A Thesis

entitled

Examining the Positional Fault of the Fibula using Diagnostic Ultrasonography after Fibular Reposition Taping in Individuals with Chronic Ankle Instability

by

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Context: Individuals with chronic ankle instability (CAI) often present with both mechanical and functional insufficiencies that contribute to long-term dysfunction. Positional fault of the distal fibula is a possible impairment that contributes to CAI. Fibular reposition taping (FRT) technique is a suggested intervention to correct this malalignment. No research has looked at the tape’s effectiveness in changing the fibular position. Objective: To examine if the position of the fibula changes after application of the FRT technique, and to assess the interrater reliability of utilizing diagnostic ultrasound. Study Design: Cross-over study. Setting: Laboratory. Participants: 20 individuals with chronic ankle instability (Age: 21.5±4.1 years, Mass: 81.8±22 kg, Height: 170±7.5 cm) with no history of lower extremity surgery, ankle fracture, ankle injury in the past 6 weeks, or any vestibular or balance disorders. Intervention: Participants completed three taping conditions: FRT technique, sham tape, and no tape. Main Outcome Measures: Ultrasound measurements were taken for each taping
condition, and the distance between the talus and fibula was measured. Paired-t tests were used to compare differences between sham to control and then sham to FRT. Alpha was set at p<.05. Intraclass correlation coefficient (ICC$_{3,1}$) and associated standard error of measure (SEM) was calculated to determine intrarater reliability. **Results:** No significant differences in fibular position were observed between taping conditions. Intertester reliability was deemed to be excellent (ICC$_{3,1}$=0.98). **Conclusion:** No significant differences were found between any of the conditions, indicating that the FRT technique did not alter the position of the fibula. Diagnostic ultrasound is a reliable tool for assessing position of the fibula.
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Chapter One

Introduction

Lateral ankle sprains are exceedingly common in athletes, and are responsible for 80% of the injuries to the ankle. These injuries can cause damage to the structures that cross the lateral ankle such as ligaments, muscles, nerves, and mechanoreceptors. Signs and symptoms of these injuries include pain, weakness during physical activity, episodes of giving way, and self-reported disability. 47%-74% of people who sprain their ankle will suffer a recurrent sprain within 6-18 months after the initial sprain. Repetitive ankle sprains accompanied by persistent symptoms, such as giving way, that last greater than one year after an ankle sprain qualify a person has having chronic ankle instability (CAI).

Individuals with CAI generally possess, in isolation or combination, mechanical and functional insufficiencies that lead to ankle instability. Mechanical insufficiencies include pathologic laxity, arthrokinematic impairments, degenerative changes, and synovial changes. Functional insufficiencies include impaired proprioception and sensation, impaired neuromuscular control, strength deficits, and impaired postural control. In regards to arthrokinematic impairments, previous research has suggested there is a positional fault of the distal fibula that is associated with the CAI population. A positional fault is a subluxation or sustained joint malalignment that results from injury, and may alter kinematics and function of the affected joint. This malalignment may result from damage to the musculotendinous and ligamentous mechanoreceptors, altering the afferent signal from the gamma motorneuron system, causing pain and decreased range of motion.
The fibular reposition taping (FRT) technique was first introduced by Mulligan in order to correct the anterior positional fault of the distal fibula on the tibia in individuals with CAI. To date, studies have been done to examine the effect the FRT technique on injury prevention, postural control, spinal reflex excitability, ankle dorsiflexion, functional activities, muscle activity, and ankle kinematics during a jump landing. However, the extent to which the FRT technique changes the fibular position, has not yet been examined.

Diagnostic ultrasound has been used previously for various purposes in the ankle. It has been found to be a reliable tool for assessing the ligaments of the ankle, provide a correct diagnosis of ligamentous lesions at the ankle joint in 80-90% of cases, and been found to be a reliable tool in examining laxity of the anterior talofibular ligament. In addition, Lee et al used it to look at tendon excursion of the gastocnemius and tibialis anterior muscles. Yet, diagnostic ultrasound has never been used to examine the position of the fibula. Therefore, the purpose of this project is to evaluate the influence of FRT on fibular positioning when assess by diagnostic ultrasound in individuals with CAI.

**Methodology**

**Study Design**

The study design was a crossover repeated measures laboratory study. The dependent variable was the distance between the fibula and the talus, and the independent variable was the taping condition. Data collection took place in the Musculoskeletal Health and Movement Sciences Laboratory in the Health and Human Services Building at the University of Toledo. The study was approved by the University’s Institutional Review Board #201476.
Participants

There were 20 participants included in this study. Participants were recruited from the University of Toledo. All participants were between the ages of 18 and 40, and active at least 3 times a week, for at least 30 minutes. Participants had either unilateral or bilateral CAI. In order to fit the criteria of having CAI, participants possessed all of the following: (1) previously sustained more than one significant lateral ankle sprain in which they still have residual symptoms, with the first occurring greater than 1 year ago; (2) score 85% or less on the Foot and Ankle Ability Measure (FAAM) Sport sub-scale; (3) score of 11 or greater on the Identification of Functional Ankle Instability (IdFAI) questionnaire; (4) involved in physical activity at least 3 times a week for at least 30 minutes as determined by a score of 24 or greater on the Godin Leisure Time Exercise Questionnaire. Participants were excluded if they report any of the following: (1) history of an ankle injury within the past six weeks; (2) history of lower extremity surgery; (3) history of an ankle fracture; (4) any vestibular or balance disorder.

Instrumentation

The echo-Doppler ultrasonography unit (Zonare Medical System, Inc., Mountain View, CA) was utilized to examine the distance between the fibula and the talus. The Zonare L8-3 probe was used, which is a linear array transducer. The frequency and scanning depth utilized was 16Hz and 30mm, respectively, because we were penetrating a superficial area.

Procedures

Upon arrival, subjects read and signed an informed consent form approved by the University of Toledo Institutional Review Board, a demographic questionnaire, the
FAAM for Sport, the IdFAI, and the Godin Leisure Time Exercise Questionnaire. If the subject had bilateral CAI, the self-perceived worst ankle was chosen for testing to compare the different taping conditions. If the subject met both the inclusion and exclusion criteria, they were officially enrolled into the study.

Subjects received all three taping applications. The order was determined using a counterbalanced method to pre-determine the sequence in which the subjects receive each taping. This sequence was determined by a third party clinician in order to blind the primary researcher, and reduce any learning effects that may influence the results.

The treatment applications were no tape, sham tape, and FRT technique. For the no tape application, no treatment of any kind was given to the subject. For the FRT technique application, the subjects were seated with their foot in a neutral position. Next, a strip of Cover-Roll was applied obliquely in a posterolateral direction beginning at the distal aspect of the lateral malleolus. Leukotape was then applied in the same manner, with a posterolateral force applied to it. A second reinforcing strip was then applied in the same manner. For the sham tape, the same procedure was followed, but without the posterolateral force applied. In order for the clinician to get a view of the lateral malleolus with the ultrasonography, the tape did not cover the entire lateral malleolus. The same third-party certified athletic trainer performed all the taping applications in order to blind the researcher to the treatment group, and was properly trained in the FRT technique application. Both ankles received each treatment in order to also blind the researcher.

After each treatment application, the diagnostic ultrasound was used to measure the position of the fibula of each ankle. The subject was sidelying on the unaffected side.
with the affected ankle propped up on a foam roller with the ankle in neutral, and the knee in about 15-20° of flexion. The lateral malleolus and talus were palpated and identified. The examiner then applied the ultrasound transducer with conducting gel and placed it over the space in between those two bony landmarks. Once both bony landmarks were identified on the viewing screen, the examiner froze and saved the image. The examiner removed the transducer, instructed the subject to dorsiflex and plantarflex the ankle 3 times, and followed by returning the ankle to a neutral position to repeat the process. This process was repeated 5 times per ankle, per condition. Both ankles were measured. Images were exported onto a flashdrive, and at a later point in time, measurements were taken of the distance between these two bony landmarks using Image J software (National Institutes of Health, Bethesda, MD). The highest point, or the peak, of each bony landmark was identified, and the distance was measured between those points using the straight line tool, and the measurement was recorded on an Excel spreadsheet. Pixels were converted to centimeters at the rate of 68.4 pixels/cm. Measurements were recorded for every ankle and condition while the researcher was still blinded, and the measurements for the affected ankles were later identified.

Walking trials were conducted during data collection as part of a larger study, but in order for these to be carried out, sensors were placed on the affected limb. In order to blind the researcher taking ultrasound measurements, a shower curtain was hung from the ceiling in between the researcher and subject, and a sham sensor was applied to the unaffected ankle. Therefore, the researcher could not tell which ankle was effected when it was sticking under the shower curtain.

**Statistical Analysis**
The Statistical Package for the Social Sciences (Version 18.0. SPSS Science, Chicago, IL) was utilized for the statistical analysis of this study. Paired t-tests were utilized to determine if there were any significant differences between the three taping conditions. Alpha level was set at p<0.05. Cohen’s d effect sizes and 95% confidence intervals were calculated. Intraclass correlation coefficient (ICC\textsubscript{3,1}) of intratester measurement reliability was calculated by having the lead researcher take ultrasound measurements for the first five subjects, and then repeat that same process three days later. The standard error of measure (SEM) was calculated as well, and this value was applied to the difference in measurements between the FRT and sham taping conditions.

**Results**

There was no statistically significant difference between the control and sham condition (p=0.853) when measuring the distance between the talus and fibula. (Table 1). Since there was no difference between these two groups, we used the sham condition as the comparison for the FRT group. There was no statistically significant difference between the sham and FRT conditions (p=0.488). (Table 1). Cohen’s d effect sizes were weak, meaning the magnitude of change was small, and the corresponding 95% confidence intervals crossed zero indicating the ineffectiveness of the FRT treatment. ICC\textsubscript{(3,1)} values were calculated to evaluate the reliability of the ultrasound measurements taken by a single researcher (0.982)(CAF). Using the ICC values calculated, the SEM was identified (0.015cm). After applying this criteria to each of the subjects, eight out of the twenty subjects were identified to have a difference greater than the error established by the single researcher following the FRT application. Average values for demographics
demonstrate that the participants had significant dysfunction with their affected ankle, and the population utilized was young and active. (Table 2).

Table 1. Average Distance between the Fibula and Talus

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean ± SD (cm)</th>
<th>Cohen’s d (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sham Condition</td>
<td>3.17 ± 0.25</td>
<td>0.04 (-0.58 – 0.66)</td>
</tr>
<tr>
<td>FRT Condition</td>
<td>3.17 ± 0.27</td>
<td>0.05 (-0.56 – 0.67)</td>
</tr>
<tr>
<td>Control Condition</td>
<td>3.16 ± 0.25</td>
<td></td>
</tr>
</tbody>
</table>

FRT=fibular reposition tape, SD=standard deviation, CI=confidence interval, cm=centimeter
*Indicates significant difference between groups (p<0.05)

Table 2. Demographics

<table>
<thead>
<tr>
<th>Both (n = 20)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21.5 ± 4.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170 ± 7.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>81.8 ± 22</td>
</tr>
<tr>
<td># of ankle sprains</td>
<td>7.2 ± 5.3</td>
</tr>
<tr>
<td>First Ankle Sprain (months)</td>
<td>98.4 ± 58.1</td>
</tr>
<tr>
<td>Most Recent Ankle Sprain (months)</td>
<td>10.5 ± 8.1</td>
</tr>
<tr>
<td>FAAM Sport (%)</td>
<td>63.9 ± 17.6</td>
</tr>
<tr>
<td>IdFAI</td>
<td>22 ± 5.5</td>
</tr>
<tr>
<td>Godin Leisure</td>
<td>67.3 ± 33.5</td>
</tr>
</tbody>
</table>

n=number of subjects, cm=centimeters, kg=kilograms, FAAM=Foot and Ankle Ability Measure, IdFAI=Identification of Functional Ankle Instability

Discussion
The purpose of this study was to examine the position of the fibula using diagnostic ultrasound between applications of no tape, sham tape, and FRT technique in individuals with CAI. No significant differences were found between any of the conditions, indicating that the FRT technique did not alter the position of the fibula. The taping technique was first introduced by Mulligan, who suggested it could be used to
correct an anterior position fault and maintain normal fibular alignment. Numerous studies\textsuperscript{20-27} have looked at the effectiveness of this taping technique in regards to different impairments associated with CAI, but findings have been inconsistent.

Studies by Grindstaff et al\textsuperscript{25} and Chou et al\textsuperscript{24} both looked at how FRT technique affected spinal reflex excitability of the soleus and peroneus longus in individuals with CAI. No increase in spinal reflex excitability of either muscle was observed in the study by Grindstaff et al\textsuperscript{25}, whereas Chou et al\textsuperscript{24} demonstrated an 11\% increase in soleus spinal reflex excitability after fibular tape application. Differences in methodology may have accounted for the conflicting results. In the study conducted by Chou et al\textsuperscript{24}, participants were taped in a supine position, but then tested in a prone position. In Grindstaff et al’s\textsuperscript{25} study, participants were both taped and tested in a supine position. Previously, Dishman et al\textsuperscript{34} found that body position changes between intervention, and testing may influence changes in spinal reflex excitability.

Several authors\textsuperscript{20-23} examined the effect of FRT technique on postural control in active individuals with CAI. Studies by Someeh et al\textsuperscript{22} and Wheeler et al\textsuperscript{23} found significant improvements in postural control, while Hopper et al\textsuperscript{21} and Delahunt et al\textsuperscript{20} did not. The study conducted by Hopper et al\textsuperscript{21} used a force plate to measure static postural sway, which may account for the contradicting findings. It has been suggested previously that while using static balance to assess postural control after an acute lateral ankle sprain is a promising tool, the changes are more subtle in participants with CAI.\textsuperscript{35} Utilizing more functional tasks, such as the star excursion balance test (SEBT), may be better for assessing postural control in individuals with CAI, since they are more challenging.\textsuperscript{35,36} Different reach differences were utilized with the remaining studies that
used SEBT to assess postural control. The study by Someeh et al\textsuperscript{22} utilized the anteromedial, medial, and posteromedial directions because Hertel et al\textsuperscript{37} previously found a high correlation between those SEBT directions and postural control deficits in participants with CAI, and found increased reach differences after FRT when compared to the no tape condition. However, Delahunt et al\textsuperscript{20} and Wheeler et al\textsuperscript{23} used the anterior, posteromedial, and posterolateral directions, which has been deemed the gold standard for measuring postural control\textsuperscript{38}, but found varying outcomes. The study by Wheeler et al\textsuperscript{23} found enhanced reach distance in the posterolateral direction with the application of FRT technique compared to the sham group. On the other hand, Delahunt et al\textsuperscript{20} found no improvements in any of the directions between the FRT technique, a lateral subtalar sling taping, and the no tape condition, yet the participants reported feeling an increased perceived sense of stability with both of the taping conditions. Although findings regarding the posterolateral reach distance were significant in Wheeler et al’s\textsuperscript{23} study, the change was not enough to exceed the minimal detectable change, and may be due to measurement error.

Other outcome measures that have been studied regarding the effectiveness of the FRT technique in individuals with CAI are ankle kinematics, ankle dorsiflexion, muscle activity, and functional tasks. A study conducted by East et al\textsuperscript{27} found that participants with CAI landed in a less plantarflexed position at initial contact during a jump landing task after application of the FRT technique and a sham taping. Tibialis anterior muscle activation was decreased as well, which may be attributed to a more efficient moment arm.\textsuperscript{27} Conversely, Wheeler et al\textsuperscript{23} found a significant increase in ankle dorsiflexion after sham and FRT taping, however, it did not exceed the minimal detectable change. A study
by Someeh et al\textsuperscript{26} found that performance with single leg hop, figure-8 hope, and side hop was increased after application of FRT technique in both healthy individuals and individuals with CAI compared to no tape. It is important to note that a sham tape was not included in the methodology, and therefore, does not eliminate the possibility of an afferent stimuli.

Due to the numerous studies that have reported significant improvements in spinal motor neuron excitability, postural control, functional activities, and kinematics during landing, it appears the FRT technique is capable of altering sensorimotor deficits associated with CAI. However, based on the findings of the present study, the changes reported in the previous literature may not be due to repositioning of the fibula, and may have occurred through another mechanism of the tape. Results of previous studies\textsuperscript{20,21,39} suggest that taping application produces a sensorimotor input, and may be responsible for the improvements in dynamic postural control.

Previous research has utilized diagnostic ultrasound to assess the distance between the talus and fibula at the ankle, but methodology differed compared to the present study. In the present study, the highest point of each bony landmark was identified and used as the reference points in which measurements were taken, whereas a study by Sisson et al\textsuperscript{40} used the anterolateral aspect of the lateral malleolus and the peak of the talus as the reference points. As a result, the mean ultrasound measurement between the fibula and talus when the ankle was in a neutral position was 18.7mm (0.187cm) for healthy individuals. Similarly, Croy et al\textsuperscript{41} found a mean ultrasound measurement of 18.8mm (0.188cm) with the ankle in neutral in individuals with CAI using the same reference points. It is important to note that purpose of both of these
studies was to examine the anterior talofibular ligament in various positions, which is why those bony reference points for measurements were chosen, as those correlate with the origin and insertion of the ligament.

Findings of this study also reveal that 8 out of the 20 subjects did exhibit a change in fibular position that exceeded the SEM after application of the FRT technique compared to the sham condition. Potential causes for this change include number of ankle sprains sustained, time since the previous ankle sprain, and individual joint mobility. Future research should be conducted to determine if there are certain characteristics that determine if an individual is more likely to respond to the FRT technique.

Clinical Implications

Although findings of this study suggest that the FRT technique does not alter fibular position, previous research suggests it may still cause functional benefits. A study conducted by McGuine found that ankle bracing may not have as much of a mechanically restrictive component as once thought, and this taping technique uses less tape than a standard external ankle tape, which may be more cost effective.

Findings of this study revealed intertester reliability to be excellent, indicating that it is a reliable tool to examine fibular position. It has been previously demonstrated to be a reliable tool in examining laxity of the anterior talofibular ligament as well. Both studies suggest that diagnostic ultrasound may be a reliable diagnostic tool to use at the ankle, with added benefit of it being cost effective, safe, and more readily available in certain settings.

Limitations
There were several limitations of this study to be considered. The tape could not cover the entirety of the lateral malleolus as demonstrated in previous studies because the ultrasound transducer was required to be in contact with a portion of the bony landmark, thus altering the amount of tension applied to the tape. In addition, the amount of tension placed on the tape was not standardized, and may have varied slightly between applications. Lastly, it was not determined if the participants possessed the impairment of a positional fault, only if the tape affected their current fibular position. Therefore, it is possible that the subset of individuals with CAI utilized may not have possessed the impairment. Future research should be conducted to determine if a difference in fibular position exists between healthy ankles and ankles with CAI with diagnostic ultrasound, as well as if all individuals with CAI possess a positional fault, or if it is an impairment that affects a subset of the CAI population.

**Conclusion**

In conclusion, no change in position of the fibula was observed between the FRT technique and sham taping, despite several studies producing favorable functional outcomes after application of the FRT technique. The rationale behind those findings is still unknown, as this was the first study examining the change in fibular position after application of the FRT technique. Several subjects exhibited changes outside the calculated SEM, and should be further investigated to determine if there is a subset of the CAI population that would respond more favorably to the FRT technique. Diagnostic ultrasound is a reliable tool in evaluating position of the fibula at the ankle.
References


Appendix A

The Problem

Problem Statement

Regarding people who have sprained their ankle, 47%-74% of them will have a recurrent ankle sprain within 6 to 18 months after the initial sprain.\textsuperscript{1-3} Repetitive lateral ankle sprains can lead to CAI.\textsuperscript{4-6} One of the mechanical insufficiencies that individuals with CAI may experience is a positional fault of the distal fibula.\textsuperscript{7} Researchers have previously used external measurement devices\textsuperscript{8}, MRIs\textsuperscript{9,10}, and fluoroscopy\textsuperscript{11,12} to determine positional fault of the fibula, but never diagnostic ultrasound. In addition, Mulligan\textsuperscript{7} introduced an FRT technique that was suggested to correct the positional fault of the fibula. To date, there have been no studies to examine the efficacy of the FRT technique in altering the position of the fibula with diagnostic imaging or external measurement of any type. This study will be the first to examine the efficacy of the FRT technique on changing the position of the fibula using a diagnostic imaging technique.

Research Questions

1. Will there be a change in the position of the fibula between three different taping conditions (FRT technique, sham tape, and no tape) in individuals with CAI using diagnostic ultrasound?

2. Is diagnostic ultrasound a reliable tool in assessing the position of the fibula?

Experimental Hypotheses

1. There will be a change in the position of the fibula between the three different taping conditions in individuals with CAI.

2. Diagnostic ultrasound will be a reliable tool in assessing the position of the fibula.
Assumptions

1. There will be consistency with the application of the tapings.
2. There will be consistency with taking ultrasonography measurements.

Delimitations

1. The study is limited to adults between the ages of 18 and 40.
2. The study is limited to adults active at least 3 times a week for 30 minutes.
3. The participants will have not sustained an ankle injury within the past 6 weeks.
4. The participants will have no history of lower extremity surgery.
5. The participants will have no history of a vestibular or balance disorder.
6. The taping will be applied by the same clinician.
7. The diagnostic ultrasound assessment will be completed by the same clinician.

Limitations

1. Subjects with unilateral CAI may have postural control deficits in the uninjured ankle.

Operational Definitions

Chronic Ankle Instability (CAI)- repetitive ankle sprains accompanied by persistent symptoms, such as giving way, that last greater than one year after an ankle sprain.\textsuperscript{13,14}

Fibular Repositioning Taping (FRT)- taping technique introduced by Mulligan with the goal of using one strip of tape to pull the distal fibula posteriorly.\textsuperscript{7}

Positional Fault- subluxation or sustained joint malalignment that results from injury, and may alter kinematics of the affected joint.\textsuperscript{7,15}

Significance of Study
Lateral ankle sprains are an extremely common musculoskeletal injury among active individuals, with an incident rate of 2.15 per 1000 person-years.\textsuperscript{16} In high school athletes, lateral ankle sprains occur at an injury rate of 0.52 per 1000 exposures, totaling 326,396 per year.\textsuperscript{17} In collegiate athletes, this injury represents 15% of all injuries in, occurring at a rate of 0.83 per 1000 exposures, resulting in about 11,000 ankle sprains per year.\textsuperscript{18} Approximately 30% of individuals that sustain a lateral ankle sprain, will go on to suffer a recurrent sprain, and present with residual symptoms that can be debilitating when leading an active life (van Rijn 2008). Despite the availability of an evaluation and treatment algorithm aimed at guiding the conservative management of chronic ankle instability\textsuperscript{19}, there is still literature lacking regarding information pertaining to arthrokinematic impairments, specifically the positional fault of the fibula thought to be associated with chronic ankle instability. While diagnostic ultrasound has been used in some capacity in clinical practice, evaluating different methods to objectively measure the distal position of the fibular provides benefit for clinicians.
Appendix B

Literature Review

Anatomy

Structural

The ankle is made up of three articulations: the talocrural joint, the subtalar joint, and the distal tibiofibular syndesmosis. The talocrural joint, also known as the “mortise” joint, is made up of the articulations between the dome of the talus, the medial malleolus, the tibial plafond, and the lateral malleolus. The lateral aspect consists of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL). The ATFL is 7.2mm wide and 24.8mm long, and connects the lateral malleolus anteriorly and medially to the talus at an angle of 45° from the frontal plane. The CFL connects the lateral malleolus posteriorly and inferiorly to the lateral aspect of the calcaneus at an angle of 133° from the long axis of the fibula. The PTFL connects the lateral malleolus posteriorly to the posterolateral aspect of the talus and fibula.

The subtalar joint is made up of the articulations between the talus and calcaneus, and can be further divided into two separate joint cavities: anterior and posterior. The anterior subtalar joint, also called the talocalcaneonavicular joint, is created by the head of the talus, the anterior-superior facets, the sustentaculum tali of the calcaneus, and the concave proximal surface of the tarsal navicular. It resembles a ball-and-socket joint. The talar head is the “ball”, and anterior calcaneal surface, proximal navicular surface, and the spring ligament form the socket. The architecture of this joint may vary greatly between individuals. The posterior subtalar joint is created by the
superior posterior facet of the calcaneus and the inferior posterior facet of the talus. The ligaments that support the subtalar joint are not well established, and there are discrepancies in the literature concerning the names of the individual ligaments, and their functions. Despite the controversy, these ligaments can be divided into three categories: deep ligaments, peripheral ligaments, and retinacula. The cervical and interosseous ligaments are the deep ligaments. The cervical ligament is found within the sinus tarsi anterior and lateral to the interosseous ligament, and extends from the cervical tubercle of the anteromedial calcaneus to the talar neck. The interosseous ligament is found posterior and medial to the cervical ligament, stemming from the calcaneus, anterior to the posterior joint capsule, and extending superiorly and medially to the talar neck. The inferior extensor retinacula is further divided into lateral, intermediate, and medial roots. The peripheral ligaments are the CFL, lateral talocalcaneal (LTCL), and fibulotalocalcaneal (FTCL) ligaments. The LTCL extends parallel and anterior to the CFL, yet it only crosses the posterior subtalar joint. The FTCL, also referred to as ligament of Rouviere, extends from the posterior surface of the lateral malleolus to the posterolateral surface of the talus and then to the posterolateral calcaneus directly posterior to the CFL. The bifurcate ligament is another vital lateral ankle ligament that is made up of two branches: the dorsal calcaneocuboid branch and dorsal calcaneonaviculcular branch.

The distal tibiofibular joint is formed by the distal articulation between the concave tibial facet and the convex fibular facet. Its structural integrity is necessary because it provides a roof for the mortise of the talocrural joint. The anterior and posterior inferior tibiofibular ligaments, as well as the distal interosseous membrane
maintain the syndesmosis. The interosseous membrane is strong fibrous connective tissue that serves as an origin of various muscles that act on the ankle. It also allows passage of the deep peroneal nerve and anterior tibial artery through a small opening proximally.

There are four lower leg compartments that contain muscles, nerves, and blood vessels that cross the ankle joint and produce motion. The anterior compartment encloses the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and the peroneus tertius muscles all innervated by the deep peroneal nerve. The extensor retinaculum crosses the anterior portion of the ankle mortise as well. The lateral compartment holds the peroneus longus and brevis innervated by the superficial peroneal nerve, and the superior and inferior peroneal retinaculums. The superficial posterior compartment contains the gastrocnemius, soleus, and plantaris muscles. The deep posterior compartment contains the tibialis posterior, flexor hallucis longus, and flexor digitorum longus. The tibial nerve innervates both the superficial and deep posterior compartment.

Functional

The three joints in the ankle work together to create synchronized rearfoot movement. The talocrural joint is responsible for dorsiflexion and plantarflexion in the sagittal plane, and the subtalar joint is responsible for inversion and eversion in the frontal plane. However, the two primary joints aforementioned have oblique axes of rotation. Pronation and supination describes coupled rearfoot motion, but differs between open and closed kinetic chain position. In the open kinetic chain, pronation occurs when the ankle is dorsiflexed, everted, and externally rotated, while supination
occurs when the ankle is plantarflexed, inverted, and internally rotated. In the closed kinetic chain, pronation occurs when the ankle is plantarflexed, everted, and externally rotated, while supination occurs when the ankle is dorsiflexed, inverted, and internally rotated. Stability of these joints depends on the congruity of the articular surfaces when the ankle is loaded, the static ligamentous restraints, and the dynamic stabilization of the musculature.

The talocrural joint has extensive ligamentous support responsible for joint stability. The ATFL limits plantar flexion, and prevents anterior translation of the talus on the lateral malleolus, as well as inversion and internal rotation of the talus on the tibia. The energy to failure and maximal load is lower in the ATFL compared to the other ligaments in the ankle, which may explain why it is injured most often. The CFL limits inversion and internal rotation of the rearfoot, and limits supination at the two primary ankle joints. It is the second most commonly injured lateral ankle ligament. The PTFL limits inversion and internal rotation of the talocrural joint when it is loaded, and is the least commonly sprained lateral ankle ligament. In addition to the ligamentous support, talar translation and rotation is limited by the articular surfaces of the ankle complex when it is fully loaded.

The subtalar joint has a complex array of ligamentous support with varying functions. The deep ligaments together create a barrier between the anterior and posterior joint capsules, and stabilize the joint. The cervical ligament is the strongest of the subtalar ligaments, and stabilizes both of the subtalar joint capsules, as well as limits supination. Parts of the interosseous ligament remain taut during pronation and supination due to its oblique fiber arrangement. The inferior extensor retinacula,
namely the lateral root, assists in providing stability to the lateral aspect of the subtalar joint. In the subtalar joint, the CFL limits inversion and internal rotation of the calcaneus on the talus. The LTCL and FTCL limit supination of the subtalar joint as well, even though they are smaller and weaker than the CFL. The bifurcate ligament limits supination of the midfoot, and serves as a static stabilizer of the lateral ankle complex.

The distal tibiofibular joint is a syndesmosis, meaning it only allows accessory motions such as gliding, yet that motion is critical for ankle kinematics to occur normally. During weight bearing, the fibula glides inferiorly to deepen the ankle mortise and tighten the interosseous membrane. During dorsiflexion, the distal fibula glides laterally and superiorly in order to achieve a horizontal alignment of the interosseous membrane and tibiofibular ligaments. During plantarflexion, the fibula glides inferiorly and medially in order to achieve a vertical alignment of the ligamentous structures.

The muscles that cross the ankle complex provide dynamic protection to the joints by contracting eccentrically. The peroneus longus and brevis control supination of the rearfoot and provide the primary protection against lateral ankle sprains. The muscles of the anterior lower leg compartment are dorsiflexors, and assist the peroneals with those actions by slowing down the plantarflexion aspect of supination. The tibialis anterior, accounting for 80% of the ankle’s dorsiflexion power, is the primary dorsiflexor and supinator. The extensor retinaculum function is to secure the distal tendons of the anterior compartment as they cross the talocrural joint. The peroneals are strong everters of the ankle, and their tendons are held down in place by the superior and inferior peroneal retinaculum. The muscles of the superficial posterior compartment...
are plantarflexors, with the gastrocnemius and soleus having the most influence on motion.\textsuperscript{29} The muscles of the deep posterior compartment invert and plantarflex the ankle\textsuperscript{29}, although the tibialis posterior primarily adducts the forefoot and controls pronation by producing substantial tension during running.\textsuperscript{41}

The ankle complex is innervated by various motor and sensory nerves that originate from the lumbar and sacral plexes. The tibial, deep peroneal, and superficial peroneal nerves provide the motor supply to the muscles, while the sural and saphenous nerves in conjunction with the motor supply provide the sensory supply to the muscles. Proprioception is controlled by the high number of mechanoreceptors that are located in the joint capsules and ligaments.\textsuperscript{22,43,44}

**Chronic Ankle Instability**

Chronic ankle instability results after an individual sustains numerous lateral ankle sprains, and possesses residual symptoms.\textsuperscript{14,37} The initial sprain is the top predisposition to recurrent sprains and the development of CAI due to the adverse effects that occur from the original injury.\textsuperscript{45} Mechanical and functional instability is the proposed cause for CAI, and explain that possible adverse effects of an initial lateral ankle sprain.\textsuperscript{14}

**Lateral Ankle Sprain**

The most common mechanism for a lateral ankle sprain is excessive inversion and internal rotation of the rearfoot, coupled with external rotation of the lower leg shortly after initial contact during gait, or landing from a jump.\textsuperscript{46,47} Increased plantarflexion at initial contact seems to increase the chances of sustaining a lateral ankle sprain too.\textsuperscript{48} The ATFL is most common ligament damaged\textsuperscript{49,50}, followed by the CFL\textsuperscript{49,50}, and the PTFL in
more severe sprains, fractures, or dislocations\textsuperscript{51}. Signs and symptoms of a lateral ankle sprain include point tenderness over the lateral ligament complex and sinus tarsi, edema, pain with inversion and plantarflexion, and trouble weight bearing.\textsuperscript{29} The research lacks in establishing definitive risk factors for first-time ankle sprains, but some potential causes are increased tibial varum\textsuperscript{52}, nonpathologic talar tilt\textsuperscript{52}, poor postural control\textsuperscript{53,54}, impaired proprioception\textsuperscript{55}, high eversion-inversion strength ratio, and high plantarflexion-dorsiflexion strength ratio\textsuperscript{56}.

**Mechanical Instability**

Mechanical instability refers to the structural changes that may occur after a lateral ankle sprain causing various mechanical insufficiencies.\textsuperscript{14} The possible mechanical insufficiencies that are thought to follow after an initial sprain are pathologic laxity, arthrokinematic impairments, degenerative changes, and synovial changes.\textsuperscript{14}

**Pathologic Laxity**

Pathologic laxity is a result of ligamentous damage causing the joint to be mechanically unstable.\textsuperscript{14} When the joint is mechanically unstable, it increases the likelihood of recurrent injury when the joint is put in a vulnerable position.\textsuperscript{14} In the CAI population, this is most common at the talocrural and subtalar joint.\textsuperscript{57} The severity of the laxity can vary, and often depends on the extent of the damage to the ligaments. In the talocrural joint, the laxity is caused by injury to the ATFL and CFL.\textsuperscript{58} During a physical examination, the laxity of the ATFL can be assessed using the anterior drawer test, while the talar tilt test can be used to assess the laxity of the CFL. However, Scranton et al\textsuperscript{59} found that 11% of healthy individuals have asymmetric ankle laxity when laxity was evaluated using the two aforementioned tests. In addition, these tests don’t take into
account the triplanar axis around which ankle motion occurs. Other ways laxity can be assessed are with stress radiography, or instrumented arthrometry.

Regarding the subtalar joint, injury to the CFL can result in simultaneous disruption to the subtalar joint capsule, cervical ligament, and other subtalar lateral ligaments. The LTCL has been found to be ruptured in cases of CAI. Clinical assessment of the anterior translation of the calcaneus from the talus can be done with the medial subtalar glide test or stress radiography. Subtalar tilt can be gauged using stress radiography as well.

*Arthrokinematic Impairments*

Arthrokinematic impairments can occur at any of the three joints of the ankle complex and may be caused by a positional fault or reduced range of motion at a joint. Mulligan proposed that there is an anterior positional fault of the lateral malleolus at the inferior tibiofibular joint in individuals with CAI that may cause dysfunction in the talus and ATFL. Reduced range of motion, specifically in dorsiflexion, may be a predisposition to a lateral ankle sprain because the ankle will not be able to obtain the closed-packed position. The closed-packed position is the most stable position of the ankle, therefore, inversion and internal rotation of the ankle aren’t easily achieved. Subtalar pronation is also increased as a result of limited dorsiflexion. Previous research has found a link between decreased dorsiflexion and repetitive lateral ankle sprains.

*Degenerative Changes*

Repetitive lateral ankle sprains have been related to degenerative changes in the joint. When comparing asymptomatic ankles to individuals having surgery for ankle-ligament repair, Scarton et al found that the injured ankles were 3.37 times more likely
to have osteophytes present in the joint. Gross and Marti\textsuperscript{72} demonstrated similar results with osteophytes and subchondral sclerosis found in volleyball players with CAI.

**Synovial Changes**

Synovial inflammation has been found in the talocrural and posterior subtalar joint capsules in the CAI population.\textsuperscript{14} The inflammation may cause hypertrophied synovial tissue between the bones of the ankle complex causing an impingement of the capsule.\textsuperscript{14} In individuals with lateral ankle instability necessitating surgical intervention, 67\% had anterolateral impingement syndrome of the talocrural joint, and 49\% had talocrural synovitis.\textsuperscript{73}

**Functional Instability**

The idea of functional instability was first described in 1965 by Freeman et al\textsuperscript{4,5}, and refers to the changes in dynamic support that may occur after a lateral ankle sprain, causing numerous functional insufficiencies. The possible functional insufficiencies that may occur after an initial sprain are impaired proprioception, impaired neuromuscular control, strength deficits, and impaired postural control.\textsuperscript{14}

**Impaired Proprioception and Sensation**

Proprioception is defined as the combination of neural input to the central nervous system from mechanoreceptors in the joint capsules and ligaments, as well as the surrounding muscles and overlying skin.\textsuperscript{74} It is further divided into kinesthesia and joint position sense for assessment purposes.\textsuperscript{75} Kinesthesia in the ankle is evaluated using threshold-to-detection of passive motion, while joint position sense is evaluated using active and passive joint reproduction.\textsuperscript{75} Proprioception is a determinant of postural control, which is essential in preventing lateral ankle sprains.\textsuperscript{76,77} If there is deficiency in
proprioception of the ankle, the lateral border of the foot could hit the ground during the swing phase causing forced inversion, resulting in injury or episode of “giving way”. This hypothesis was confirmed by Delahunt et al, who found that individuals with CAI have a decreased foot-floor clearance during the terminal swing phase with treadmill walking compared to healthy individuals.

Joint kinesthesia in the ankle has been examined in both the sagittal and frontal planes. In the sagittal plane, the evidence is split in determining if there is a dysfunction. Garn and Newton and Mulloy Forkin et al found individuals with unilateral CAI had more trouble detecting changes in passive motion in their injured ankle compared to their uninjured counterpart. However, Refsheuge et al found no significant differences in detecting changes in passive motion when compared to uninjured control. Evidence is inconsistent regarding joint positions sense in the frontal plane as well. Lentell et al found a deficit in inversion kinesthesia, whereas Hubbard and Kaminski found no deficits in inversion or eversion kinesthesia in subjects with unilateral CAI.

Evidence surrounding frontal plane joint positions sense is more in agreement, with several studies all demonstrating that active and passive joint position replication deficits are present in the CAI population.

**Impaired Neuromuscular Control**

Neuromuscular control is defined as the unconscious activation of dynamic restraints occurring in preparation for and in response to joint motion and loading for the purpose of maintaining and restoring functional joint stability. In the ankle, response time of the peroneals to an unexpected inversion perturbation is the most commonly researched. Konradsen and Ravn, Karlsson and Andreasson, Lofvenberg et al, and
Vaes et al\textsuperscript{91} found that there was a longer peroneal reflex response time after an unexpected inversion mechanism in subjects with CAI compared to controls. On the contrary, Ebig et al\textsuperscript{92}, Fernandes et al\textsuperscript{93}, and Vaes et al\textsuperscript{94} found the opposite. Therefore, there is a discrepancy in the literature as to whether there really is a delayed reflex peroneal response time to sudden unexpected inversion stress.\textsuperscript{95} The reflex response time of the peroneus longus to a sudden inversion perturbation has been shown to be a reliable measure.\textsuperscript{96} The variation in findings may be largely attributed to the researcher’s definition and inclusion criteria of functional ankle instability, which should be standardized.\textsuperscript{95} The angles of perturbation differed in all the studies as well.\textsuperscript{95}

**Impaired Postural Control**

Impaired postural control is exhibited in the CAI population\textsuperscript{97,98}, and results secondary to a deficit in neuromuscular control and proprioception\textsuperscript{14}. Individuals with CAI possess poor ankle strategy, instead adopting an inefficient hip strategy in order to maintain a single-leg stance.\textsuperscript{99} Ankle strategy is the pronation and supination of the foot in order to maintain the body’s center of gravity above its base of support.\textsuperscript{100} The movement at the hip in order to maintain balance in these individuals causes a large shear forces with the ground, increasing ankle inversion.\textsuperscript{101} Many individuals with CAI complain of the ankle “giving way” as a result of this.\textsuperscript{101} The cause of poor ankle strategy may be changes in central neural control due to the injury at the joint.\textsuperscript{14}

Examples of techniques in order to evaluate postural control include single leg stance [10,14]\textsuperscript{102,103}, star excursion balance test (SEBT)\textsuperscript{104-106}, time to stabilization (TTS)\textsuperscript{107,108}, and the dynamic postural stability index\textsuperscript{109}. While the static single leg stance
task has been replaced by the more dynamic SEBT, TTS, and dynamic postural stability index, all have been used to show postural control deficits in individuals with CAI.

Olmstead et al\textsuperscript{105} and Gribble et al\textsuperscript{106} found decreased reach distances during the SEBT in subjects with CAI when compared to either healthy controls or the uninjured ankle. In addition, Gribble et al\textsuperscript{106} found decreased knee and hip flexion angles during the SEBT. Ross et al\textsuperscript{107} and Brown and Mynark\textsuperscript{108} found that there is a longer TTS after dynamic activity in individuals with CAI. Ross et al\textsuperscript{107} hypothesized that the incorrect proper landing techniques these subjects had could would make the ankle joint susceptible to recurrent injury. Wikstrom et al\textsuperscript{109} found postural control deficits as well in the same population using a dynamic postural stability index.

**Strength Deficits**

The musculature of the ankle joint plays a crucial role in dynamic stabilization via co-contraction.\textsuperscript{110} Co-contraction reduced ground reaction forces (GRFs) during high-load dynamic activities, such as running, cutting, and jump landing.\textsuperscript{111} Strength deficits after repetitive ankle injury cause co-contraction muscular imbalance, which may leave the joint vulnerable to injury because the GRFs will not be dissipated as well.\textsuperscript{110} As a result of this poor dissipation, ligamentous structures and articular structures of the ankle may be affected by abnormal forces.\textsuperscript{112,113}

The two primary muscle groups that were thought to be affected were the evertors and inverters.\textsuperscript{111} Decreased strength in the peroneals was thought to be detrimental because they wouldn’t be able to resist the inversion moment and bring the ankle back to a neutral position.\textsuperscript{114} Decreased inverter strength was thought to be harmful because they control the rate of calcaneal eversion in the closed kinetic chain when the body’s center
of mass is displaced laterally past the base of support.\textsuperscript{115} In the event of excessive calcaneal eversion, the medial forefoot would lift up from the ground, causing a lateral ankle sprain from the inversion torque about the forefoot and rearfoot.\textsuperscript{115}

Conversely, current literature refutes the hypothesis of everter weakness by means of isokinetic dynamometry in individuals with CAI.\textsuperscript{116-120} Inverter weakness, though, is suggested to exist in the CAI population.\textsuperscript{117,121,122} Ryan\textsuperscript{117} has proposed that selective inhibition is the cause of the inverter strength deficits. Selective inhibition development may be the result of arthrogenic muscle inhibition (AMI), which is an ongoing reflex inhibition of the musculature surrounding a joint following injury to the structures of that joint.\textsuperscript{123} AMI makes rehabilitation difficult because it impedes appropriate activation of surrounding muscles of the affected joint.\textsuperscript{123} Selective inhibition is thought to occur by inhibiting muscles that are able to increase tensile stress on damaged ligamentous and articular structures in order to protect those structures.\textsuperscript{124} Since the inverters produce inversion at the ankle and stress the lateral ankle ligament complex, they may be inhibited reflexively to protect the joint.\textsuperscript{111}

**Positional Fault of the Fibula**

One of the potential causes of mechanical instability that is frequently overlooked is a positional fault.\textsuperscript{7} Positional fault is a subluxation or sustained joint malalignment that results from injury, and may alter joint kinematics of the affected joint.\textsuperscript{7,15} These malalignments cannot be seen on a radiograph or detected through palpation due to their subtle nature.\textsuperscript{7} Consequences of positional faults include decreased range of motion and pain.\textsuperscript{8} In individuals suffering from CAI, there is a discrepancy in the current literature regarding the direction in which the distal fibula displaces.
**Anterior Positional Fault**

Several studies suggest there is an anterior positional fault of the fibula in this population. Mulligan hypothesized that the fibula is anteriorly translated on the tibia at the inferior tibiofibular joint when the foot is inverted past its normal range causing a positional fault. This dysfunction may cause the ATFL to be more slack in its resting position, allowing the talus to go through a greater amount of motion during rearfoot supination before the ATFL becomes taut. Hubbard et al also proposed that the anterior positional position may be caused by disruption to the peroneus longus and brevis muscles. Damage to the musculotendinous and ligamentous mechanoreceptors may alter the afferent input from the gamma motorneuron system, causing the positional fault. That positional fault after an ankle sprain causes an extra amount of anterior-posterior movement at the distal fibula. In these studies, the position of the fibula in direct relationship to the tibia was measured in the sagittal plane. The distance between the anterior borders of the distal fibula and the tibia were used to obtain this measurement.

**Posterior Positional Fault**

On the other hand, several studies have suggested there is a posterior positional fault of fibula after an acute lateral ankle sprain. In these studies, the axial malleolar index was used to determine the positional fault. They measured the relationship in the transverse plane at the talocrural joint, which relies on the position of the talus. The problem with this technique is that the talus may be displaced anteriorly after a lateral ankle sprain, making the fibula appear to be displaced.
posteriorly. Therefore, the discrepancy is likely due to the measurement technique used, in regards to whether the position of the talus is considered.

**Fibular Reposition Taping Technique**

The FRT technique was first proposed by Mulligan, with the claim that it can maintain correct fibular alignment and correct an anterior positional fault of the fibula after an ankle sprain. The resultant effect of this correction may be to prevent additional ankle sprains.

**Injury Prevention**

Moiler et al found a lower incidence of recurrent ankle injury when the FRT technique was applied prophylactically among basketball players with a history of a previous ankle sprain. When looking at numbers needed to treat, the FRT technique is as effective as traditional taping, with the benefit of less tape being used and quicker application. One roll of tape can provide a FRT to 17 players. However, it was not found to be as effective as bracing.

**Postural Control**

Delahun et al found the FRT improved perceived stability, but failed to objectively improve dynamic postural control using the SEBT. Wheeler also did not find an improvement in dynamic postural control using the SEBT. Hopper et al found similar results with FRT failing to improve static or dynamic balance at rest or when fatigued using postural sway on a forceplate. Both studies used subjects with CAI. These findings support the proposed explanation that a placebo effect is taking place because the benefits of taping were emphasized to the subjects. On the other hand, Someeh et al found that FRT improved reach distance in both healthy athletes and athletes with
CAI using the SEBT. The discrepancy between this study and the one conducted by Delahunt\textsuperscript{129} may be due to the variation in directions chosen for the reach distances. Someeh\textsuperscript{132} used the anteromedial, medial, and posteromedial directions, while Delahunt\textsuperscript{129} and Wheeler\textsuperscript{130} used the anterior, posteromedial, and posterolateral directions.

**Neuromuscular Changes**

Chou et al\textsuperscript{133} and Grindstaff et al\textsuperscript{134} found facilitation of soleus $h$-reflex amplitude immediately following FRT application in individuals with CAI, suggesting spinal reflex excitability changes in the soleus muscle. However, no changes in soleus $v$-wave or peroneal $h$-reflex were observed. Previous research has suggested that individuals with CAI suffer from AMI in the soleus and peroneus longus muscles.\textsuperscript{135,136} AMI is an ongoing reflex inhibition of the musculature surrounding a joint following injury to the structures of that joint.\textsuperscript{123} Therefore, the results from the aforementioned study suggest that FRT technique may serve as an afferent flood technique to disinhibit the soleus in the treatment of AMI.\textsuperscript{133} The lack of peroneal $h$-reflex following application of the FRT technique may be attributed to not enough spinal reflex excitability present to stimulate the peroneal motoneuron pool.\textsuperscript{133} East et al\textsuperscript{137} found no change in electromyography amplitude of the tibialis anterior or peroneus longus during jump landing task as well. One of the proposed theories for the lack of change in activation of the tibialis anterior is that when the ankle is in a more dorsiflexed position, the moment arm of the muscle is longer, making it more efficient.\textsuperscript{137} This efficiency reduces the need for more muscle activation.\textsuperscript{137} The decreased activity of the tibialis anterior may even be beneficial because it has the ability to produce inversion at the ankle.\textsuperscript{137}

**Ankle Kinematics**

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East et al\textsuperscript{137} found that the FRT altered ankle kinematics in the sagittal plane in individuals with CAI. Subjects tended to land in a less plantarflexed position at initial ground contact, increasing the bony joint congruency between the talus and the ankle mortise.\textsuperscript{137} This altered position may decrease the risk of recurrent ankle injury due to the improved landing mechanics.\textsuperscript{137} However, similar results were found with the placebo tape group.\textsuperscript{137} Previous literature suggests that traditional ankle taping\textsuperscript{138} and bracing\textsuperscript{139,140} limits plantarflexion at initial ground contact as well, but the maximum amount of dorsiflexion obtained during loading was not found with FRT\textsuperscript{137}. This could be due to the differing clinical implications of the various techniques. Traditional taping and bracing are thought to provide mechanical restraint to joint motion\textsuperscript{138}, while the FRT is thought to restore proper distal tibiofibular joint arthrokinematics\textsuperscript{7}. Taping in general also stimulates the cutaneous receptors leading to improved proprioception and joint position sense, explaining why the placebo group experienced similar outcomes.\textsuperscript{141-143} Another possibility is that even the taping techniques with one strip of tape offer a small amount of mechanical restriction to plantarflexion because they cross the talocrural joint.\textsuperscript{137}

**Diagnostic Ultrasound**

Researchers have previously used external measurement devices\textsuperscript{8}, MRIs\textsuperscript{9,10}, and fluoroscopy\textsuperscript{11,12} to determine positional fault in the ankle, but never diagnostic ultrasound. The ligaments of the ankle have been previously evaluated with diagnostic ultrasound.\textsuperscript{144,145} Croy et al used ultrasound imaging to determine the laxity of the ATFL during an anterior drawer test\textsuperscript{146}, as well as to compare various populations\textsuperscript{147}, and other diagnostic techniques\textsuperscript{148}. Lee et al\textsuperscript{149} used ultrasonography to measure tendon excursion of the gastrocnemius and tibialis anterior muscles.
Appendix C

Additional Methods

Executive Summary

Title: Examining the Positional Fault of the Fibula using Diagnostic Ultrasonography after Fibular Reposition Taping in Individuals with Chronic Ankle Instability

Project Supervisor: Neal Glaviano, PhD, ATC

Research Team: Neal Glaviano, PhD, ATC (Lead Investigator)
Luke Donovan, PhD, ATC (Co-Investigator)
Christopher Ingersoll, PhD, ATC (Co-Investigator)
Charles Armstrong, PhD (Co-Investigator)
Caroline Fitch, ATC (Co-Investigator)

Purpose:

The purpose of the study is to examine the position of the fibula using diagnostic ultrasound between application of no tape, placebo tape, and FRT technique in individuals with chronic ankle instability (CAI).

Participants:

There were 20 participants included in this study. Participants were recruited from the University of Toledo. All participants were between the ages of 18 and 40, and active at least 3 times a week, for at least 30 minutes. Participants had either unilateral or bilateral CAI.

Inclusion Criteria:

In order to fit the criteria of having CAI, participants possessed all of the following: (1) previously sustained more than one significant lateral ankle sprain in which they still
have residual symptoms, with the first occurring greater than 1 year ago; (2) score 85% or less on the Foot and Ankle Ability Measure (FAAM) Sport sub-scale; (3) score 11 or more on the Identification of Functional Ankle Instability; (4) involved in physical activity at least 3 times a week for at least 30 minutes as determined by a score of 24 or more on the Godin Leisure Time Exercise Questionnaire.150.

**Exclusion Criteria:**

Participants were excluded if they report any of the following: (1) history of an ankle injury within the past six weeks; (2) history of lower extremity surgery; (3) history of an ankle fracture; (4) any vestibular or balance disorder.

**Study Design:**

The study design was a crossover repeated measures. The dependent variable was the distance between the fibula and the talus, and the independent variable was the taping condition. Data collection took place in the Musculoskeletal Health and Movement Sciences Laboratory in the Health and Human Services Building at the University of Toledo. The study was approved the University’s Institutional Review Board #201476.

**Independent Variables:**

1. Taping
   a) No tape
   b) Placebo tape
   c) FRT tape

**Dependent Variables:**

1. Distance between the talus and fibula

**Procedures:**
1. Obtained informed consent

2. Screening (Demographics, FAAM Sport, IdFAI, Godin-Leisure)

3. Randomized Taping Condition

4. Ultrasound measurements
   a. Sidelying position
   b. 5 images
   c. 3 ankle pumps in between

5. Walking trials (for purpose of another study)

6. Repeat steps 3-5 an addition two times

**Statistical Analysis:**

The Statistical Package for the Social Sciences (Version 18.0. SPSS Science, Chicago, IL) was utilized for the statistical analysis of this study. Paired t-tests were utilized to determine if there were any significant differences between the three taping conditions. Alpha level was set at p<0.05. Cohen’s d effect sizes and 95% confidence intervals were calculated. Intraclass correlation coefficient (ICC$_{3,1}$) of intratester measurement reliability was calculated by having the lead researcher take ultrasound measurements for the first five subjects, and then repeat that same process three days later. The standard error of measure (SEM) was calculated as well, and this value was applied to the difference in measurements between the FRT and sham taping conditions.

**Research Hypothesis:**

1. There will be a change in the position of the fibula between the three different taping conditions in individuals with CAI.

2. Diagnostic ultrasound will be a reliable tool in assessing the position of the fibula.
Consent Form

RESEARCH SUBJECT INFORMATION AND CONSENT FORM

Lower Extremity Gait Kinematics in Chronic Ankle Instability Individuals and Diagnostic Ultrasound on Distal Fibula and Talus Distance

Principal Investigator: Neal Giavano, PhD, ATC (Lead Investigator)

Other Staff (identified by role): Grant Norte, PhD, ATC (Co-Investigator)
Luke Donovan, PhD, ATC (Co-Investigator)
Charles Armstrong, PhD (Co-Investigator)
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Caroline Fitch, ATC (Co-Investigator)

Contact Phone number(s): (419) 530-4501 (Neal Giavano)
(616) 400-1740 (John McClave)
(484) 767-5325 (Caroline Fitch)

What you should know about this research study:

- We give you this consent/authorization form so that you may read about the purpose, risks, and benefits of this research study. All information in this form will be communicated to you verbally by the research staff as well.

- Routine clinical care is based upon the best-known treatment and is provided with the main objective of helping the individual patient. The main goal of research studies is to gain knowledge that may help future patients.

- We cannot promise that this research will benefit you. Just like routine care, this research can have side effects that can be serious or minor.

- You have the right to refuse to take part in this research, or agree to take part now and change your mind later.

- If you decide to take part in this research or not, or if you decide to take part now but change your mind later, your decision will not affect your routine care.

- Please review this form carefully. Ask any questions before you make a decision about whether or not you want to take part in this research. If you decide to take part in this research, you may ask any additional questions at any time.

- Your participation in this research is voluntary.

PURPOSE (WHY THIS RESEARCH IS BEING DONE)

You are being asked to take part in a research study examining how a taping technique affects your ankle, knee, and hip positions during walking. The bone position in your ankle will also be assessed using ultrasound. The purpose of the study is to examine the difference in how your lower legs function with different taping techniques. You were selected as someone who may want to take part in this study.
because you are between the ages of 18 and 40 years old, and may be identified as having chronic ankle instability in at least one ankle. This research study will be conducted in the Musculoskeletal Health and Movement Science Laboratory at the Health Science and Human Service Building at the University of Toledo Main Campus. We will be enrolling 20 subjects for this study.

DESCRIPTON OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT
If you decide to take part in this study, you will be asked to report to the Musculoskeletal Health and Movement Sciences Laboratory at the University of Toledo. You will perform a controlled walking task while we record your leg movement. Afterwards, you will also be asked to lay down on a cushioned examination table for 10 minutes while we take measurements between the bones of your ankle using the ultrasound. Your entire testing session will take approximately 2 hours.

Eligibility Screening
Before you can officially enroll in this study, you will be given multiple questionnaires to determine your eligibility. You will be given a general health questionnaire, the Foot and Ankle Ability Measure Sport subscale, the Godin Leisure Time Exercise Questionnaire, and the Identification of Functional Ankle Instability. The general health questionnaire will ask questions similar to ones you would be asked in a health history screening at your doctor’s office. All female participants will be asked to disclose if they may be pregnant. There are no known risks to unborn children or pregnant women at this point. The other questionnaires will help researchers determine your eligibility for the study by asking about how well your ankle functions, as well as your physical activity level. These will take about 10 minutes to complete.

Warm-Up
It will not be necessary to warm-up before undergoing ultrasound. However, before the walking task you will have as much time as you need to adequately warm-up and prepare.

Treatment
You will receive 3 treatments in a random order: no tape, ankle taping 1, and ankle taping 2. The materials we will be using to complete the tappings are tape adherent, Cover-Roll, and Leukotape. Tape adherent is a spray that will help the tape stick better, Cover-Roll is a sticky mesh cloth tape, and Leukotape is a sticky sturdy tape.

Diagnostic Ultrasound
We will use a clinical tool called diagnostic ultrasound on your ankle to take measurements of bone position.

Walking Task
First, we will place wired sensors to your involved foot, lower leg, thigh, hip, and spine so that we can measure joint angles of the hip, knee, and ankle. Then you will be given the chance to warm-up. When you are ready, we will ask you to walk as normal as possible while trying to land on the force platform with your involved ankle. When you feel ready, you will repeat the same task for a total of ten trials. This same process will be repeated a total of three times.

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH
Likely Risks
- The tape or ultrasound gel may cause skin irritation.
The walking task may cause muscle soreness or foot discomfort. You will be offered ice bags after participation to reduce the risk of soreness and discomfort.

There is also the risk of falling or losing balance.

Unlikely Risks

- Injury to your foot or ankle. This risk is unlikely if you have been cleared for full activity according to the health history form.

There are no known risks to unborn children at this point. There may be risks that the researchers are unaware of at this time.

POSSIBLE BENEFIT TO YOU IF YOU DECIDE TO TAKE PART IN THIS RESEARCH

This study is designed for the investigators to learn more about the effects of the Fibular Reposition Taping (FRT) on lower body biomechanics while walking, as well as bone alignment in the ankle in young adults.

COST TO YOU FOR TAKING PART IN THIS STUDY

You will be asked to pay for all costs associated with travel to and from the University of Toledo’s main campus as a result of participating in this study.

PAYMENT OR OTHER COMPENSATION TO YOU FOR TAKING PART IN THIS RESEARCH

If you decide to take part in this research you will not receive any financial compensation for participating.

ALTERNATIVE(S) TO TAKING PART IN THIS RESEARCH

The only alternative to taking part in this research is not to participate. Your care through the University of Toledo Medical Center will not be affected should you decline participation.

CONFIDENTIALITY - (USE AND DISCLOSURE OF YOUR PROTECTED HEALTH INFORMATION)

By agreeing to take part in this research study, you give to The University of Toledo (UT), the Principal Investigator and all personnel associated with this research study your permission to use or disclose health information that can be identified with you that we obtain in connection with this study. We will use this information for the purpose of conducting the research study as described in the research consent/authorization form.

Under some circumstances, the Institutional Review Board, or the Research and Sponsored Programs of the University of Toledo may review your information for compliance audits. If you receive any payments for taking part in this study, your personal information and limited information about this study will be given to The University of Toledo’s accounts payable department as necessary to process payment to you. We may also disclose your protected health information when required by law, such as in response to judicial orders.

The University of Toledo is required by law to protect the privacy of your health information, and to use or disclose the information we obtain about you in connection with this research study only as authorized by you in this form. There is a possibility that the information we disclose may be re-disclosed by the persons we give it to, and no longer protected. However, we will encourage any person who receives your information from us to continue to protect and not re-disclose the information.
Your permission for us to use or disclose your protected health information as described in this section is voluntary. However, you will not be allowed to participate in the research study unless you give us your permission to use or disclose your protected health information by signing this document.

You have the right to revoke (cancel) the permission you have given to us to use or disclose your protected health information at any time by giving written notice to:

Neal Giavano, PhD, ATC at 419-530-4501.

However, a cancellation will not apply if we have acted with your permission, for example, information that already has been used or disclosed prior to the cancellation. Also, a cancellation will not prevent us from continuing to use and disclose information that was obtained prior to the cancellation as necessary to maintain the integrity of the research study.

Except as noted in the above paragraph, your permission for us to use and disclose your protected health information will stop at the end of the research study.

A more complete statement of University of Toledo’s Privacy Practices is set forth in its Joint Notice of Privacy Practices. If you have not already received this Notice, a member of the research team will provide this to you. If you have any further questions concerning privacy, you may contact the University of Toledo’s Privacy Officer at 419-383-0933.

The information that we will use or disclose will be de-identified information only, and will be used for publication in a scientific peer-reviewed journal. We may use this de-identified information ourselves, or we may disclose or provide access to the information to other researchers conducting similar research, and possibly a statistician to help analyze data collection as part of the research study. This study is not sponsored by any outside agencies. There is not a plan to share this data with any outside agency.

IN THE EVENT OF A RESEARCH-RELATED INJURY
In the event of injury resulting from your taking part in this study, treatment can be obtained at a health care facility of your choice. You should understand that the costs of such treatment will be your responsibility. Financial compensation is not available through The University of Toledo or The University of Toledo Medical Center.

By signing this form, you are not giving up any of your legal rights as a research subject. In the event of an injury, contact

Neal Giavano, PhD, ATC at 419-530-4501.

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

NEW FINDINGS
You will be notified of new information that might change your decision to be in this study if any becomes available.
OFFER TO ANSWER QUESTIONS
Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have questions regarding the research at any time before, during or after the study, you may contact: Charles Armstrong, PhD at 419-530-5369

If you have questions beyond those answered by the research team or your rights as a research subject or research-related injuries, please feel free to contact the Chairperson of the University of Toledo Biomedical Institutional Review Board at 419-383-6790.

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

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

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

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

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

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

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

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</table>

Please check below if you have had any of the following and explain checked items on line.

**General Medical**
- [ ] Allergies/Sensitivities (latex, cold, medications, etc.)
- [ ] Biomedical devices (implants, pacemaker, etc.)
- [ ] Recent illness (cold, flu, infection, etc.)
- [ ] Asthma
- [ ] Diabetes
- [ ] Pregnancy or nursing
- [ ] Other: __________

Please Explain: __________

**Neurological**
- [ ] Epilepsy/Seizures
- [ ] Multiple Sclerosis
- [ ] Recent illness (cold, flu, infection, etc.)
- [ ] Anxiety disorder
- [ ] Parkinson disease
- [ ] Concussion or Traumatic brain injury
- [ ] ADHD
- [ ] Cerebral Palsy
- [ ] Other: __________

Please Explain: __________

**Cardiovascular**
- [ ] High blood pressure
- [ ] Stroke
- [ ] Sickle cell trait
- [ ] Shortness of breath
- [ ] Heart murmur
- [ ] Cardiac Arrhythmia (irregular heart beat)
- [ ] Heart attack
- [ ] Thrombosis or Embolism
- [ ] Other: __________

Please Explain: __________

**General Orthopedic**
- [ ] Surgery
- [ ] Osteoarthritis
- [ ] Gout
- [ ] Previous fracture
- [ ] Rheumatoid arthritis
- [ ] Osteoporosis/Osteopenia
- [ ] Sprains or Strains (ligament/muscle/tendon)
- [ ] Assistive devices (canes, braces, etc.)
- [ ] Other: __________

Please Explain: __________

**Other**
- [ ] Have you taken any prescription or over-the-counter medications within the last 24-hours?  
  [ ] YES  [ ] NO  *If yes, please list: ____________________________*
- [ ] Have you consumed any of the following stimulants or depressants in the last 12-hours?  
  [ ] Caffeine  [ ] Alcohol  [ ] Tobacco  
  *If yes, please explain: ____________________________*
- [ ] Do you exercise regularly?  [ ] YES  [ ] NO  
  *If yes, what type and for how long? ____________________________*
- [ ] Are you currently experiencing physical pain?  [ ] YES  [ ] NO  
  *If yes, please indicate location, severity, and current treatments for you pain: ____________________________*
Because of your foot and ankle how much difficulty do you have with:

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<th>No Difficulty at all</th>
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<tr>
<td>Starting and stopping quickly</td>
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<td>□</td>
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<td>Ability to participate In your desired sport As long as you like</td>
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<td>□</td>
<td>□</td>
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<td>□</td>
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</table>

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

__ __ __% 0%

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

□ Normal □ Nearly Normal □ Abnormal □ Severely Abnormal
IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IDFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement: "Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one’s ankle.

I am completing this form for my RIGHT/LEFT ankle (circle one).

1.) Approximately how many times have you sprained your ankle? ________

2.) When was the last time you sprained your ankle?
   □ Never □ > 2 years □ 1-2 years □ 6-12 months □ 1-6 months □ < 1 month

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?
   □ Have not seen someone □ Mild (Grade I) □ Moderate (Grade II) □ Severe (Grade III)

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?
   □ Never used a device □ 1-3 days □ 4-7 days □ 1-2 weeks □ 2-3 weeks □ >3 weeks

5.) When was the last time you had "giving way" in your ankle?
   □ Never □ > 2 years □ 1-2 years □ 6-12 months □ 1-6 months □ < 1 month

6.) How often does the "giving way" sensation occur in your ankle?
   □ Never □ Once a year □ Once a month □ Once a week □ Once a day

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?
   □ Never rolled over □ Immediately □ Sometimes □ Unable to stop it

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?
   □ Never rolled over □ Immediately □ < 1 day □ 1-2 days □ > 2 days

9.) During "Activities of daily life" how often does your ankle feel UNSTABLE?
   □ Never □ Once a year □ Once a month □ Once a week □ Once a day

10.) During "Sport/or recreational activities" how often does your ankle feel UNSTABLE?
    □ Never □ Once a year □ Once a month □ Once a week □ Once a day
Godin Leisure-Time Exercise Questionnaire

INSTRUCTIONS

In this excerpt from the Godin Leisure-Time Exercise Questionnaire, the individual is asked to complete a self-explanatory, brief four-item query of usual leisure-time exercise habits.

CALCULATIONS

For the first question, weekly frequencies of strenuous, moderate, and light activities are multiplied by nine, five, and three, respectively. Total weekly leisure activity is calculated in arbitrary units by summing the products of the separate components, as shown in the following formula:

Weekly leisure activity score = (9 × Strenuous) + (5 × Moderate) + (3 × Light)

The second question is used to calculate the frequency of weekly leisure-time activities pursued "long enough to work up a sweat" (see questionnaire).

EXAMPLE

Strenuous = 3 times/wk
Moderate = 6 times/wk
Light = 14 times/wk

Total leisure activity score = (9 × 3) + (5 × 6) + (3 × 14) = 27 + 30 + 42 = 99

Godin Leisure-Time Exercise Questionnaire

1. During a typical 7-Day period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time (write on each line the appropriate number).

   Times Per Week

a) STRENUOUS EXERCISE  
   (HEART BEATS RAPIDLY)
   (e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)

b) MODERATE EXERCISE  
   (NOT EXHAUSTING)
   (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing)

c) MILD EXERCISE  
   (MINIMAL EFFORT)
   (e.g., yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking)

2. During a typical 7-Day period (a week), in your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?

   OFTEN          SOMETIMES          NEVER/RARELY
   1. ○              2. ○               3. ○
Data Collection Forms

Subject #: ___________  Investigator Initials: ___________
Age: ___________  Height (in): ___________  Weight (lbs): ___________  Gender: ___________
Date of Visit: ___________  Time of Day: ___________

Right Ankle History:  Answer:
1. How many times have you sprained your right ankle?  ___________
2. How many years/months ago was your first right ankle sprain?  ___________
3. How many years/months ago was your most recent right ankle sprain?  ___________

Left Ankle History:
1. How many times have you sprained your left ankle?  ___________
2. How many years/months ago was your first left ankle sprain?  ___________
3. How many years/months ago was your most recent left ankle sprain?  ___________

Subjective Questionnaires:

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<td>Godin Leisure-time questionnaire</td>
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</table>

INCLUSION CRITERIA
Yes  No
☐  ☐  Age of 18 – 40 years
☐  ☐  History of more than one ankle sprain with the first ankle sprain occurring greater than one year ago.
☐  ☐  Self-reported ankle deficits qualified by a score of < 85% on the Foot and Ankle Ability Measure (FAAM) Sport Scale.
☐  ☐  Self-reported ankle deficits qualified by a score of ≥ 11 on the Identification of Functional Ankle Instability scale (idFAI).
☐  ☐  Involved in moderate to vigorous physical activity at least 3 times per week as determined by a score of ≥ 24 on the Godin’s Leisure Time Exercise Questionnaire.

EXCLUSION CRITERIA
Yes  No
☐  ☐  History of ankle fracture
☐  ☐  History of ankle surgery
☐  ☐  An acute ankle sprain within 6 months prior to data collection
☐  ☐  Any vestibular disorder

Assigned Version Date: 09/06/2016
Total Practice Trials:
  Treatment 1:
  Treatment 2:
  Treatment 3:

Difference between Taping Techniques:   Answer
  Could subject feel the difference between the two tappings?   ____

Additional Comments:
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Specific Testing Protocol

Demographics

- Age
- Height
- Weight
- # of ankle sprains
- Time since first ankle sprain
- Time since most recent ankle sprain

Questionnaires

- Foot and Ankle Ability Measure (FAAM) Sport sub-scale
- Identification of Functional Ankle Instability
- Godin-Leisure Time Exercise

Taping

1. Randomized Counterbalanced Method
   a. All of the taping conditions were done by the same third party clinician and were determined by a counterbalanced method. Order of the tapings for each subject were predetermined before the start of the study, and placed in an envelope.

2. Taping Condition
   a. No tape
   b. Sham tape
i. Seated with foot in a neutral position

ii. Cover-Roll was applied obliquely in a posterolateral direction beginning at the distal aspect of the lateral malleolus, but not covering the entirety of it.

iii. Two strips of leukotape were applied in the same manner without tension.

iv. Both ankles were taped.

c. FRT Technique

i. Seated with foot in a neutral position

ii. Cover-Roll was applied obliquely in a posterolateral direction beginning at the distal aspect of the lateral malleolus, but not covering the entirety of it.

iii. Two strips of leukotape were applied with significant tension.

iv. Both ankles were taped.
Ultrasound Images

1. Patient position
   a. Sidelying on a treatment table on the unaffected side with the affected ankle propped up on a foam roller in neutral
   b. Unaffected knee flexed to about 30 degrees
   c. Foam cushion was placed between the individual’s knee for patient comfort.
   d. Patient was instructed to keep their ankle relaxed, so the clinician is able to manipulate it to place it in a neutral position.

2. Blinding
   a. Sham sensor was placed on the unaffected limb.
   b. Shower curtain was hung from the ceiling in the lab above the treatment table, so the researcher could not see the sensors on the affected limb.
3. Zonare Diagnostic Ultrasound

a. After the ultrasound machine is turned on, a new patient file is opened, and the subject’s identifying number, ankle being examined, and condition number is placed in the name box.

b. After clicking “done,” the exam is made full-screen by pressing F1. (Figure 1, Marker 1).

c. The depth is changed to 30mm. (Figure 1, Marker 2).

d. Ensure frequency is set at 16Hz (Figure 1, Marker 3).

e. Once the parameters are set, ultrasound gel is applied to the patient’s ankle and the ultrasound transducer.

f. The researcher palpates the talus and distal lateral malleolus, and places the transducer between those two identified landmarks.

g. The gain parameters on the machine are altered to provide a clear image. (Figure 1, Marker 4).
h. Once the peaks of both bony landmarks are visible on the image, the image is stilled using the freeze button. (Figure 1, Marker 5).

i. The image is saved. (Figure 1, Marker 6).

j. Participant completes 3 ankle pumps.

k. Steps f-j are repeated 5 times for a total of 5 images for that ankle.

l. Once 5 images are taken for that ankle, the third party clinician assists the patient in flipping over to the other side and steps a-k are repeated for the contralateral ankle.

m. This entire process is completed a total of 3 times for each taping condition.

**Ultrasound Measurements**

1. Ultrasound images were exported onto a flash drive.

2. Open image in ImageJ.

   a. Conversion from pixels to centimeters

      i. Drop down analyze → set scale → change distance in pixels to 168.4 → change known distance to 1 → change unit of length to cm → click OK.
b. Straight line tool was chosen.

c. The peak of both the talus and fibula were identified, and a line was drawn between them.
d. Drop down analyze→Measure

e. Record measurement into Excel spreadsheet.

f. Repeat all these steps for each image.
Tables or Figures that augment method

Figure 1. Zonare Ultrasound Unit

Sample Size Estimation

Convenience sample
Appendix D

Additional Results

Statistical Tables

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Appendix E

Back Matter

Recommendations for Future Research

Future research should be conducted to determine if a difference in fibular position exists between healthy ankles and ankles with CAI with diagnostic ultrasound, as well as if all individuals with CAI possess a positional fault, or if it is an impairment that affects a subset of the CAI population. In addition, future research should be
conducted to determine if there are certain characteristics that determine if an individual is more likely to respond to the FRT technique.

**NATA Conference Abstract**

Examining the Positional Fault of the Fibula using Diagnostic Ultrasonography after Fibular Reposition Taping in Individuals with Chronic Ankle Instability

Fitch CF*, Armstrong CW*, Ingersoll CD*, Donovan LT†, Glaviano NR*: *University of Toledo, Toledo, OH; †University of North Carolina at Charlotte, Charlotte, NC

**Context:** Individuals with chronic ankle instability (CAI) often present with both mechanical and functional insufficiencies that contribute to long-term dysfunction. Positional fault of the distal fibula is a possible impairment that contributes to CAI. Fibular reposition taping (FRT) technique is a suggested intervention to correct this malalignment. Numerous studies have looked at the effectiveness of this taping technique in regards to different impairments associated with CAI, but findings have been inconsistent. However, no research has looked at the tape’s effectiveness in changing the fibular position. **Objective:** To examine if the position of the fibula changes after application of the FRT technique, and to assess the interrater reliability of utilizing diagnostic ultrasound. **Study Design:** Cross-over study. **Setting:** Laboratory.

**Participants:** 20 individuals with chronic ankle instability (Age: 21.5±4.1 years, Mass: 81.8±22kg, Height: 170±7.5cm) with no history of lower extremity surgery, ankle fracture, ankle injury in the past 6 weeks, or any vestibular or balance disorders.

**Intervention:** Participants completed three taping conditions: FRT technique, sham tape,
and no tape. **Main Outcome Measures:** Diagnostic ultrasound measurements were taken for each taping condition, and the distance between the talus and fibula was measured. Paired-t tests were used to compare differences between sham to control and then sham to FRT. Alpha was set at p<.05. Intraclass correlation coefficient (ICC$_{3,1}$) and associated standard error of measure (SEM) was calculated to determine intrarater reliability.

**Results:** No significant differences in fibular position were observed between taping conditions. Intertester reliability was deemed to be excellent (ICC$_{3,1}$=0.98), and the associated SEM (0.015cm) was applied to the difference between the FRT and sham conditions for each subject. Out of the 20 subjects, 8 were identified to have changes in fibular position outside the SEM after the FRT technique. **Conclusion:** No significant differences were found between any of the conditions, indicating that the FRT technique did not alter the position of the fibula. Since previous studies found significant improvements in other tasks after application of FRT, it is possible that changes are occurring through other mechanisms of the tape. Findings of the present study suggest diagnostic ultrasound is a reliable tool for assessing position of the fibula. Further research should be conducted to determine if there are certain characteristics that determine if an individual is more likely to respond to the FRT technique.
Appendix F

Bibliography


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