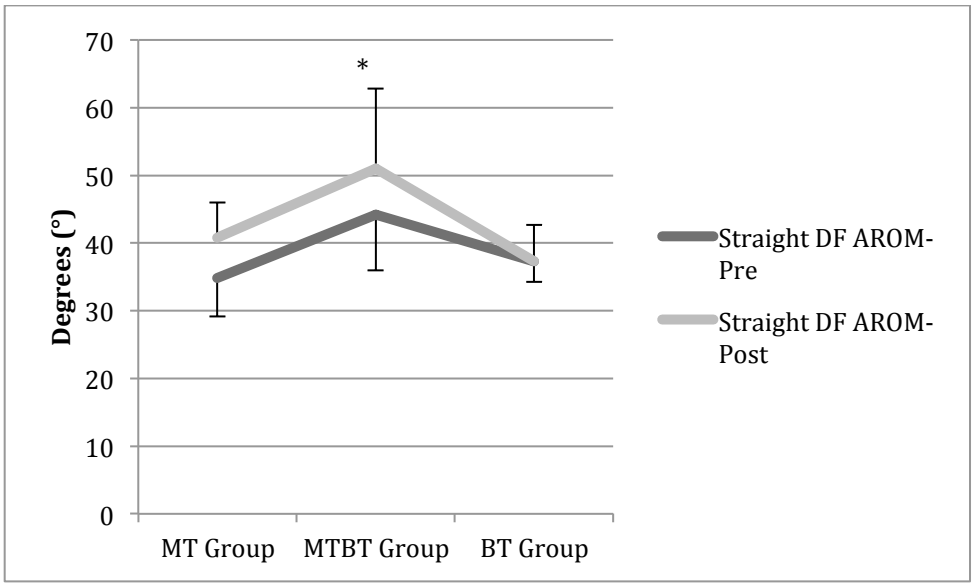
	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
FADI (PRE)	7.2 ± 6.7		4.7 ± 3.6		5.3 ± 3.7	
FADI (POST)	4.8 ± 3.5	-48.3	2.3 ± 2.7	-100	5.3 ± 3.3	0
FAAM (PRE)	5.8 ± 5.1		4.3 ± 3.5		4.7 ± 3.9	
FAAM (POST)	4.3 ± 2.6	-34.6	1.8 ± 1.3	-136.4	4.0 ± 2.5	-16.7

PRE: Pre-Intervention; POST: Post-Intervention; Diff = Difference

Values are Mean ± Standard Deviation

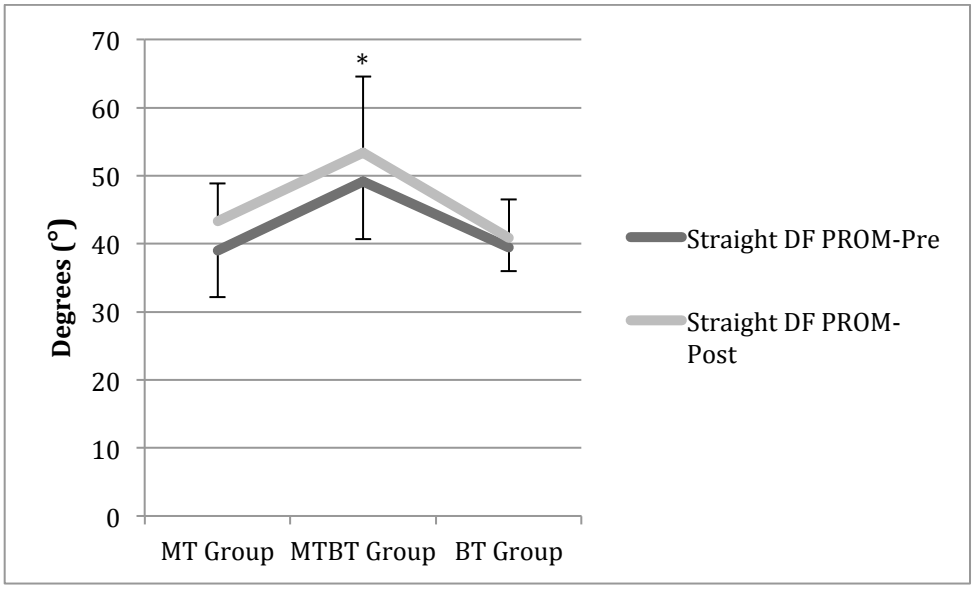
Dorsiflexion Range of Motion:

Residual analyses for these data met the assumptions for ANOVA. Significant differences were found in group means among the conditions for both active (Group: P = 0.000; Time: P = 0.111; Extremity: P = 0.712; Group-Time Interaction: P = 0.581; Group-Extremity Interaction: P = 0.604; Time-Extremity Interaction: P = 0.332) and passive (Group: P = 0.000; Time: P = 0.214; Extremity: P = 0.612; Group-Time Interaction: P-value = 0.908; Group-Extremity Interaction: P = 0.693; Time-Extremity Interaction: P = 0.458) straight-leg DF ROM measures. Pairwise comparisons revealed that straight-leg active and passive DF ROM measures were significantly greater for the MTBT group compared to the MT and BT groups at pre-treatment and post-treatment for both the involved (Figure 3.1, Figure 3.2) and uninvolved legs (Figures 3.3 and 3.4). No significant differences were found for active (Group: P = 0.180; Time: P = 0.260; Extremity: P = 0.756; Group-Time Interaction: P = 0.526; Group-Extremity Interaction: P = 0.559; Time-Extremity Interaction: P = 0.319) or passive (Group: P = 0.165; Time: P = 0.061; Extremity: P = 0.756; Group-Time Interaction: P = 0.575; Group-Extremity Interaction: P = 0.559; Time-Extremity Interaction: P = 0.319) bent-leg DF ROM. Descriptive statistics for bent-knee DF ROM are presented in Table 3.2 and Table 3.3. All other pairwise comparisons were statistically insignificant.



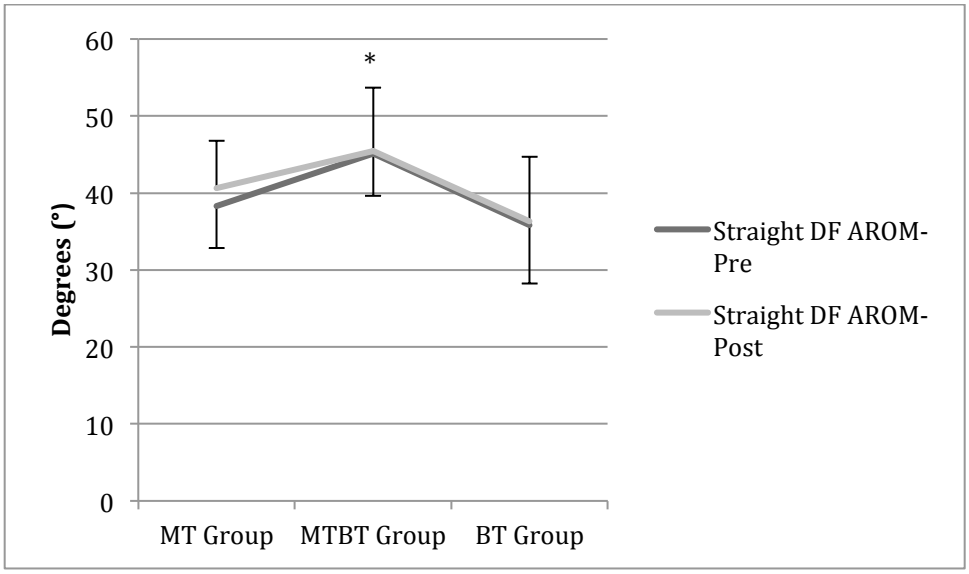
*Denotes statistical significance occurring among the MTBT, BT and MT groups.

Figure 3.1: Straight-Leg DF AROM Among Groups for the Involved Leg



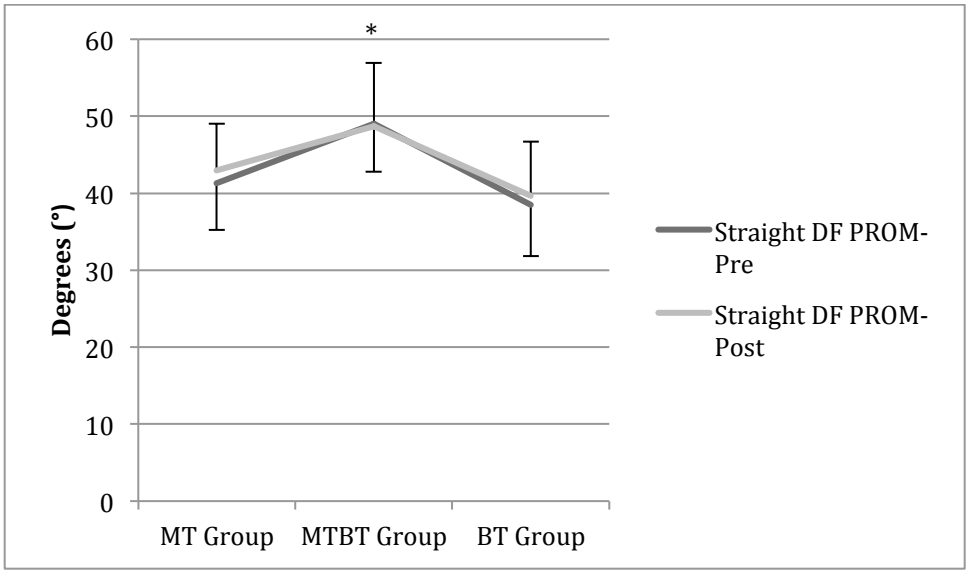
*Denotes statistical significance occurring among the MTBT, BT and MT groups.

Figure 3.2: Straight-Leg DF PROM Among Groups for the Involved Leg



*Denotes statistical significance occurring among the MTBT, BT and MT groups.

Figure 3.3: Straight-Leg DF AROM Among Groups for the Involved Leg



*Denotes statistical significance occurring among the MTBT, BT and MT groups.

Figure 3.4: Straight-Leg DF PROM Among Groups for the Uninvolved Leg

Table 3.2: ROM Descriptive Statistics of the Involved Leg (°)

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Bent DF Passive (PRE)	41.33 ± 7.63		39.50 ± 3.56		45.67 ± 8.66	
Bent DF Passive (POST)	48.33 ± 4.89	21.4	45.00 ± 6.36	7.3	51.83 ± 7.00	19.6
Bent DF Active (PRE)	38.00 ± 8.32		40.33 ± 4.27		41.67 ± 6.47	
Bent DF Active (POST)	43.33 ±3.83	12.3	41.33 ± 5.54	-2.1	47.33 ± 7.00	12.0

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

Table 3.3: ROM Descriptive Statistics of the Uninvolved Leg (°)

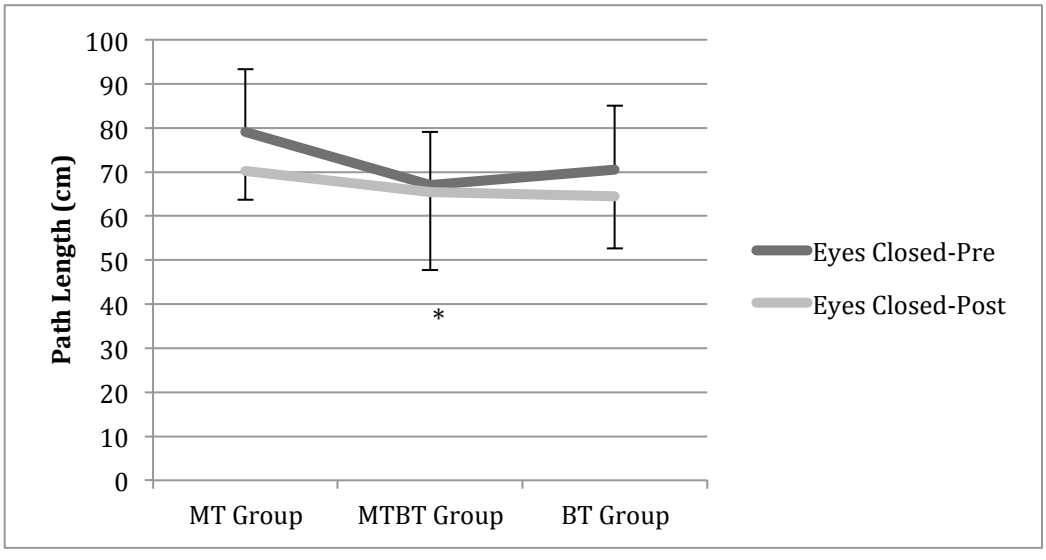
	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Bent DF Passive (PRE)	43.33 ± 6.12		44.50 ± 5.99		45.17 ± 8.73	
Bent DF Passive (POST)	45.17 ± 4.26	4.1	45.00 ± 6.36	1.1	47.17 ± 10.42	4.2
Bent DF Active (PRE)	39.83 ± 5.23		42.00 ± 5.25		42.67 ± 12.04	
Bent DF Active (POST)	40.50 ± 4.55	1.6	41.33 ± 5.54	-1.6	43.33 ± 9.50	1.5

PRE: Pre-Intervention, POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

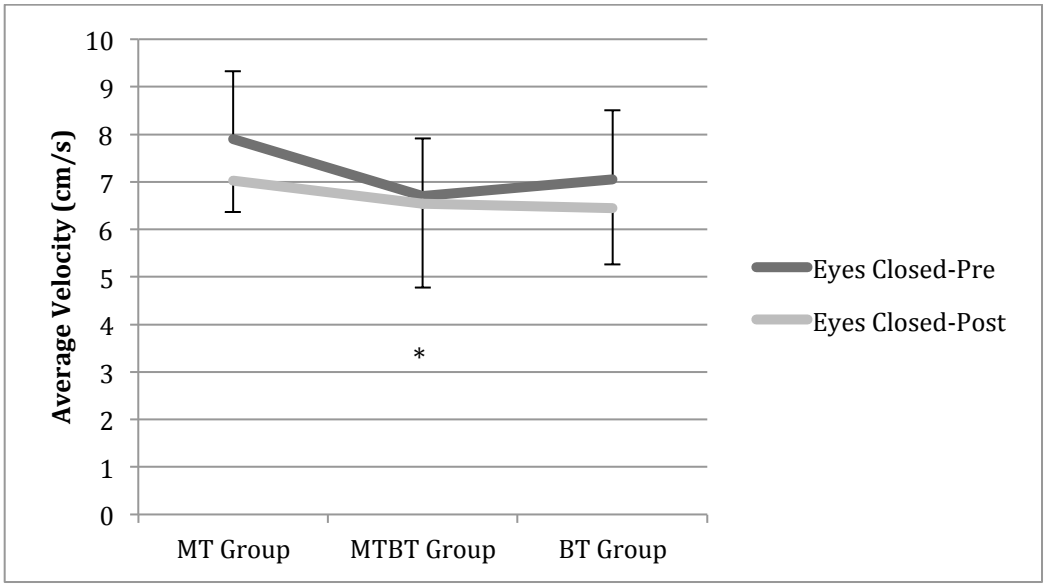
Static Balance:

Residual analyses for these data met the assumptions for ANOVA. No significant differences were found for path length (Group: P = 0.171; Time: P = 0.098; Extremity: P = 0.931; Group-Time Interaction: P = 0.525; Group-Extremity Interaction: P = 0.722; Time-Extremity Interaction: P = 0.656) or average velocity (Group: P = 0.181; Time: P = 0.084; Extremity: P = 0.844; Group-Time Interaction: P = 0.465; Group-Extremity Interaction: P = 0.782; Time-Extremity Interaction: P = 0.584) with the eyes open. Significant differences were found among group means for path length (Group: P = 0.026; Time: P = 0.168; Extremity: P = 0.333; Group-Time Interaction: P = 0.610; Group-Extremity Interaction: P = 0.539; Time-Extremity Interaction: P = 0.675) and average velocity (Group: P = 0.026; Time: P = 0.168; Extremity: P = 0.334; Group-Time Interaction: P = 0.610; Group-Extremity Interaction: P = 0.539; Time-Extremity Interaction: P = 0.673) with the eyes closed. Pairwise comparisons revealed that path length and average velocity were significantly lower for the MTBT group compared to the MT group at pre-treatment and post-treatment for both the involved (Figure 3.5, Figure 3.6) and uninvolved (Figure 3.7, Figure 3.8) legs. Descriptive statistics for path length and average velocity are displayed in Table 3.4 and Table 3.5. All other pairwise comparisons were statistically insignificant.



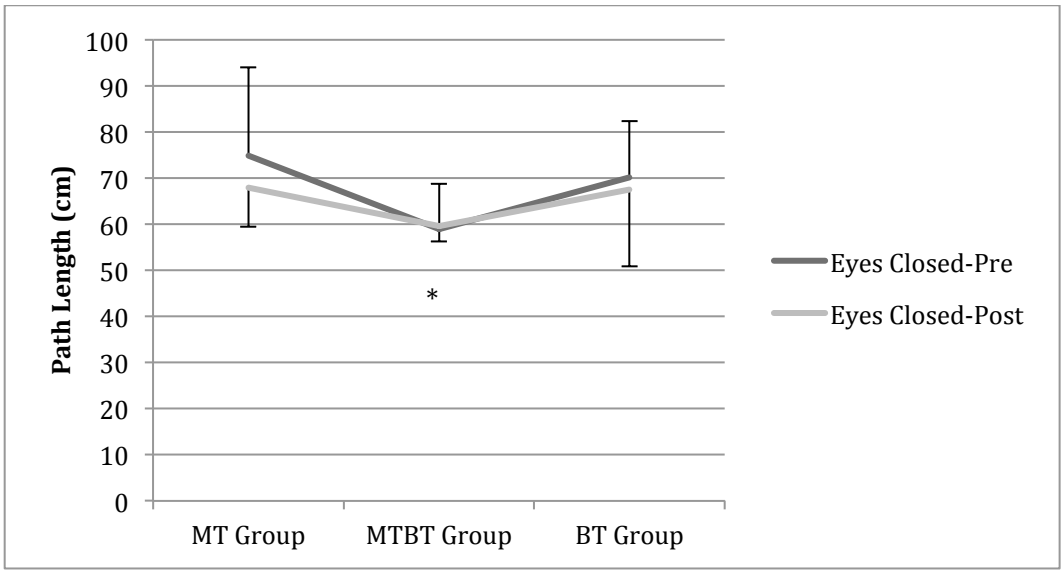
*Denotes statistical significance occurring between the MTBT group and the MT group

Figure 3.5: Path Length with Eyes Closed Among Groups for the Involved Leg



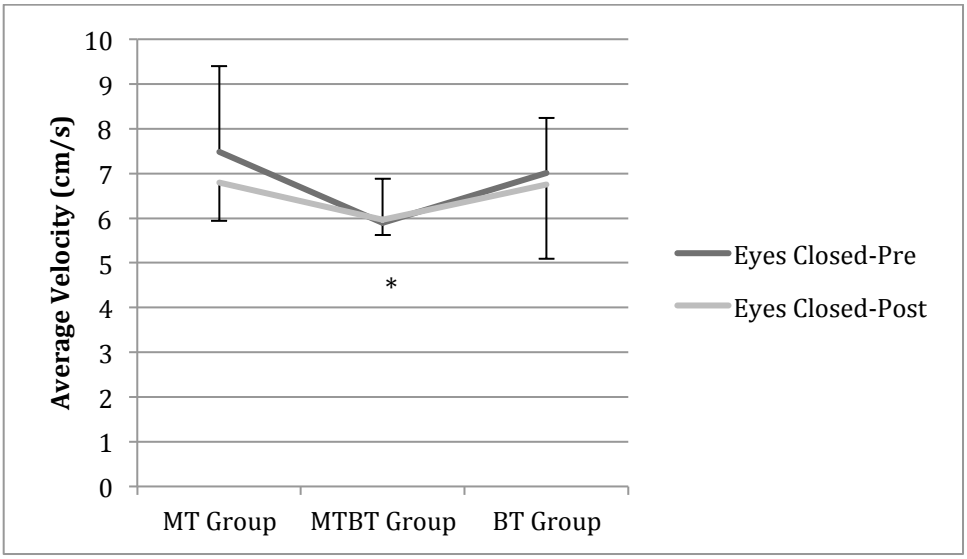
*Denotes statistical significance occurring between the MTBT group and the MT group

Figure 3.6: Average Velocity with Eyes Closed Among Groups for the Involved Leg



*Denotes statistical significance occurring between the MTBT group and the MT group

Figure 3.7: Path Length with Eyes Closed Among Groups for the Uninvolved Leg



*Denotes statistical significance occurring between the MTBT group and the MT group

Figure 3.8: Average Velocity with Eyes Closed Among Groups for the Uninvolved Leg

Table 3.4: Single Leg Stance Descriptive Statistics of the Involved Leg

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Path Length Eyes Open (PRE) (cm)	36.8 ± 4.6		36.7 ± 5.5		33.6 ± 8.8	
Path Length Eyes Open (POST) (cm)	33.9 ± 5.3	-8.3	34.7 ± 4.1	-5.8	33.6 ± 4.7	-0.1
Avg Velocity Eyes Open (PRE) (cm/s)	3.7 ± 0.5		3.7 ± 0.5		3.4 ± 0.9	
Avg Velocity Eyes Open (POST) (cm/s)	3.4 ± 0.5	-8.4	3.5 ± 0.4	-5.8	3.4 ± 0.5	-0.1

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

Table 3.5: Single Leg Stance Descriptive Statistics of the Uninvolved Leg

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Path Length Eyes Open (PRE) (cm)	36.9 ± 6.4		38.8 ± 5.1		33.4 ± 7.8	
Path Length Eyes Open (POST) (cm)	32.1 ± 3.8	-15.1	35.7 ± 6.4	-8.8	33.0 ± 2.3	-1.2
Avg Velocity Eyes Open (PRE) (cm/s)	3.8 ± 0.7		3.9 ± 0.5		3.3 ± 0.8	
Avg Velocity Eyes Open (POST) (cm/s)	3.2 ± 0.4	-17.9	3.6 ± 0.6	-8.8	3.3 ± 0.2	-1.2

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

Dynamic Balance:

Residual analyses for these data met the assumptions for ANOVA. No significant differences were found for reach distance in the anterior direction (Group: P = 0.130; Time: P = 0.206; Extremity: P = 0.899; Group-Time Interaction: P = 0.789; Group-Extremity Interaction: P = 0.729; Time-Extremity Interaction: P = 0.639). No significant differences were found for reach distance in the PL direction (Group: P = 0.642; Time: P = 0.139; Extremity: P = 0.901; Group-Time Interaction: P = 0.773; Group-Extremity Interaction: P = 0.460; Time-Extremity Interaction: P = 0.918). No significant differences were found for reach distances in the PM direction (Group: P = 0.865; Time: P = 0.825; Extremity: P = 0.859; Group-Time Interaction: P = 0.616; Group-Extremity Interaction: P = 0.779; Time-Extremity Interaction: P = 0.948). Descriptive statistics for reach direction are displayed in Tables 3.6 and 3.7.

Table 3.6: SEBT Reach Descriptive Statistics of the Involved Leg (%LL)

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Ant Reach (PRE)	72.4 ± 7.0		75.0 ± 8.7		77.0 ± 9.3	
Ant Reach (POST)	73.8 ± 5.3	1.9	78.7 ± 6.6	4.7	81.0 ± 9.7	4.9
PL Reach (PRE)	76.7 ± 8.2		78.2 ± 17.4		87.1 ± 10.0	
PL Reach (POST)	83.8 ± 4.4	8.5	84.9 ± 16.6	8.0	86.2 ± 10.6	-1.1
PM Reach (PRE)	86.9 ± 6.1		89.3 ± 12.1		91.9 ± 9.7	
PM Reach (POST)	89.8 ± 5.1	3.2	88.9 ± 13.8	-0.4	91.3 ± 10.8	-0.7

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

Table 3.7: SEBT Reach Descriptive Statistics of the Uninvolved Leg (%LL)

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Ant Reach (PRE)	74.6 ± 8.3		75.2 ± 6.7		76.5 ± 6.5	
Ant Reach (POST)	74.4 ± 5.3	-0.2	78.5 ± 6.8	4.2	77.5 ± 7.7	1.4
PL Reach (PRE)	79.9 ± 9.3		83.5 ± 14.0		80.4 ± 8.4	
PL Reach (POST)	84.8 ± 3.6	5.8	86.2 ± 16.2	3.1	84.1 ± 10.4	4.4
PM Reach (PRE)	88.6 ± 5.4		87.4 ± 13.4		91.3 ± 7.0	
PM Reach (POST)	90.7 ± 2.9	2.3	90.9 ± 13.0	3.8	86.8 ± 7.3	-5.2

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

Crossover Hop for Distance:

Residual analyses for these data met the assumptions for ANOVA. No significant differences were found for the crossover hop (Group: P = 0.338; Time: P = 0.079; Extremity: P = 0.566; Group-Time Interaction: P = 0.680; Group-Extremity Interaction: P = 0.990; Time-Extremity Interaction: P = 0.814). Descriptive statistics for the crossover hop are displayed in Table 3.8 and 3.9.

Table 3.8: Crossover Hop Descriptive Statistics of the Involved Leg (%LL)

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Hop Distance (PRE)	422.0 ± 122.8		410.0 ± 105.5		338.7 ± 149.9	
Hop Distance (POST)	458.0 ± 106.7		443.9 ± 129.9		436.5 ± 108.6	
		7.9		7.6		22.4

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

Table 3.9: Crossover Hop Descriptive Statistics of the Uninvolved Leg (%LL)

	MT Group	% Diff	BT Group	% Diff	MTBT Group	% Diff
Hop Distance (PRE)	434.0 ± 103.4		431.1 ± 101.4		373.2 ± 156.1	
Hop Distance (POST)	468.0 ± 94.1		456.2 ± 118.3		442.6 ± 114.9	
		7.3		5.5		15.7

PRE: Pre-Intervention; POST: Post-Intervention; Diff: Difference

Values are Mean ± Standard Deviation

CHAPTER 4: DISCUSSION

The statistically significant results of this research study displayed that the MTBT group presented with overall greater bilateral straight-leg active and passive DF ROM measures when compared to the MT and BT groups. Furthermore, the MTBT group displayed overall better static balance bilaterally in the eyes-closed condition when compared to the MT group. These post hoc noted differences, especially at baseline, suggest disparity among the group conditions. Thus, while our demographic and anthropometric comparisons suggest homogeneity among the groups, baseline measures of the dependent variables, specifically DF ROM and eyes-closed static balance demonstrate otherwise. Therefore, our results must take into account this significant limitation.

FADI and the FAAM:

Although no statistically significant differences were noted between pre-intervention and post-intervention among all the treatment groups, a potential trend of slight improvement in the questionnaire scores was apparent. The MTBT group was the only group that did not report improvement in function following treatment per the FADI. However, the MTBT group did display an improvement in functional score per the FAAM following treatment. Slight improvements in FADI and FAAM scores following treatments may suggest that a therapeutic effect was elicited in this pragmatic clinical study and, therefore, that the various treatments may be clinically significant even though statistical significance was not established.

Range of Motion:

Significant differences were noted among the treatment groups for both active and passive straight-leg DF ROM. Specifically, the MTBT group displayed an overall significantly greater amount of straight-leg DF ROM bilaterally compared to the MT and BT groups. This particular limitation, especially at baseline, suggests heterogeneity among the groups, thereby potentially influencing our outcome measures and

confounding our results. No other differences were noted for comparisons of ROM measures among the different conditions.

Previous literature[4,29,30] has reported that Maitland Grade III joint mobilizations of the talocrural joint, such as the ones used in this study, can cause an increase in DF ROM; therefore, the observed increases in DF ROM for the MT and MTBT groups following treatment, though statistically insignificant, were expected. Consequently, though the MT and MTBT groups did not demonstrate statistically significant differences for DF ROM when compared to the BT group, a therapeutic effect, as evidenced by the related post-treatment measures, may have been elicited with joint mobilizations as suggested by previous research.[31,32] The BT group did not show any improvement in DF ROM, but this finding was expected since no treatment was directly applied that targeted an increase in DF ROM. Furthermore, no significant differences were found for active and passive bent-leg DF ROM. Unfortunately, most studies similar to ours, such as Landrum et al,[31] only measured straight-leg DF ROM. Thus, less research has examined bent-leg DF ROM, which identifies an area where further research is warranted in order to better compare and contrast our associated results.

Denegar et al[33] reported that following an inversion ankle sprain, DF ROM usually gradually returns back to normal, but a restriction in talocrural joint arthrokinematics remains. Therefore, based on our observed baseline to post-treatment trends in the MT and MTBT groups, joint mobilization techniques, such as the ones utilized in this research study, may be beneficial in correcting the disrupted arthrokinematics in CAI patients and possibly reduce the recurrence of further ankle sprain injuries.[30,33]

Static Balance:

Previous studies[18,34] have reported that individuals with CAI display deficits in postural control. In a study by McKeon et al,[34] significant deficits were found during a single-leg static balance task in an eyes-closed condition. Since this is a common deficit that is present in CAI, an important aspect of the rehabilitative process is to improve postural control in order to improve functional performance and prevent further injury.[35]

Surprisingly, we found that the BT group did not display statistically significant differences for the static balance task under eyes-open and eyes-closed conditions when comparing baseline to post-treatment measures or among groups. Instead, we observed the MTBT group displayed overall statistically significant lower center of pressure path length and average velocity bilaterally with the execution of a single-leg static balance task in an eyes-closed condition compared to the MT group. Therefore, the outcomes may be influenced by the post hoc baseline differences noted among groups.

Even though no statistically significant differences were observed for static balance, there was a potential trend present suggesting slight improvements in center of pressure path length and average velocity as it pertains to the eyes-closed condition. For example, all groups, mostly the BT and MT, displayed lesser center of pressure path length with the eyes-closed condition following treatment. These results, even though not statistically significant, suggest a potential therapeutic effect observed among the treatments. Clinically, these treatments may suggest benefits in the rehabilitation process for individuals with CAI.

Previous studies have found that joint mobilization[4,36] and balance-training programs[37-39] can improve postural control in individuals with CAI represented by decrease in path length and average velocity for a single-leg stance balance task. However, most of the studies investigating the effects of balance training on postural control use very different balance training programs. The balance training program used in this study was modeled after one used in a study by McKeon et al[2] except for the omission of the 'Unanticipated Hop to Stabilization' and alterations to the single-leg stance activity. All single-leg stance activities were completed on a BOSU balance trainer. According to Laudner et al,[40] the utilization of the BOSU balance trainer improves postural control, but not any more than other balance-training programs. More research should be conducted to determine if a specific type of balance training would be more beneficial in improving postural control than others, especially in patients with CAI.

The results in this study may not have shown statistically significant differences as the literature suggests because of the small sample size. McKeon et al[2] conducted a study investigating the effect of balance training on postural control in individuals with

CAI and found significant improvements, but the sample size they used in their study was almost twice as large as the sample size in this study. A larger sample size in this study may have shown more significant results considering there was a trend in this data showing improvement for each group after intervention.

Dynamic Balance:

The results of our study suggest that there were no improvements in dynamic balance as determined by the modified SEBT among the groups. Furthermore, no statistically significant differences were noted between the involved compared to the uninvolved legs. Our results contradict Olmsted et al,[23] who reported that individuals with CAI were unable to reach as far when they were standing on their injured leg compared to their healthy leg. Furthermore, our results do not complement those of Filipa et al,[41] who found significant improvements in reach distance following an 8-week balance-training program. The lack of improvement in dynamic balance following the specific balance-training program used in our study may be explained by the relatively short treatment period. Thus, four weeks may not be enough time to gain significant improvements that would be noticeable during a dynamic balance task. In addition, further research is needed to determine the effectiveness of different balance-training programs as determined by clinical tests such as the dependent variables of interest investigated in our study.

Crossover Hop for Distance:

The results of this study did not demonstrate any significant differences in the crossover hop for distance task. Upon observing the means for each condition, a slight improvement can be noted post-treatment, which may a potential therapeutic effect was elicited as a result of treatment rendered in our study; thereby suggesting potential clinical significance for our results even though statistical significance was not established. According to a study by Herrington,[42] a four week jump-training program caused a significant increase in hop distance for the crossover hop in healthy participants. Similarly, our study used a four week balance-training protocol that focused on hop to stabilization exercises. Therefore, our balance training protocol may have facilitated

results, though statistically insignificant, similar to Herrington[42] for improvements in crossover hop performance, specifically to the BT and MTBT groups as the result of jump or hop training. Thus, further research is needed in order to investigate the effects of balance training on functional tests such as the crossover hop for distance, especially in CAI patients.

Limitations:

Several limitations were present in our study that may have affected the results. The most notable limitation for our study was the post hoc differences observed for the baseline measures of DF ROM and eyes-closed static balance in the MTBT group. Thus, the heterogeneity that existed among the groups at baseline may have confounded our results for the related outcome measures. Furthermore, the clinicians reported that variability existed among the ankles as it pertained to the practitioner perceived quality of ankle joint mobility. Thus, the clinicians perceived various ankles as being stiff while others lax, which reinforces the concept that a lack of or excessive mobility may contribute to CAI. Therefore, although the inclusive participants enrolled in our research study self-reported symptoms of CAI, the quality of joint play at the ankle varied between individuals. This suggests that no one mode of treatment rendered to all patients presenting with CAI will produce outcome success.

Similar issues have arisen with regards to the lumbar spine. Current research dealing with the lumbar spine has shown contradicting results for the effects of manipulation in treating low back pain, which may suggest that certain individuals respond well to manipulative treatment while others benefit from other types of interventions.[43] Thus, researchers are investigating patient classification systems that utilize sub-groups, which reflect homogeneous patient characteristics to guide treatment. [43,44] Clinical prediction rules are being developed to identify patients that fit into the sub-group classification model to predict treatment success. [43,44] Currently, no clinical prediction rules to guide the treatment of CAI have been developed. Although, Whitman et al[8] have developed a clinical prediction rule for the treatment of acute ankle sprains. These authors[8] found that 75% of all acute ankle sprain patients treated in this study positively responded to clinical interventions; however, the success rate increased to 95%

if patients met the criteria for the related clinical prediction rule. Interestingly, similar to our study, the treatment interventions used in the study by Whitman et al[8] consisted of manipulations, mobilization and general mobility exercises.

We observed a trend for a therapeutic effect with various treatments implemented for the heterogeneous cohort of participants enrolled in our study. However, the amount of variability in the groups suggests that some individuals responded well to treatments while others did not. This indicates that a clinical prediction rule should be developed and implemented to assist in the categorization of patients into sub-groups to dictate treatment and predict successful outcomes. Thus, continued research should focus on this theme.

Another limitation of our study was the relatively small sample size enrolled compared to previous studies. Due to logistical considerations and strict inclusion/exclusion criteria, only 18 participants (6 participants per group) were enrolled in our research study. Continued investigation needs to be completed with a larger sample size to observe if new trends arise or statistical significance is observed in our outcome measures. Limitations were also present with regards to ROM. Greater variability may be present because three different examiners were responsible for taking goniometric measurements. A final limitation was that two different clinicians performed the joint mobilization treatments. Differences in treatment technique may have affected the related outcomes for the various participants. In addition, blinding may have assisted in preventing examiner bias.

CHAPTER 5: CONCLUSION

Three different treatments to improve performance outcomes in individuals with CAI were investigated in our research study. Although no statistically significant results existed among the groups or between pre- and post-treatment for the related outcome measures examined, a trend for improvement was noticeable, which may suggest a potential therapeutic effect was elicited and thus promote the clinical significance of our findings in the treatment of CAI patients. A similar study should be replicated with a larger sample size and/or a longer balance-training period to determine if these factors have an effect on the specific dependent variables identified in our research study. Further research could also investigate different balance-training protocols in order to determine if one is more effective than another as well as the development of a clinical prediction rule that would aid in determining the appropriate treatment for individuals with CAI.

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LITERATURE REVIEW

Joint Mobilizations and Range of Motion

Wikstrom et al[45] has reported that individuals with CAI have an anterior talar position in the sagittal plane on the injured limb compared to the uninjured limb. Other studies have also suggested that a talar positional fault may be present following a lateral ankle sprain or in those who have CAI.[32,33] Although Denegar et al[33] did not investigate the talar positional fault directly, they found that there was a reduction in posterior talar glide in individuals who had suffered from a lateral ankle sprain. They hypothesized that this may have been caused by an anteriorly subluxated talus.

Many studies have investigated the effects of joint mobilization at the ankle. Limited ankle dorsiflexion is common after lateral ankle sprains and it has been suggested that this may be a risk factor for recurrence of ankle sprains.[46] Many studies use Maitland Grade III joint mobilization to determine if the manual therapy treatment has an effect on the amount of dorsiflexion an individual is able to produce.[31,47,48] Landrum et al[31] performed a study to determine if one session of two joint mobilization treatments would cause a significant improvement in dorsiflexion at the ankle. Ankle dorsiflexion range of motion as well as posterior talar mobility and stiffness were measured. All subjects received both treatments and data was recorded pre-treatment, post-treatment one, and post-treatment two. Results showed a significant increase in dorsiflexion after each treatment; however, stiffness measures increased as well. Hoch et al[4] completed a similar study in which two 2-minute sets of joint mobilizations were performed. Similar findings in the amount of dorsiflexion range of motion were reported, but no significant differences in posterior stiffness were observed.

Another interesting aspect that should be taken into consideration when completing manual therapy is the amount of force applied during joint mobilization. Venturini et al[48] investigated the amount of force applied during antero-posterior talocrural joint mobilization. Two testers were examined and the amount of force applied throughout the joint mobilization technique was measured using a force platform. Significant differences between the maximum forces applied by each examiner were noted; however, for both examiners there was a significant increase in dorsiflexion range

of motion. When examining the entire joint mobilization technique, it was reported that the amount of force applied varied from minimum to maximum creating a cyclic stretching, which may lead to the gradual decrease in the resistance of the posterior tissues. This may facilitate the movement of the talus in the posterior direction. Another study performed a similar procedure to test inter-rater reliability and the effects on dorsiflexion.[47] They also observed that raters differed significantly in the amount of force applied during joint mobilizations. In addition, the results showed that there was a significant positive correlation between the force range and the amount of joint displacement; however, the strength of correlation was not strong. De Souza et al[47] discussed the fact that a longer, slower force appeared to be correlated more with larger joint displacement. Overall, the amount of dorsiflexion increased significantly after the joint mobilizations were applied.

Joint Mobilizations and Postural Control

Individuals with CAI have been shown to have deficits in both dynamic and static postural control.[18,34,49,50] A study by Hertel et al[18] reported that individuals with CAI displayed impairments in all time-to-boundary measures except for one. Ross et al,[51] however, found that there was no significant difference between individuals with CAI and healthy individuals for static postural control. The study did show differences during single-leg jump-landing tests. Dynamic postural control was shown to be decreased in individuals with CAI in studies by Brown et al[49] and Gribble et al.[50]

Some research studies have investigated the effects of joint mobilization on postural control. The results of these studies could be beneficial in determining if joint mobilization techniques are effective in improving functional performance. Hoch et al[4] examined the improvements of dorsiflexion range of motion as well as the effects on postural control in subject who were classified as having chronic ankle instability. Subjects completed a dynamic postural control test using the Star Excursion Balance Test as well as a static postural control test using eyes-open and eyes-closed single-leg stance trials on a force plate. The tests were completed before and after the joint mobilization treatment was administered. A significant difference was noted for eyes-open single-leg stance test, but not for the dynamic postural control or the eyes-closed trials. Joint

mobilizations are thought to stimulate mechanoreceptors which may lead to an increase in afferent input form the talocrural joint.[4] This may explain the improvements in the single-leg balance test.

Balance Training

According to McKeon et al,[2] a dynamic stabilization program that includes exercises such as hopping and dynamic reaching tasks may be better at improving postural control than traditional balance exercises. All subjects had chronic ankle instability and were assigned to complete the balance training program or to a control group that was instructed to maintain their normal amount of physical activity. The balance-training program consisted of five activities that contained seven levels of difficulty through which the subjects progressed. Activities included hop to stabilization, hop to stabilization and reach, hop to stabilization box drill, progressive single-limb stance balance activities with eyes open, and progressive single-limb stance balance activities with eyes closed. The results of the Star Excursion Balance Test and the single-limb stance tests were significantly different between the intervention group and the control group. Pre-test measures were not significantly different indicating that both groups began at around the same level. For this study, we will use the same balance-training protocol except we will adjust the single-limb stance portion by including a BOSU balance trainer.

Balance Training and Recurrence of Ankle Sprains

A consistent finding in the literature is that an improvement in postural control can aid in reducing the incidence of ankle sprains.[1,5] Hupperets et al[5] examined the effect of an unsupervised home proprioception training program on the recurrence of ankle sprains. A two-fold reduction in the occurrence of ankle sprains was observed. McGuine et al[1] and Mohammadi et al[7] were randomized controlled trials with more supervision than the previous study[5] discussed. McGuine et al[1] utilized a four-week balance program that included five different phases and noted that the risk of ankle sprains for the individuals completing the balance program was 62% of that of the control group. Similarly, the intervention group in Mohammadi et al[7] had a significantly lower

incidence of ankle sprains compared to the control group (p=.02). McHugh et al[6] was a cohort study that followed two high school football teams over the course of three years. Players were divided into a high-risk group, moderate-risk group, and a low-risk group and the ankle sprains were recorded pre- and post- intervention. The combined incidence for all groups post-intervention were significantly lower than pre-intervention (p<.01). The findings of these studies could be significant because it could affect the way ankle sprains are treated in order to reduce their occurrence.

Star Excursion Balance Test

The Star-Excursion Balance Test (SEBT) is a test of dynamic postural control that requires a participant to maximize their reach with one leg while balancing on the other. Because it is commonly used in clinical practice, several studies have further investigated the utility of the test. In a study by Hertel et al,[21] the SEBT was shown to have intra-tester reliability in addition to inter-tester reliability. Kinzey and Armstrong[22] also found that the test has intra-tester reliability. Furthermore, based on the increase in reliability with more practice trials, Kinzey and Armstrong[22] recommend that at least six practice trials should be implemented.

Because this many practice trials may be time-consuming when used in a clinical setting, Robinson and Gribble[24] investigated the possibility of decreasing the number of necessary trials without decreasing the test's validity. Stance leg angular displacement values and maximum excursion distances were recorded after each trial and it was reported that these values stabilized within four practice trials for the majority of directions. These results suggest that the number of trials may be decreased and the SEBT will still be a valid test. Hertel et al[52] reports that a decrease in the number of test directions may also be reduced without affecting the validity of the test. Testing in the anteromedial, medial, and posteromedial directions is recommended because it was shown these directions are more sensitive in detecting functional deficits in individuals with CAI.[52]

To improve upon the accuracy of the SEBT in measuring dynamic postural control, Gribble et al[25] investigated the role of various factors including gender, leg length, and height on the results of the SEBT in order to determine the need for

normalization. Men were shown to have significantly higher reach distances in the posterior, posteromedial, and medial directions before the use of any normalization method; however, after normalization based upon leg length, no significant differences were revealed. Based on their findings, Gribble et al[25] recommends the normalization of SEBT data based on leg length.

Quiet Single-Leg Balance Task

The Quiet Single-Leg Balance Task has been commonly used as a measure of static postural control. Traditionally, center of pressure excursions are recorded. A study by Hertel et al[53] examined the time-to-boundary measures of center of pressure excursions, which is typically only used for double leg stance, for the single leg stance. Reliability of the time-to-boundary measures was comparable to the traditional measures for single-leg stance; however, the correlations between the two were weaker than correlations within each category of measures. This may suggest that the two methods examine different aspects of postural control.

Crossover Hop

The Cross-Over Hop Test is a functional test that requires the participant to maximize the distance they travel in three successive single-leg hops.[26] With each hop, the participant must hop across a pre-set area. For instance, the subject is asked to stand on one foot to the right side of the pre-set area. They then must hop over to the left side, back to the right side, and then back to the left side.

Several studies have investigated the reliability of the cross-over hop test and its effectiveness in determining functional limitations. Clark et al[27] displayed that the adapted cross-over hop for distance has a high measurement reliability and an acceptable measurement error in a healthy population. Reid et al[54] and Hopper et al[55] further investigated the test by observing subjects undergoing anterior cruciate ligament reconstruction. They also found that the crossover hop for distance was both reliable and valid in assessing functional limitations in this population. Munro et al[56] also found that the cross-over hop test was a reliable functional test, however, they found that four

practice trials should be used because of the learning effect present with the test. In addition, this study normalized distance values based on leg length.

A study by Caffrey et al[28] chose to include subjects who suffered from chronic ankle instability. Instead of using a crossover hop for distance, they instead chose to use a cross-over hop in which subjects had to cover six meters in as little time possible. This study found a significant difference for individuals with CAI hopping on their affected limb and individuals with CAI hopping on their unaffected limb as well as healthy individuals. This suggests that the test is an effective way in determining functional deficits in individuals with CAI.

APPENDICES

A: Screening Questionnaire

PENNSTATE

1855

Title of Project: The Effect of Balance Training and Manual Therapy on Performance Outcomes in Individuals with Chronic Ankle Instability

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

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

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 to only one ankle 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**

B: Recruitment Flyer (Under 18)

PENNSTATE

Athletic Training Research Laboratory

Research Volunteers Needed

Are you interested in learning more about chronic ankle instability?
If so, you may be interested in participating in our research study.

Measurements: ankle joint range of motion, postural control (balance), functional tests, and subjective ankle joint performance surveys.

Purpose: Study the effects of balance training and manual therapy treatment on performance outcomes (balance and function) and subjective rating of ankle joint performance.

Three (3) 30 minute sessions per week for four (4) weeks or three (3) 30 minute sessions for one (1) week depending on the group to which you are randomly assigned. Two selected sessions will be an additional 30 minutes for data collection. All sessions will be in the Athletic Training Research Laboratory in 21D&E Recreation Building over four (4) weeks.

Requirements:

- Boys, girls, men and women ages 16 – 35 years old (*If you are under the age of 18 years old, parental or legal guardian consent is required for your participation*)
- Good general health
- Not overweight
- Physically-active

Dr Sayers John Miller and John Vairo
Department of Kinesiology

For more information, contact John Vairo at
glv103@psu.edu or 814-865-2725

C: Recruitment Flyer (18-35 years)

PENNSTATE

Athletic Training Research Laboratory

Research Volunteers Needed

Do you sprain your ankle often?
If so, you may be interested in participating in our research study at Penn State.

Measurements: ankle joint range of motion, postural control (balance), functional tests, and subjective ankle joint performance surveys.

Purpose: Study the effects of balance training and manual therapy treatment on performance outcomes (balance and function) and subjective rating of ankle joint performance.

Three (3) 30 minute sessions per week for four (4) weeks or three (3) 30 minute sessions for one (1) week depending on the group to which you are randomly assigned. Two selected sessions will be an additional 30 minutes for data collection. All sessions will be in the Athletic Training Research Laboratory in 21D&E Recreation Building over four (4) weeks.

In order to qualify for the research study you must be:
• Boys, girls, men and women ages 16 – 35 years old (*If you are under the age of 18 years old, parental or legal guardian consent is required for your participation*)
• Good general health
• Not overweight
• Physically-active

Dr Sayers John Miller and John Vairo
Departments of Kinesiology

For more information, contact John Vairo at
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D:Verbal Script

PENNSTATE

1855

Title of Project:	The Effect of Balance Training and Manual Therapy on Performance Outcomes in Individuals with Chronic Ankle Instability
Principal Investigator:	Sayers John Miller, PhD, PT, ATC
Project Coordinator:	Giampietro L Vairo, MS, ATC
Co-Investigator:	Wayne J Sebastianelli, MD
Research Support:	Erin Stokes
Script:	Chronic Ankle Instability Patients (18 – 35 years old) and Parents of Chronic Ankle Instability Patients (16 – 17 years old)

Hello, my name is (*Penn State Institutional Review Board-approved investigator*) and I work with the Athletic Training Research Laboratory at Penn State. I am currently looking for research volunteers and was wondering if you would be interested in participating or at least hearing more about this study. I am looking for a group of participants who are 16 to 35 years old, have been diagnosed with chronic ankle instability and not undergoing a formal rehabilitation program. If you are under the age of 18 years old, parental or legal guardian consent is required for your participation in this research study. Participants in this research study should be in good general health, not overweight and physically-active. If you are undergoing physical therapy or sports rehabilitation under the supervision of a physical therapist or athletic trainer you will not be eligible to participate. I will be examining ankle performance and how balance training and manual therapy treatments may affect balance and functional performance in chronic ankle instability patients. If you are interested in participating, you would be required to come to the Athletic Training Research Lab in 21D&E Recreation Building for either three times a week for four weeks or three times a week for one week depending upon the group to which you are randomly assigned. All sessions except for two will last approximately thirty minutes. On those two selected sessions, you will be required to stay an additional thirty minutes for data collection. During the first visit you will be asked to perform two balancing exercises and a functional test followed by treatment. During the visits over the next one or four weeks you will only undergo your designated treatment. The final visit will be a repeat of the balancing tests and functional test. As a participant we will be happy to provide you with your specific measurement results. If you have any questions or need to get in touch with me for any reason, my phone number is (*respective Penn State Institutional Review Board-approved investigator*) and my e-mail is (*respective Penn State Institutional Review Board-approved investigator*). Thank you.

E: Consent Form (Under 18)

Informed Consent Form for Biomedical Research
The Pennsylvania State University
PARENTS OF CHRONIC ANKLE INSTABILITY PARTICIPANTS (16 – 17 years old)

Title of Project: The Effect of Balance Training and Manual Therapy on Performance Outcomes in Individuals with Chronic Ankle Instability

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1. **Purpose of the study:** The purpose of this research is to study the effects of balance training and manual therapy treatments on balance in people with chronic ankle instability. Chronic ankle instability is a condition in which an individual suffers from multiple episodes of weakness or giving way of the ankle over a long period of time. A total of 78 people between the ages of 16-35 years old will be taking part in this study. Thirty people have already completed the study. The remaining 48 people will be divided into three groups. Sixteen

people are in the manual therapy and balance training treatment group, sixteen in the stand-alone manual therapy group, and sixteen in the stand-alone balance training group.

2. **Criteria for inclusion of participants:** You and your child are being invited to participate in this research study because your child is healthy, physically active and between the ages of 16-35 years old. Your child must 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 is not currently in a rehabilitation program.

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

Procedures

A. We will begin the study by asking your child to complete two subjective analyses questionnaires which will determine the severity of his/her 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 your child would personally describe his/her ankle during activities of daily living or during athletic tasks such as running. The results of these questionnaires will help us assess how your child feels before and after treatment. Your child will need to repeat these questionnaires during the final session.

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

C. Your child will be asked to perform a single leg balance stance task. Your child will be standing on one leg barefoot while maintaining balance for a ten second trial with eyes open and then eyes closed. Your child will be instructed to stand as still as possible with his/her arms crossed over his/her 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. Your child will be asked to perform another single-leg balance task called the Star Excursion Balance Test. For the Star Excursion Balance Test your child will stand in place on one leg in the middle of the star and reach as far as possible with his/her 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. Your child will be given four (4) practice trials and complete three (3) testing trials. Your child 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. Your child will be asked to perform a functional test called the Cross-Over Hop Test. For the test, your child will be asked to stand on one leg to one side of a line. He or she will then complete three consecutive hops on that leg without pausing. With each hop, your child will have to cross over to the other side of the line. The goal is to cover the most distance with the three hops. Your child will be given three practice hops followed by three measured trials. Each hop will be separated by a one minute rest period. A picture of the Cross-Over Hop Test is below.

F. After your child is done with testing procedures A through E he/she has finished the baseline testing of his/her first session. Your child will then undergo a treatment sessions and be asked to perform testing procedures A through E again during the final treatment session. If your child is assigned to the balance training and manual therapy group, he or she will be asked to come back to the Athletic Training Research Laboratory three times a week for the next four weeks. During the first week, your child will undergo manual therapy treatment as well as balance training. The remaining three weeks your child will complete balance training only. If your child is assigned to the stand-alone manual therapy group, he or she will be asked to come back to the Athletic Training Research Laboratory three times a week for one week to complete sessions comprised of only manual therapy. After completing the three sessions your child will report back once more after three weeks and will perform testing procedures A through E again. If your child is assigned to the stand-alone balance training group, he or she will be asked to come back to the Athletic Training Research Laboratory three times a week for the next four weeks to complete a balance training program. After the final session, your child will be asked to complete testing procedures A through E again.

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, your child will also be shown how to properly perform every task in the experiment. Possible discomfort may consist of post mobilization soreness associated with ankle mobilization treatments as well as delayed onset muscle soreness 48 to 72 hours following testing. As with any research study, it is possible that unknown harmful effects may happen. However, the chance for injury in this type of research study is minimal and includes muscle strains, ligament sprains, or aggravation of previously experienced 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 your child 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 and final testing sessions will last about one hour each. All treatment sessions during the four weeks will be 72 hours apart and will last about thirty minutes each. All testing takes place in the Athletic Training Research Laboratory in 21D&E Recreation Building on Penn State's University Park Campus.

7. **Statement of confidentiality:** Your child's and your participation in this research study is strictly confidential. All research records from your child's and 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 child's identity on research records. In the event of any publication resulting from this research study, no personally identifiable information will be disclosed. Penn State's Office for Research Protections, the Institutional Review Board and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this research study. Penn State policy requires that research records be kept for a minimum period of three years at the end of the study. Three years following the end of this research study all records will be appropriately destroyed.

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

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

   If your child is not a Penn State student, please contact his or her Primary Care Physician for additional assistance.

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

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

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

    Student Health Center
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    814-863-0774

    If you are not a Penn State student and cannot reach Dr. Miller or your child's 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 and your child are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

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

You must be 18 years of age or older to sign consent for participating in this research study. If you are under the age of 18 years old (between 16-17 years old), your parent or legal guardian must sign consent for your participation in this research study. If you agree to participate in this research study as described in this informed consent form, 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.

I give permission for my child, _____ , to participate in this research study.

_____ _____
PARENT CONSENT: Signature of Parent/Legal Guardian Date

_____ _____
ASSENT: Teenager ages 16-17 years old Signature Date

_____ _____
Person Obtaining Consent Date

F: Consent Form (18-35)

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

Title of Project: The Effect of Balance Training and Manual Therapy on Performance Outcomes in Individuals with Chronic Ankle Instability

Principal Investigator: Sayers John Miller, PhD, PT, ATC
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12. **Purpose of the study:** The purpose of this research is to study the effects of balance training and manual therapy treatments on balance in people with chronic ankle instability. Chronic ankle instability is a condition in which an individual suffers from multiple episodes of weakness or giving way of the ankle over a long period of time. A total of 78 people between the ages of 16-35 years old will be taking part in this study. Thirty people have already completed the study. The remaining 48 people will be divided into three groups. Sixteen

people are in the manual therapy and balance training treatment group, sixteen in the stand-alone manual therapy group, and sixteen in the stand-alone balance training group.

13. **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.

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

Procedures

G. 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 final session.

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

I. 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.

J. 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.

K. You will be asked to perform a functional test called the Cross-Over Hop Test. For the test, you will be asked to stand on one leg to one side of a line. You will then complete three consecutive hops on that leg without pausing. With each hop, you have to cross over to the other side of the line. Your goal is to cover the most distance you can with the three hops. You will be given three practice hops followed by three measured trials. Each hop will be separated by a one minute rest period. A picture of the Cross-Over Hop Test is below.

L. After you're done with testing procedures A through E you have finished the baseline testing of your first session. You will then undergo treatment sessions and be asked to

perform testing procedures A through E again after the final session. If you are assigned to the balance training and manual therapy group, you will be asked to come back to the Athletic Training Research Laboratory three times a week for the next four weeks. During the first week, you will undergo manual therapy treatment as well as balance training. The remaining three weeks you will complete balance training only. If you are assigned to the stand-alone manual therapy group, you will be asked to come back to the Athletic Training Research Laboratory three times a week for one week to complete sessions comprised of only manual therapy. After completing the three sessions you will report back once more after 3 weeks and will perform testing procedures A through E. If you are assigned to the stand-alone balance training group, you will be asked to come back to the Athletic Training Research Laboratory three times a week for the next four weeks to complete a balance training program. After the final session, you will be asked to complete testing procedures A through E again.

15. **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.

16. **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.

17. **Duration/time of the procedures and study:** The first and final testing sessions will last about one hour each. All treatment sessions during the four weeks will be 72 hours apart and will last about thirty minutes each. All testing takes place in the Athletic Training Research Laboratory in 21D&E Recreation Building on Penn State's University Park Campus.

18. **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.

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answer questions about research procedures. Questions about research procedures can be answered by the research team. Referral information for Penn State students who wish to seek additional assistance includes the following:

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

20. **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.

21. **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
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    If you are not a Penn State student and cannot reach Dr. Miller or your doctor please leave them voicemails and contact your private medical provider.

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

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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

G: FADI

Foot and Ankle Disability Index (FADI)

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).

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Standing	O	O	O	O	O	O
Walking on even ground	O	O	O	O	O	O
Walking on even ground witout shoes	O	O	O	O	O	O
Walking up hills	O	O	O	O	O	O
Walking down hills	O	O	O	O	O	O
Going up stairs	O	O	O	O	O	O
Going down stairs	O	O	O	O	O	O
Walking on uneven ground	O	O	O	O	O	O
Stepping up and down curbs	O	O	O	O	O	O
Squatting	O	O	O	O	O	O
Sleeping	O	O	O	O	O	O
Coming up on your toes	O	O	O	O	O	O
Walking initially	O	O	O	O	O	O
Walking 5 minutes or less	O	O	O	O	O	O
Walking approximately 10 minutes	O	O	O	O	O	O
Walking 15 minutes or greater	O	O	O	O	O	O

1999 FADI Interim 1/2

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

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

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

	None	Mild	Moderate	Severe	Unbearable
General level of pain	O	O	O	O	O
At rest	O	O	O	O	O
During your normal activity	O	O	O	O	O
First thing in the morning	O	O	O	O	O

FADI Sports Scale

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

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Running	O	O	O	O	O	O
Jumping	O	O	O	O	O	O
Landing	O	O	O	O	O	O
Starting and stopping quickly	O	O	O	O	O	O
Cutting/lateral movements	O	O	O	O	O	O
Low impact activities	O	O	O	O	O	O
Ability to perform activity with your normal technique	O	O	O	O	O	O
Ability to participate in your desired sport as long as you would like	O	O	O	O	O	O

1999 FADI Interim 2/2

H: FAAM

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).

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

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

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

How would you rate your current level of function during 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:

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Running	☐	☐	☐	☐	☐	☐
Jumping	☐	☐	☐	☐	☐	☐
Landing	☐	☐	☐	☐	☐	☐
Starting and stopping quickly	☐	☐	☐	☐	☐	☐
Cutting/lateral movements	☐	☐	☐	☐	☐	☐
Low impact activities	☐	☐	☐	☐	☐	☐
Ability to perform activity with your normal technique	☐	☐	☐	☐	☐	☐
Ability to participate in your desired sport as long as you would like	☐	☐	☐	☐	☐	☐

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

☐☐☐.0 %

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

☐ Normal ☐ Nearly normal ☐ Abnormal ☐ Severely abnormal

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Appendix: Balance Training Protocol

Single-Limb Hops to Stabilization (10 Repetitions per Direction)

Subject performed 10 hops in each direction. Each repetition consisted of a hop from the starting position to the target position (18, 27, or 36 inches). After stabilizing balance in a single-limb stance, participants hopped in the exact opposite direction back to the starting position and stabilized in the single-limb stance.

Four directions of hops (Fig. 1): 1) anterior/posterior, 2) medial/lateral, 3) anterolateral/posteromedial, and 4) anteromedial/posterolateral. Participants were not able to move to the next level in each category until they demonstrated 10 repetitions error-free. Errors were determined on the basis of the following:

a. Touching down with opposite limb
b. Excessive trunk motion (>30° lateral flexion)
c. Removal of hands from hips during hands on hips activities
d. Bracing the nonstance limb against the stance limb
e. Missing the target

Hop to Stabilization and Reach (Five Repetitions)

Combined with the mentioned exercises, however, after stabilization in the single-limb stance, participants had to reach back to the starting position. Repetitions were counted in the same manner mentioned previously. Participants hopped, stabilized, and reached back to the starting position. Then they hopped back to the starting position and reached to the target position.

Participants were not able to advance to the next level in each direction until they demonstrated five repetitions error-free. Errors were determined on the basis of the following:

a. All errors associated with hop to stabilization
b. Using the reaching leg for a substantial amount of support during reaching component

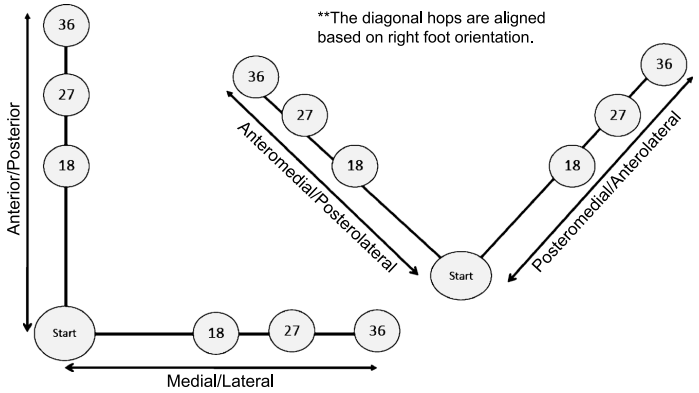

FIGURE 1—Directions and distances (in inches) for hop to stabilization activities.

All directions for Hop to Stabilization and Hop to Stabilization and Reach had seven levels of difficulty to progress:

1. 18-inch hop. Allowed to use arms to aid in stabilizing balance after landing.
2. 18-inch hop with hands on hips while stabilizing balance after landing.
3. 27-inch hop. Allowed to use arms to aid in stabilizing balance after landing.
4. 27-inch hop with hands on hips while stabilizing balance after landing.
5. 36-inch hop. Allowed to use arms to aid in stabilizing balance after landing.
6. 36-inch hop with hands on hips while stabilizing balance after landing.
7. 36-inch hop from a 6-inch platform.

Unanticipated Hop to Stabilization

Participants stood in the middle of a nine-marker grid (see Figure 2). A sequence of numbers was displayed on a computer screen in front of the participants. Each number corresponded to a target position to which they would hop. As the progression of numbers changed, participants would hop to the new target position. The hop to stabilization rules were applied for this activity; however, in this case, participants were allowed to use any combination of hops (AP, ML, AM/PL, or AL/PM) they desired to accomplish the goal of getting through the sequence error-free. As a participant developed proficiency, the amount of time per move was reduced. In each session, participants performed three sequences of numbers.

Levels of unanticipated hop to stabilization

Level 1: 5 s per move.

Level 2: 3 s per move.

Level 3: 1 s per move.

Level 4: If subject can progress to completion of all moves within 1 s without error, a foam pad will be placed on one of the numbers during the sequence. The subject will then continue the progression at the same level of intensity. If he or she cannot complete the course error-free, the time constraint will be reduced to the level below.

Level 5: If subject can progress to completion of all moves at Level 3 with the foam pad error-free, a step will be added to an additional number.

Level 6: If a subject progresses error-free, an additional foam pad will be added to one of the numbers, resulting in two foam pads and one step.

Level 7: If a subject progresses error-free, an additional step will be included, resulting in two foam pads and two steps.

Errors were determined on the basis of the following:

a. Touching down with opposite limb
b. Excessive trunk motion (>30° lateral flexion)
c. Removal of hands from hips during hands on hips activities
d. Bracing the nonstance limb against the stance limb
e. Missing the target

Each sequence of numbers was random such as 9, 7, 1, 6, 4, 5, 3, 8, 2.

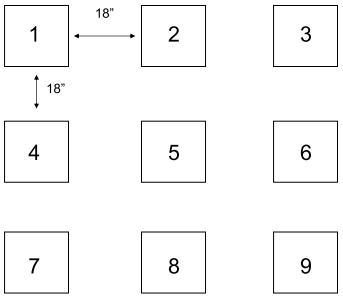

FIGURE 2—Nine marker grid for unanticipated hop to stabilization.

ACADEMIC VITA

Education

Pennsylvania State University **2008-Present**

Currently completing necessary coursework for Bachelor of Science in Athletic Training – Expected graduation date: May 2012

Schreyer Honors College **2008-Present**

Honors and Awards

Schreyer Honors College Academic Excellence Scholarship Recipient **2008-2011**

The Jean Phillips Shibley Memorial Health Education Scholarship Recipient **Spring 2010-11**

The Mary Boyle Weaver and Rebecca Boyle Sutherland Scholarship Recipient **Fall 2010-11**

Thomas J. Watson Scholarship Recipient **2008-Present**

Association Memberships

National Athletic Trainer's Association Student Member **Spring 2010-Present**

Professional Experience

Pennsylvania State University Sports Camps, State College, PA **Summer 2011**

- Acted as a First Responder during camp sessions
- Provided first aid care to campers

Intern at HealthSouth Rehabilitation Hospital, Pleasant Gap, PA **May-June 2011**

- Worked in the physical therapy clinic, helped transfer patients, keep the clinic clean, and observed physical therapists in an inpatient setting

German Academy of Applied Sports Medicine, Germany, Austria, and Switzerland **January 2011**

- Studied abroad in Germany, Austria, and Switzerland for one month through the Chapman University Athletic Training Program
- Completed workshops in Kinesiotape and diagnostic ultrasound

University of Kentucky Sports Camps, Lexington, KY **Summer 2010**

- Acted as a First Responder during camp sessions
- Provided first aid care to campers
- Acted as Gatorade Team Leader; Provided hydration information to campers and promoted Gatorade "G Series"