The immediate effects of fibular repositioning tape on ankle kinematics and muscle activity

Megan East

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Approved by:

Advisor: Troy Blackburn, PhD, ATC
Steven Zinder, PhD, ATC
Lindsay DiStefano, MA, ATC
ABSTRACT
Megan East
The immediate effects of fibular repositioning tape on ankle kinematics and muscle activity
(Under the direction of Dr. Troy Blackburn)

Objective: To evaluate the immediate effects of fibular repositioning tape on ankle kinematics and muscle activity during a single-leg drop landing in subjects with chronic ankle instability. Design: An experimental research design was used to compare a fibular repositioning tape group (n=10), placebo tape group (n=10), and control group (n=10) before and after a taping intervention. Subjects: Thirty subjects with chronic ankle instability volunteered to participate. Measurements: Ankle kinematics and lower extremity EMG data were recorded. A mixed-model ANOVA was used for statistical analyses for each dependent variable. Post-hoc testing was done with independent and dependent t-tests. Results: The fibular repositioning tape group landed with a decreased plantarflexion angle at initial contact (p<0.0005) and had decreased mean amplitude EMG of the tibialis anterior during the preparatory phase (p<0.0005). Conclusions: Fibular repositioning tape may cause beneficial changes in landing kinematics that may lead to a decreased rate of ankle sprains.
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<table>
<thead>
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<th>Abbreviation</th>
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<tr>
<td>CAI</td>
<td>chronic ankle instability</td>
</tr>
<tr>
<td>EMG</td>
<td>electromyography</td>
</tr>
<tr>
<td>FAI</td>
<td>functional ankle instability</td>
</tr>
<tr>
<td>FRT</td>
<td>fibular repositioning tape</td>
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<tr>
<td>MAI</td>
<td>mechanical ankle instability</td>
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<td>PT</td>
<td>placebo tape</td>
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CHAPTER 1

Introduction

Lateral ankle sprains are among the most common injuries in athletic activities. The most common mechanism of injury for a lateral ankle sprain involves a plantarflexed, inverted, and internally rotated position of the ankle, and typically occurs after initial contact of the rearfoot during gait or landing from a jump. Approximately 85% of all ankle sprains are due to inversion, and cause subsequent damage to the lateral ligament complex. However, up to 55% of individuals with an ankle sprain do not seek treatment from a health care professional. Many individuals experience residual symptoms, and up to 70% will suffer recurrent sprains. Typical residual symptoms include pain during activity, recurrent swelling, feeling of “giving way,” and weakness. The development of lingering symptoms and repetitive ankle sprains has been termed chronic ankle instability (CAI).

CAI is typically attributed to two potential causes: functional instability (FAI) and mechanical instability (MAI), or a combination of both. FAI has been described as the sensation of joint instability due to contributions of proprioceptive and neuromuscular deficits. These deficits result in increased postural sway, delayed peroneal reflexes, and joint position sense insufficiencies. MAI is an alteration in joint mechanics resulting from pathologic laxity, impaired arthokinematic motion, and/or degenerative changes in the joint.
Several studies have examined changes in ankle joint kinematics and lower leg electromyography (EMG) during static stances, gait, and jump landings in subjects with CAI. The results of these studies indicate that subjects with CAI demonstrate a significantly more inverted ankle position and alterations in peroneus longus activity during the tasks when compared to control subjects. The peroneal musculature is the primary eccentric control to resist ankle inversion, thus serving as a protective mechanism to lateral ankle sprains, and adding to the dynamic stability of the ankle joint. Peroneal activity alterations coupled with the vulnerable ankle position of inversion may explain why individuals with CAI suffer repetitive ankle sprains.

Recently, the role of positional faults at the ankle complex has become a topic of much debate. Mulligan first proposed that an anterior fault of the distal fibula on the tibia occurs in some individuals after lateral ankle sprains. During the plantarflexion and inversion mechanism of lateral ankle sprain, the anterior talofibular ligament (ATFL) places tension on the distal fibula, causing it to move anteriorly. With a more anteriorly positioned fibula, the ATFL has less tension on it, thereby allowing further ranges of inversion before restraint is provided and potentially leading to repetitive sprains and instabilities. It has been hypothesized that individuals with CAI maintain anterior positional faults due to changes in peroneal muscle tone from alterations in the neuromuscular control system.

Manual repositioning of the fibula either by rigid tape or manual therapy has been shown to have positive effects on ankle joint pain, range of motion, and disability. Fibular repositioning tape (FRT) is used clinically as a treatment following ankle sprains. Mulligan proposed that fibular repositioning tape can correct an anterior
positional fault and maintain normal fibular alignment\textsuperscript{19}, however there is no research evidence to support this method. Fibular repositioning tape is believed to prevent fibular forward displacement, and may be effective in ankle injury prevention.\textsuperscript{22} An early pilot study indicated that prophylactic fibular repositioning tape may decrease the rate of ankle sprains in basketball players.\textsuperscript{22} Despite the growing use of fibular repositioning techniques clinically for athletic competition, there is little evidence in the literature as to why these methods are effective or what mechanisms result in improved function.

**Purpose**

The purpose of this study was to investigate the immediate effects of fibular repositioning tape on ankle kinematics and muscle activity during a drop landing task.

**Dependent Variables**

1. Ankle kinematics as measured by an electromagnetic motion analysis system.
   a. Ankle angle at initial contact in the sagittal plane
   b. Maximum ankle angle in sagittal plane
   c. Ankle angle at initial contact in frontal plane
   d. Maximum ankle angle in frontal plane

2. Peroneus longus muscle activity as measured by electromyography (EMG).
   a. Mean amplitude
      i. Preparatory phase
      ii. Loading phase
   b. EMG onset time
3. Anterior tibialis muscle activity as measured by electromyography (EMG).
   a. Mean amplitude
      i. Preparatory phase
      ii. Loading phase
   b. EMG onset time

Independent Variables

1. Group
   a. Fibular repositioning tape (FRT)
   b. Placebo tape (PT)
   c. Control (no tape)

2. Test
   a. Pre-test
   b. Post-test

Research Questions

1. What is the effect of FRT on ankle kinematics during a single leg drop landing?
   a. Ankle angle at initial contact in the sagittal plane
   b. Maximum ankle angle in the sagittal plane
   c. Ankle angle at initial contact in the frontal plane
   d. Maximum ankle angle in the frontal plane
2. What is the effect of FRT on lower extremity EMG during a single leg drop landing?
   a. Peroneus longus muscle activity
      i. Mean amplitude
         1. Preparatory phase
         2. Loading phase
      ii. EMG onset time
   b. Tibialis anterior muscle activity
      i. Mean amplitude
         1. Preparatory phase
         2. Loading phase
      ii. EMG onset time

Null Hypotheses

1. There is no effect of FRT on the following kinematic variables:
   a. Maximum ankle angle in the sagittal plane
   b. Ankle angle at initial contact in the sagittal plane
   c. Ankle angle at initial contact in the frontal plane
   d. Maximum ankle angle in the frontal plane

2. There is no effect of FRT on the following lower extremity EMG variables:
   a. Peroneus longus muscle activity
      i. Mean amplitude
1. Preparatory phase
2. Loading phase
   ii. EMG onset time
b. Tibialis anterior muscle activity
   i. Mean amplitude
   1. Preparatory phase
      2. Loading phase
         ii. EMG onset time

Research Hypotheses

There will be significant differences between the fibular repositioning tape and placebo tape groups on the following dependent variables.

Kinematics

1. Maximum ankle dorsiflexion angle will be significantly greater in the FRT group than in the PT and control groups.
2. Ankle dorsiflexion angle at initial contact will be significantly greater in the FRT group than in the PT and control groups.
3. Ankle inversion angle at initial contact will be significantly less in the FRT group than in the PT and control groups.
4. Maximum ankle inversion angle will be significantly less in the FRT group than in the PT and control groups.
Electromyography

1. Mean amplitude EMG of peroneus longus will be significantly greater during the preparatory phase in the FRT group than in the PT and control groups.

2. Mean amplitude EMG of peroneus longus will be significantly greater during the loading phase in the FRT group than in the PT and control groups.

3. EMG onset time of the peroneus longus will occur significantly earlier in the FRT group than in the PT and control groups.

4. Mean amplitude EMG of the anterior tibialis will be significantly greater during the preparatory phase in the FRT group than in the PT and control groups.

5. Mean amplitude EMG of the anterior tibialis will be significantly greater during the loading phase in the FRT group than in the PT and control groups.

6. EMG onset time of the anterior tibialis will occur significantly earlier in the FRT group than in the PT and control groups.

Operational Definitions

1. Subjects with chronic ankle instability – Individuals who have a previous history of at least one inversion ankle sprain that required a period of protected weight-bearing and/or immobilization, current giving-way of the ankle, feelings of instability, and decreased function.

2. Fibular repositioning tape – Subject’s skin is prepared with adhesive. A 20 centimeter length of non-stretch tape (leukotape) is applied obliquely starting at the distal end of the lateral malleolus. A pain-free posterolateral force is applied to
the distal fibula while tape is applied. A second reinforcing strip is then applied in the same manner. \(^{22}\)

3. **Placebo tape** – The same process as the fibular repositioning tape is followed without the posterolateral force applied during application.

4. **Single leg drop landing** – Subjects stand on healthy limb on a box 30 centimeters high with injured limb relaxed and non-weightbearing. Subjects then drop from box using uninjured limb and land with the injured limb onto a forceplate.

5. **Initial ground contact** – The time when the vertical ground reaction force exceeds 10 N during the drop landing.

6. **Loading phase** – The time period from initial ground contact to the first local minima of vertical ground reaction force (See Figure 11).

7. **Ankle sagittal plane angle at initial contact** – The ankle angle in the sagittal plane at initial contact of the drop landing task.

8. **Maximum sagittal plane angle** – The largest ankle angle in the sagittal plane during the loading phase of the drop landing task.

9. **Ankle inversion angle at initial contact** – The ankle angle in the frontal plane at initial contact of the drop landing task.

10. **Maximum inversion angle** – The largest ankle angle in the frontal plane during the loading phase of the drop landing task.

11. **Preparatory phase EMG mean amplitude** – The mean amplitude of EMG over the time interval from EMG onset to initial ground contact.
12. **Loading phase EMG mean amplitude** – The mean amplitude of EMG over the time interval from initial ground contact to the first local minima of vertical ground reaction force.

13. **EMG onset time** – The time point at which the EMG amplitude exceeds 3 standard deviations of the baseline EMG.

**Assumptions**

1. Subjects were honest regarding their medical history.
2. There was no training effect for the drop landings.
3. Subjects gave their best effort in drop landings.
4. Subjects did not intentionally alter their landing strategy due to equipment.
5. Tape was uniformly applied to all subjects.
6. Equipment provided reliable and valid data.

**Limitations**

1. This study only investigates the immediate effects of fibular repositioning tape.
2. The conditions are not counterbalanced in the experimental group.
3. This study will not control for differences in foot posture.
4. It is unknown if the FRT condition actually alters fibular position.
5. It is unknown if the subjects will actually possess an anterior fibular positional fault.
Delimitations

1. Subjects were only between the ages of 18-25.

2. The subjects all had chronic ankle instability.

3. The subjects had no previous history of lower extremity fracture, ankle surgery, or ankle sprain in the past six weeks.

4. The same clinician applied all fibular repositioning tape.
CHAPTER 2

Introduction

Lateral ankle sprains are one of the most common injuries suffered in athletic activity. An estimated 23,000 ankle sprains occur per day in the United States. Despite the prevalence of ankle sprains, an estimated 55% of individuals suffering from ankle sprains do not seek treatment from a health care professional. This leads to many individuals suffering residual symptoms of ankle sprains such as pain and loss of function. These residual symptoms can affect between 55% to 72% of patients six weeks to 18 months after injury. This phenomenon of repetitive ankle sprains and the presence of residual symptoms has been termed chronic ankle instability.

This literature review focuses on the anatomy of the ankle joint, mechanisms of lateral ankle sprains, the components and characteristics of chronic ankle instability, fibular positional faults and methods of correction, and the biomechanics of jump landings.

Articulations

The ankle is comprised of three articulations: the talocrural joint, the subtalar joint, and the distal tibiofibular joint. The talocrural joint is formed by the articulation of the dome of the talus, the medial malleolus, the tibial plafond, and the lateral malleolus. The superior portion of the talus is known as the trochlea and is wedge shaped, wider
anteriorly than posteriorly. The talocrural joint is a hinge joint that allows the motions of plantarflexion and dorsiflexion, although small amounts of frontal-plane and transverse-plane movement occur because the axis of rotation lies in a slightly oblique position, resulting in motion in all three anatomic planes.

The subtalar joint is formed by the talus and the calcaneus. It is surrounded by a weak joint capsule, but is structurally supported by the talocalcaneal ligaments. In the frontal plane, the motions of inversion and eversion occur around an oblique axis. The axis of rotation for the subtalar joint is tilted approximately 42° upward and has a 23° medial angulation from the perpendicular axes of the foot. This oblique axis allows a small amount of plantarflexion and adduction to occur with inversion and dorsiflexion and abduction to occur with eversion.

The oblique axes of both the talocrural and subtalar joints allow the triplanar movements known as supination and pronation to occur. During weight bearing, pronation consists of the talar external rotation, plantarflexion, and abduction. Conversely, supination consists of talar internal rotation, dorsiflexion, and adduction.

The distal tibiofibular joint is a syndesmosis that allows for very limited movement between the tibia and fibula. Although the main function of this joint is to provide a stable base for the roof of the talocrural joint, proper arthrokinematic motion at this joint contributes to the normal mechanics of the entire ankle joint.

### Ligaments

Although much of the stability of the ankle joint is derived from the congruency of articulations, the ankle joint relies heavily on static stabilizers. Ligaments of the ankle
provide the primary static restraint to excessive motion at the ankle joint. The ankle joint is reinforced laterally by three ligaments: the anterior talofibular ligament (ATFL), the posterior talofibular ligament (PTFL), and the calcaneofibular ligament (CFL).\textsuperscript{28}

The anterior talofibular ligament extends anteromedially from the lateral malleolus to the talus. The ATFL prevents anterior displacement of the talus from the ankle mortise as well as excessive inversion and internal rotation of the tibia on the talus.\textsuperscript{26} Additional strain is placed on the ATFL as the ankle moves from dorsiflexion into plantarflexion, therefore it is the primary restraint against inversion in the plantarflexed position.\textsuperscript{30} The ATFL demonstrates the lowest maximal load and energy to failure values under tensile stress when compared to the PTFL, CFL, anterior inferior tibiofibular ligament of the subtalar joint, and the deltoid ligament.\textsuperscript{31} This may explain why the ATFL is the most commonly injured ligament of the ankle.\textsuperscript{1,32} The posterior talofibular ligament runs horizontally and slightly posteriorly from the posterior portion of the lateral malleolus to the posterolateral aspect of the talus.\textsuperscript{25} The PTFL provides restraint to inversion and internal rotation of the talocrural joint.\textsuperscript{25} The PTFL is the strongest of the three lateral ligaments of the ankle, and is the least injured of the lateral ankle ligaments.\textsuperscript{26} The calcaneofibular ligament runs inferiorly and posteriorly from the distal portion of the lateral malleolus to the lateral aspect of the calcaneus.\textsuperscript{25,26} The CFL is the only lateral ligament that crosses both the talocrural and subtalar joint and prevents excessive supination of both joints.\textsuperscript{25} It also serves as the primary restraint of talar inversion when the ankle is in a dorsiflexed position.\textsuperscript{26}

The ankle is reinforced medially by a large, strong group of four ligaments collectively called the deltoid ligament. The four ligaments, the tibionavicular ligament,
the tibiocalcaneal ligament, and the anterior and posterior tibiotalar ligaments all originate across the medial malleolus and attach distally to the navicular, calcaneous, and talus, respectively. Together these ligaments restrict eversion.

Muscles

The ankle joint is protected dynamically by the eccentric function of muscles crossing the joint. There are four compartments of the lower leg containing muscles that contribute to ankle movement and stability. The anterior compartment contains the tibialis anterior, extensor digitorum longus, extensor hallicus longus, and the peroneus tertius. Collectively, these muscles produce dorsiflexion but also eccentrically control plantarflexion. In addition, the tibialis anterior inverts the ankle and the peroneus tertius everts the ankle. Posteriorly, there are two compartments: superficial and deep. These compartments house the gastrocnemius, soleus, flexor hallicus longus, flexor digitorum longus, and the tibialis posterior which act to plantarflex the ankle. The tibialis posterior also contributes to ankle inversion. The lateral compartment is comprised of the peroneus longus and peroneus brevis which evert the ankle and eccentrically control inversion. Therefore, peroneal muscles play a critical role in preventing inversion ankle sprains.

Mechanism of Injury

The most common mechanism of injury for a lateral ankle sprain is a plantarflexed, inverted, and internally rotated position of the ankle, typically occurring after initial contact of the rearfoot during gait or landing from a jump. Approximately
85% of all ankle sprains are due to inversion, and cause subsequent damage to the lateral ligament complex.\textsuperscript{3}

The basic anatomy of the ankle complex provides several reasons for a higher rate of inversion ankle sprains compared to eversion mechanisms. The lateral malleolus extends more distally than the medial malleolus, which limits the amount of eversion possible at the ankle.\textsuperscript{28} Another reason the lateral ligaments are more frequently injured is that the deltoid ligaments on the medial aspect of the ankle complex are stronger than the lateral ligaments.\textsuperscript{28} The irregular wedge shape of the talus also plays a role in the stability of the ankle. During dorsiflexion, the wider anterior portion of the talus brings the ankle mortise into a closed pack position and increases the articular congruency within the talocrural joint, making the joint more stable. Conversely, during plantarflexion, the narrower posterior portion of the talus rests in the ankle mortise, thus decreasing articular congruency and making the joint more unstable.

Collectively, the lateral ligament complex provides restraint against inversion, but depending on the position of the ankle, individual ligaments may be placed in a more vulnerable position. When the ankle is placed into a plantarflexed and inverted position, the ATFL is in its most taut position, possibly explaining why the ATFL is the most commonly injured ligament during lateral ankle sprain.\textsuperscript{1, 25} The CFL becomes more taut when the ankle is in a dorsiflexed position, and is the second-most injured of the lateral ankle ligaments.\textsuperscript{28, 33}

During sudden ankle inversion stress, the peroneal muscles are the first to react by contracting to slow the rate of inversion.\textsuperscript{18} Therefore, the peroneal muscles are a critical component of the dynamic stability of the ankle. However, some question the ability of
the peroneals to respond in time to unexpected inversion stress.\textsuperscript{18, 34} If the peroneals cannot eccentrically control the rate of inversion during an unexpected perturbation, their role in the dynamic defense mechanism may be diminished.\textsuperscript{18}

**Chronic Ankle Instability**

Chronic ankle instability is traditionally attributed to two potential causes: functional ankle instability (FAI) and mechanical ankle instability (MAI).\textsuperscript{25} Broadly, FAI results from adverse changes in the neuromuscular system due to ligamentous injury that provides dynamic stability to the ankle joint.\textsuperscript{25} Currently, there is no consensus in the literature on a clinical definition of FAI. A common description of functional ankle instability in the literature is a previous history of ankle sprain, feelings of “giving way” in the ankle, and subjective complaints of the involved ankle being weaker, more painful, and having decreased function compared to the uninjured side.\textsuperscript{14, 15, 25, 35} However, discrepancies exist in quantifying how many previous ankle sprains or feelings of “giving way” constitute FAI.

Freeman et al.\textsuperscript{36} first described the concept of FAI in 1965 when they attributed balance and proprioceptive deficits in subjects with lateral ankle sprains to damaged articular mechanoreceptors. A disruption in mechanoreceptors, known as articular deafferentation, results in the decreased ability to sense changes in joint position.\textsuperscript{6} A more recent definition of FAI includes the contributions of neuromuscular deficits as postural stability deficits, joint position sense deficits, delayed peroneal muscle reaction time, and strength deficits all play a role in FAI.\textsuperscript{6, 25}
Single leg balance deficits have been found in ankle instability using a variety of parameters and measures.\textsuperscript{6-9, 37, 38} Balance can be assessed using both subjective and objective measures. Using the Balance Error Scoring System (BESS) to count errors made during various stance and surface conditions, Docherty et al.\textsuperscript{37} found that subjects with functionally unstable ankles committed significantly more errors (had poorer postural stability) than healthy controls. The Star Excursion Balance Test, in which subjects must maintain a single leg stance while reaching for maximal distance in three different directions (anterior, posterior, and medial), has also demonstrated deficits in subjects with FAI, as significantly smaller maximal reach values have been observed compared to healthy subjects.\textsuperscript{7} Studies using the more objective measure of force plate kinetic data show similar results.\textsuperscript{8, 9, 38} Hertel et al.\textsuperscript{8} calculated time to boundary measures in subjects with FAI and controls during single leg stance. Time to boundary was determined by how quickly the center of pressure reached the boundary of the foot. Decreased time to boundaries (worse postural control) was found in subjects with FAI.\textsuperscript{8} Using a more dynamic measure of balance, subjects with FAI demonstrated significantly longer time to stabilization measures during a single-leg jump landing.\textsuperscript{9}

The ability to sense position and movement of the ankle joint is adversely affected by FAI.\textsuperscript{11, 39, 40} Functionally unstable ankles have diminished capacities to reproduce various positions of plantarflexion\textsuperscript{40}, detect passive plantarflexion\textsuperscript{39}, and detect passive inversion.\textsuperscript{11} Impaired joint position sense has also been shown to be a predictor of FAI in individuals with no history of FAI.\textsuperscript{41}

Conflicting literature exists concerning the existence of delayed peroneal reaction times in individuals with FAI. Significantly slower reaction times in the peroneus longus
in response to sudden inversion have been reported in subjects with previously injured ankles.\textsuperscript{18, 42} Other authors have shown no significant delays in peroneal reaction time in injured subjects.\textsuperscript{43}

Weakness of the muscles that evert the ankle has been shown to be a contributor to FAI.\textsuperscript{44-46} However, several studies have shown that no difference in eversion strength exists in subjects with FAI.\textsuperscript{11, 47} The importance of evertor strength in the ankle joint was demonstrated by Ashton-Miller et al.\textsuperscript{44} They found that the evertor muscles were able to produce greater moments when the ankle was subjected to 15° of inversion compared to ankle braces or taping.\textsuperscript{44} Discrepancies among the literature in regard to eversion strength may be in part due to methodology. Most strength assessments are done isokinetically at speeds slower than most functional activities. Assessing concentric eversion strength by isokinetic dynamometer at 30 and 120° per second, Tropp et al. found weakness in subjects with FAI.\textsuperscript{45} Peak torque deficits ranging from 5 to 18\% have been found between ankles in subjects with unilateral FAI.\textsuperscript{46} Conversely, no significant differences in isometric or concentric evertor strength tested at 30° per second were found in subjects with FAI.\textsuperscript{11} Similarly Bernier et al.\textsuperscript{47} found no significant differences in eccentric evertor strength at 90° per second in subjects with FAI compared to controls.

Mechanical instability has been defined as ankle joint motion that exceeds normal physiological range.\textsuperscript{38} MAI can result from pathologic laxity, arthrokinematic restrictions, and degenerative changes in the joint.\textsuperscript{25, 48}

Pathologic laxity is the result of ligamentous damage incurred through injury, and may be assessed through clinical physical examination, stress radiography, or instrumented arthrometry.\textsuperscript{25} In lateral ankle sprains, the most common sites of pathologic
laxity are in the talocrural and subtalar joints.\textsuperscript{49} In the talocrural joint, instability is caused primarily by injury to the ATFL and CFL.\textsuperscript{50} Clinically, the presence of laxity of the ATFL is determined through the amount of anterior translation of the talus from the ankle mortise known as an anterior drawer test. Laxity of the CFL can be assessed by the amount of talar tilt present during inversion of the talus with the talocrural joint in a dorsiflexed position. The relationship between pathologic laxity of the ankle joint and chronic ankle instability is not fully understood. Tropp et al.\textsuperscript{38} performed anterior drawer tests on 159 subjects with CAI and found that 58% demonstrated a negative test, meaning there was no ligamentous laxity present. Similarly, Ryan\textsuperscript{51} used the talar tilt in addition to the anterior drawer to assess subjects with unilateral CAI. Out of the 45 subjects tested, 76% had negative talar tilt tests and 91% had negative anterior drawer tests.\textsuperscript{51} In contrast, there are several studies that report ligamentous laxity in subjects with CAI.\textsuperscript{11, 52} Hertel et al.\textsuperscript{52} examined talar tilt angles in subjects with CAI by taking AP views of the ankle by x-ray with and without supination stress. Ankles with CAI had significantly greater talar tilt angles compared to controls.\textsuperscript{52} These results confirmed previous findings of greater talar tilt angles in subjects with CAI using stress talar tilt by Lentell et al.\textsuperscript{11} Differences in the results of these studies could be due to the method of measurement, as ligamentous testing depends on the skill and experience of the examiner which may lead to questionable reliability, while stress radiograph is a more objective means of measurement.

Restricted arthrokinematic motion of the talocrural, subtalar, and distal tibiofibular joint may also contribute to MAI.\textsuperscript{25, 27, 48} Restricted dorsiflexion is thought to be a predisposition to lateral ankle sprain.\textsuperscript{53} Dorsiflexion restrictions have also been seen
in athletes with repetitive ankle sprains.\textsuperscript{54} If the talocrural joint cannot reach its closed-pack position during stance or weight-bearing, it will be able to move into inversion and internal rotation more easily.\textsuperscript{25} During dorsiflexion, the talus must glide posteriorly for complete range of motion to be achieved, although individuals may compensate for a potential loss of dorsiflexion by excessive stretching of the heel cord.\textsuperscript{55} Denegar et al. reported that after lateral ankle sprain, significant limitations of posterior talar glide are evident when compared to the uninjured ankle.\textsuperscript{55} However, there were no significant differences in physiological dorsiflexion range of motion.\textsuperscript{55} In a randomized controlled study that examined treating lateral ankle sprains with posterior talar joint mobilizations and rest, ice, compression, and elevation (RICE) compared to just RICE alone, Greene et al.\textsuperscript{56} noted fewer treatments are needed to achieve full pain-free dorsiflexion range of motion with talar mobilizations.

Restrictions of arthrokinematic movement at the distal tibiofibular joint may also restrict dorsiflexion. During dorsiflexion, the fibula must glide superiorly and displace laterally. During an inversion ankle sprain, it has been suggested the fibula displaces anteriorly at its distal end, known as a positional fault.\textsuperscript{19} This alteration affects normal excursion of the fibula, thereby affecting dorsiflexion range of motion.\textsuperscript{27}

\textit{Altered Kinematics}

Identification of altered movement patterns during gait of chronically unstable ankles suggests that adaptive changes may potentially be attributed to CAI.\textsuperscript{14, 16} In the first study to look at 3D joint kinematics via a motion analysis system and kinetics in all lower extremity joints during the stance phase of gait, Monaghan et al.\textsuperscript{16} examined data
from 100 ms before heel strike to 200 ms after heel strike in 25 subjects with CAI and 25 controls. They observed that CAI subjects were significantly more inverted by approximately 6-7° compared to the control group during the entire time period. Greater angular velocity in the frontal plane in CAI subjects in the period immediately prior to and post-heel strike were also noted, indicating a lack in the ability to control movement and thus stability. Lastly, a significant difference in joint moments of the ankle were noted, as CAI subjects demonstrated an evertor moment throughout the 200 ms post-heel strike, while controls exhibited an invertor moment during this same time period. By having an increased inversion angle and greater angular velocity at heel strike, or the loading phase of gait, an external inversion load is placed on the ankle joint and may increase the potential for a hyperinversion injury and subsequent damage to the lateral ligament complex of the ankle. These differences may be explained by the aforementioned decreased detection of passive inversion movements in subjects with CAI, therefore the joint may not be able to detect its vulnerable position.

A similar study conducted by Delahunt et al. examined ankle joint kinematics and electromyography (EMG) of ankle musculature during gait in 24 subjects with FAI and 22 control subjects. A significant difference in ankle joint inversion of approximately 3° was present in FAI subjects 50 ms before heel strike, at heel strike, and 50 ms after heel strike. These authors asserted that subjects with FAI are unable to utilize the protective reflex of the peroneals to protect them from this inverted position due to the combination of peroneal reflex latency and electromechanical delay taking approximately 126 ms after heel strike to occur.
Ankle kinematics have also been studied during more functional tasks, most commonly by single-leg jump or drop landing.\textsuperscript{13, 15} Caulfield and Garrett\textsuperscript{13} had 14 subjects with unilateral FAI and 10 controls perform a single-leg drop from a height of 40 centimeters and recorded ankle joint angular displacement in the sagittal plane during the time period from 100 ms prior to initial ground contact to 200 ms after initial ground contact. FAI subjects had significantly greater amounts of ankle dorsiflexion ranging from 5-7° more in the time period from 10 ms before heel strike to 20 ms after heel strike.\textsuperscript{13} No differences in timing of initiation of flexion movements were identified. The authors hypothesized that the difference between FAI subjects and controls may reflect a learned adaptation as a result of previous injury.\textsuperscript{13} The closed pack position and the position of greatest articular congruency and stability of the talocrural joint is in dorsiflexion. This position offers the greatest protection from injury to the lateral ligament complex. Subjects with FAI, therefore may subconsciously be attempting to protect their ankles from injury.\textsuperscript{13} A limitation of this study is that it strictly examined kinematic data and only in the sagittal plane. Additionally, recording kinetic data to analyze ground reaction forces would help to clarify the relationship between increased dorsiflexion measures and potential protective mechanisms to lessen impact forces as hypothesized by the authors.

As a follow up to their previous work, Delahunt et al.\textsuperscript{15} conducted a study examining lower limb kinematics, kinetics, and muscle activity during a drop landing in 24 subjects with FAI and 24 healthy subjects. FAI subjects again demonstrated a more inverted ankle position from 200 ms – 95 ms before initial ground contact.\textsuperscript{15} Results that show FAI ankles differing from controls while no external forces are acting upon the
ankles (such as time before heel strike in gait and time before initial ground contact in drop landings) indicate potential differences in feed-forward motor control programs. A primary mechanism of inversion ankle sprain involves landing on irregular playing surfaces such as another player’s foot before reaching initial ground contact. By coming down from a jump in a more inverted position, it is reasonable to hypothesize that functionally unstable ankles may become injured from unexpected ground contact.

Unlike the previous study conducted by Caulfield and Garrett, FAI subjects in the Delahunt et al. study had significantly lesser amounts of dorsiflexion of the ankle joint during the time period from 90 ms – 200 ms after initial contact. Additionally, FAI subjects showed a decreased angular velocity in the sagittal plane from 50 ms – 125 ms after initial ground contact, meaning they were moving into dorsiflexion at a slower rate than controls. These results suggest that subjects with FAI are not as efficient in reaching the closed pack dorsiflexed position of the ankle joint.

**Altered EMG Activity**

Santilli et al. were the first to examine peroneus longus activation in functionally unstable ankles during gait. Peroneus longus activity was expressed as mean activation time as a percentage of the stance phase of the gait cycle. They found that in the ankle with FAI, the peroneus longus was only active during 23% of the gait cycle compared to 38% of the gait cycle in the non-injured limb. The peroneus longus plays an important role in the middle-to-late stance phase of gait in providing lateral support to the ankle while in single-leg stance. Decreased levels of activation may indicate that functionally unstable ankles may have reduced protection against lateral ankle sprains.
A limitation of this study is that it did not look at the onset time of peroneus longus activity or which specific phases of gait that the activation of the peroneus longus may have varied from the uninjured side.

Using integral EMG to measure peroneus longus activity during gait, Delahunt et al.\textsuperscript{14} found a significant increase in peroneus longus integral EMG in FAI subjects compared to healthy controls in the time period from heel strike to 80 ms after heel strike.\textsuperscript{14} This was coupled with a more inverted position of the ankle as measured by a motion analysis system. The increased activity of the peroneus longus could be an attempt to eccentrically control the rate of inversion occurring at the ankle joint.\textsuperscript{14}

There are limited studies that have investigated peroneal muscle activity in unstable ankles during more functional activities.\textsuperscript{15} Delahunt et al.\textsuperscript{15} used similar methodology and measures from their previous study examining kinematics, kinetics, and muscle activity of functionally unstable ankles during gait to examine the effects of a single-leg drop jump from a height of 35 centimeters. FAI subjects demonstrated significantly greater peroneus longus integral EMG in the time before initial ground contact.\textsuperscript{15}

\textbf{Positional Faults}

Mulligan first proposed that an anterior fault of the distal fibula occurs as a result of lateral ankle sprain.\textsuperscript{19} During the plantarflexion and inversion mechanism of lateral ankle sprain, the ATFL places tension on the distal fibula, causing it to move anteriorly.\textsuperscript{19} With a more anteriorly positioned fibula, the ATFL has less tension on it, thereby
allowing further ranges of inversion before restraint is provided, and potentially leading to repetitive sprains and instabilities.\textsuperscript{19}

Since Mulligan’s initial hypothesis, several studies have attempted to examine fibular positioning in subjects with ankle instabilities.\textsuperscript{35, 57-60} Inconsistent results have been found, with some studies reporting an anterior fault\textsuperscript{35, 59, 60}, while others have reported a posterior fault.\textsuperscript{57, 58}

Kavanagh\textsuperscript{60} used a series of cases to determine if the presence of a positional fault was possible after ankle sprain, and hypothesized that greater anterior-posterior movement of the fibula would be possible if a fault was present. Subjects with lateral ankle injuries demonstrated a significantly greater amount of fibular movement.\textsuperscript{60} However, a small sample size of six subjects makes it difficult to generalize these results to a larger population.

Imaging by x-ray has been used as a means to assess fibular position in subjects with lateral ankle pathology.\textsuperscript{35, 59} The distance between the most anterior point of the tibia and the anterior margin of the fibula is measured. A smaller distance between points compared to side-matched controls suggests an anteriorly placed fibula.\textsuperscript{35, 59} Subjects with sub-acute lateral ankle sprains were found to have an anterior positional fault when compared to side-matched controls.\textsuperscript{59} A significant positive correlation between the amount of swelling present at the time of measurement and anterior fibular positioning was found, suggesting that positional faults may be maintained acutely by swelling.\textsuperscript{59}

Using the same x-ray methodology, Hubbard et al.\textsuperscript{35} found that subjects with self-reported chronic ankle instability displayed an anteriorly positioned fibula compared to side-matched controls. Fibulas in subjects with CAI had a group mean of 14.3 mm
posterior to the anterior edge of the tibia, compared to 16.7 mm in controls.\textsuperscript{35} As part of the exclusion criteria for this study, subjects with chronic instability did not have a history of acute ankle sprain within the previous six weeks and therefore no acute swelling.\textsuperscript{59} Therefore, the authors hypothesized that fibular position was maintained by neuromuscular changes of the peroneal muscle tone.\textsuperscript{35}

Despite evidence to suggest an anterior positional fault, several studies have reported a posterior fibular fault in subjects with ankle pathology.\textsuperscript{57, 58, 60} The axial malleolar index, a measure that relates lateral malleolar position to the talus, was utilized as the method of measurement for each of these studies. Eren measured the axial malleolar index by CAT scan in subjects with acute ankle sprains.\textsuperscript{58} Injured subjects had significantly higher malleolar indexes (more posteriorly positioned fibulas) than controls. Berkowitz\textsuperscript{57} retrospectively examined the axial malleolar index of pre-operative MRIs and CAT scans in subjects who underwent lateral ankle stabilization procedures. They also reported a posteriorly positioned fibula relative to the medial malleolus.\textsuperscript{57}

The differences in the findings of the previously discussed studies reporting an anterior positional fault to those reporting a posterior positional principally lie in the methodology of measurement. The axial malleolar index is based on the position of the talus. Previous research has demonstrated that the talus may become anteriorly displaced after ankle sprains.\textsuperscript{55} Therefore it is possible that in these studies, an anteriorly positioned talus would make the fibula appear to be more posteriorly positioned.
Repositioning the fibula either manually or by nonstretch tape has been used clinically as a treatment following ankle sprain. An immediate reduction in pain, increases in range of inversion, and improvements in subjective function were demonstrated in two subjects with acute ankle sprain after receiving posterior mobilizations to the fibula. Mulligan suggests that fibular repositioning tape (FRT) can correct an anterior positional fault of the fibula, although there is no scientific evidence to support this claim.

To date, the role of FRT as a method of correcting an anterior positional fault of the distal fibula has not been extensively studied in the literature. Moiler et al. suggested that by returning the fibula to optimal position and preventing forward displacement, FRT may serve as a prophylactic measure to prevent lateral ankle sprains. A pilot study prospectively analyzing the number of ankle sprains per exposure in recreational basketball players during games was conducted by applying the FRT to one team and using the opposing team as a control. Although conditions were not randomized and subjects were not controlled for utilizing other prophylactic braces or taping during play, a statistically significant decrease in injury rate was found in the subjects with the FRT, as those subjects were five times less likely to sustain an ankle sprain during participation than those without the FRT. Although this pilot study can only provide limited results, it introduces the possibility of the possible preventative role of FRT. Currently, there is no literature that attempts to examine or explain the potential mechanisms of effectiveness of FRT.
Proprioceptive Effects of Tape

In addition to providing increased mechanical support to a joint, taping and bracing is also thought to increase proprioception through the stimulation of cutaneous nerve receptors.\(^6^2-^6^4\) Several studies have shown that taping or bracing has positive effects on joint position sense in the shoulder, knee, and ankle.\(^6^2-^6^4\) In examining the proprioceptive effects of a neoprene shoulder stabilizer in subjects with anterior glenohumeral instability, Chu et al.\(^6^3\) found a decrease in the mean error of an active joint repositioning task during the braced condition. These authors noted that the brace did not significantly restrict the maximal external rotation range of motion in their unstable subjects, therefore mechanical restriction did not explain their findings.\(^6^3\)

In the ankle, a decrease in mean error of a non weight-bearing plantarflexion angle reproduction task was found by placing two strips of athletic tape (one on the anterior portion of the talus, the other on the posterior aspect of the Achilles’ tendon) on the tested ankle.\(^6^4\) Although this study can only provide results limited to non weight-bearing tasks, and therefore are not completely applicable to athletic activity, it provides some evidence that the stimulation of cutaneous receptors can affect joint proprioception independent of mechanical restriction.
CHAPTER 3

Experimental Design

We used a randomized, single-blinded, repeated measures design to investigate the effects of fibular repositioning tape on ankle joint kinematics and muscle activity. Subjects were randomly assigned into one of three groups: fibular repositioning tape (FRT) group, the placebo tape (PT) group, or the control group (no tape). Data were collected twice during one testing session, before and after an intervention (taping) period.

Subjects

Thirty subjects volunteered to participate in this study. Subjects were eligible for participation in this study if they were between the ages of 18-30 and were identified as having unilateral chronic ankle instability. Chronic ankle instability criteria included: 1) a self-reported previous history of at least one inversion ankle sprain that required a period of protected weight-bearing and/or immobilization; 2) the subject reported a tendency for the ankle to “give way” during activity; 3) the involved ankle was subjectively reported to be less functional compared to uninvolved ankle at the time of testing. Exclusion criteria included any previous history of lower extremity fracture, ankle surgery, or acute ankle sprain within the six weeks prior to data collection. Signs and symptoms of acute ankle sprain were any pain, redness, swelling, or self-reported loss of typical function at
the time of testing. Subject demographics are presented in Table 1. Prior to testing, all subjects read and signed an informed consent form approved by the Biomedical Institutional Review Board of the School of Medicine at the University of North Carolina at Chapel Hill.

**Instrumentation**

*Kinematics*

A Flock of Birds (Ascension Technologies, Inc., Burlington, VT) electromagnetic motion analysis system controlled by Motion Monitor (Innovative Sports Training, Inc., Chicago, IL) data acquisition computer software was used for kinematic data collection at a sampling rate of 100 Hz. The Flock of Birds has been shown to be a reliable and valid measure of joint kinematics. Meskers et al. examined the accuracy of the Flock of Birds in shoulder measurements and determined that it was effective system for measuring shoulder kinematics.\(^5\) Umberger et al. reported the Flock of Birds to be reliable and valid in measuring first metatarsophalangeal joint motion.\(^6\) The Flock of Birds has also demonstrated high intertester and intratester reliability when measuring elbow sagittal plane motion.\(^7\) The electromagnetic motion analysis system was calibrated prior to data collection to maximize reliability and validity of the system.

*Electromyography*

A surface electromyography (EMG) system (Delsys Bagnoli-8, Boston, MA: interelectrode distance = 10 mm; amplification factor = 1,000 (20 – 450 Hz); CMRR @ 60 Hz > 80 dB; input impedance > 10\(^{15}\)/0.2 ohm//pF) was used to measure muscle
activity in the peroneus longus and anterior tibialis muscles. Data was collected with a gain of 10 and sampling rate of 1000 Hz.

**Force Plate**

A nonconductive force plate (Bertec Corporation, Columbus, OH) was used to collect vertical ground reaction force data to determine the instant of initial contact during the single leg drop landing task. Data were synchronized with ankle kinematic data and sampled at a rate of 1000 Hz. Initial contact was defined as the point at which the vertical ground reaction forces exceed 10N.

**Procedures**

All subjects reported to the Motor Control Laboratory at the University of North Carolina at Chapel Hill for one testing session lasting approximately one hour. Prior to testing, subjects were randomly assigned to one of three groups: fibular repositioning tape group, placebo tape group, or the control group. Subject assignment occurred through random assignment without replacement. The subject was blinded to group assignment. Subjects were dressed for physical activity (shorts and t-shirt) during the testing session. Upon arriving at the lab, subjects completed a questionnaire to ensure they met the inclusion criteria and to screen for any of the exclusion factors. All subjects were weighed on a scale and had their height measured and recorded prior to testing.

Electromagnetic sensors were placed on the limb with the chronically unstable ankle of each subject over the shank, posterior calcaneus, and the lateral dorsum of the foot. The sensor on the tibia was placed in an area consisting of the least amount of
muscle mass to minimize potential artifact induced by muscle contraction. Sensors were attached by double-sided tape and secured to the body with prewrap and athletic tape.

The EMG electrodes were then secured to the subject’s lower leg. The area where the electrodes were placed was shaved to remove any hair, lightly abraded with an abrasive pad, and cleansed using isopropyl alcohol to reduce impedance of the EMG signal. Electrodes were placed over the muscle bellies of the peroneus longus and anterior tibialis. A reference electrode was placed over the tibial tuberosity. Electrodes were secured to the skin with prewrap and athletic tape. A manual muscle test was performed to ensure proper positioning of electrodes.

The subject’s injured limb was then digitized after sensor application while subjects stood in a neutral and relaxed stance. The following bony landmarks were palpated and digitized by a moveable sensor attached to a wooden stylus: medial and lateral epicondyle of the femur, medial and lateral malleoli of the ankle, and the most distal portion of the 2nd phalanx.

Ankle kinematic and EMG data were collected during a single leg drop landing task. The primary investigator explained the drop landing task and subjects practiced the task a maximum of three times or until they felt comfortable with the task. All subjects performed this task barefoot to control for any differences in shoe type. The drop landing task required the subject to stand on his/her unaffected limb on a box 30 centimeters high placed 10 centimeters from the edge of a force plate with affected limb relaxed and non-weightbearing. Subjects then dropped from the box using the unaffected limb, and landed with the affected limb on the middle of the force plate.
Each subject performed five trials of single leg drop landings with 30 seconds of rest between trials to minimize the risk of fatigue. Trials with incorrect landings or errors in data collection were considered invalid, and a new trial was performed. Incorrect landings were those in which the subject’s tested limb did not land completely on the force plate, or if the untested limb touched down during the trial.

After recording the first five drop landings, subjects received the FRT, the PT, or no tape as determined by group assignment. All taping procedures were performed by the same trained clinician. For the FRT, the subject was seated with the foot in a relaxed position. The subject’s skin was prepared with adhesive. A 20 centimeter length of non-stretch tape (leukotape) was applied obliquely starting at the distal end of the lateral malleolus. A pain-free posterolateral force was applied to the distal fibula while tape was applied. A second reinforcing strip was then applied in the same manner. For the placebo tape, the same process as the FRT was followed without a posterolateral force applied during application. The control group received no tape and rested quietly during the treatment period. There was ten minutes between testing sessions for all subjects. After the treatment period, an additional five single leg drop landings were performed identical to the procedures described previously.

A five-second maximal voluntary contraction (MVIC) against a manual resistance was then performed for each muscle to normalize muscle activity. For the peroneus longus muscle, the tester stabilized the tibia and resisted eversion and plantarflexion manually by placing her hand on the lateral dorsal aspect of the foot. The tibialis anterior muscle was tested manually by stabilizing the tibia and providing resistance to dorsiflexion and inversion.
**Data Reduction**

Raw kinematic data were converted to the aligned anatomical coordinate axes. The three dimensional global and local coordinate systems were defined as follows: the positive x-axis was the direction the subject faced, the positive y-axis was to the left of the subject, and the positive z-axis was directed upward. The Motion Monitor software processed the raw sensor data, and a Butterworth low pass filter (4th order, zero phase lag) smoothed the data at a frequency of 10 Hz.

Ankle angles in the frontal and sagittal plane at initial ground contact and maximum ankle angle in the frontal and sagittal plane during the loading phase of the drop landing task were then determined through customized software in MatLab (The Mathworks, Inc., Natick, MA).

Raw EMG data were passively demeaned, processed through a band-pass filter of 20 Hz and 350 Hz, and a RMS smoothing technique with a time constant of 20 ms was used to smooth and rectify the data using a customized software program (MatLab). We then determined the mean EMG amplitude of the peroneus longus and tibialis anterior for the preparatory and loading phases of the drop landing as well as the onset time for each muscle.

**Statistical Analysis**

A mixed model repeated measures ANOVA with one between subjects factor (3 levels: fibular repositioning tape, placebo tape, and control) and one within subjects factor (2 levels: pre-test and post-test) was used to compare the groups and testing sessions for each of the dependent variables. Dependent and independent samples t-tests
were then conducted as *post-hoc* tests after a Bonferroni adjustment for Type I error rate.

All data were analyzed with SPSS Version 13.0 statistical software (SPSS, Inc., Chicago, IL) with an *a priori* alpha level set at 0.05.
CHAPTER 4

Of the original 30 subjects recruited and randomly assigned to the FRT (n=10), PT (n=10), or control (n=10) group, the data for one subject in the FRT group and one subject in the PT group were not used for statistical analyses due to data reduction errors. Specifically, the algorithms used in data processing to were unable detect EMG onset. Therefore, data from 9 FRT group subjects, 9 PT subjects, and 10 control group subjects were used for data analyses. Additionally, the algorithms used for data reduction were unsuccessful for 4 trials (within 3 subjects) out of 280 total trials included in data analyses. These trials were discarded, and in those subjects, averages were calculated across four trials instead of five in that test condition. Subject demographics are presented in Table 1 for the 28 subjects included in the analysis.

Sagittal Plane Ankle Angles

Means and standard deviations for ankle angle at initial contact in the sagittal plane are presented in Table 2. A significant main effect for Test ($F_{(1,25)}=73.942$, $p<0.0005$) was found. Overall, subjects had a smaller plantarflexion angle at initial contact during the post-test compared to the pre-test. There was also a significant main effect for Group ($F_{(2,25)}=4.979$, $p=0.015$). Subjects in the FRT and the PT groups demonstrated smaller plantarflexion angles at initial contact when compared to the control group, but were not different from each other. There was a significant Group x
Test interaction ($F_{(2,25)}=17.492$, $p<0.0005$). Pairwise comparisons indicated that subjects in both the FRT and PT groups demonstrated smaller plantarflexion angles at initial contact during the post-test when compared to the control group during post-test, but were not different from each other. There were no differences between groups during the pre-test. Additionally, the FRT and PT groups demonstrated smaller plantarflexion angles at initial contact during the post-test when compared to the pre-test.

Means and standard deviations for the maximum ankle angle in the sagittal plane are presented in Table 2. There was a significant main effect for Test ($F_{(1,25)}=5.405$, $p=0.028$). Subjects demonstrated greater maximum angles in the sagittal plane in the post-test when compared to the pre-test. There was no significant main effect for Group or Group x Test interaction.

**Frontal Plane Ankle Angles**

Means and standard deviations for ankle angle at initial contact in the frontal plane are presented in Table 3. There were no significant main effects for Group or Test as well as no significant Group x Test interaction ($p>0.05$).

Means and standard deviations for maximum ankle angles in the frontal plane are presented in Table 3. There were no significant main effects for Group or Test as well as no significant Group x Test interactions ($p>0.05$).
Tibialis Anterior

Means and standard deviations for tibialis anterior onset times are presented in Table 4. There were no significant main effects for Group or Test as well as no significant Group x Test interactions (p>0.05).

Means and standard deviations for the tibialis anterior mean amplitude EMG during the preparatory phase are presented in Table 5. There was a significant main effect for Test ($F_{(1,25)}=24.279$, p<0.0005). Subjects demonstrated decreased mean amplitude EMG values of the tibialis anterior in the preparatory phase during the post-test when compared to the pre-test. There was also a significant Group x Test interaction ($F(2,25)=11.082$, p<0.0005). Pairwise comparisons indicated that subjects in the FRT group demonstrated a decreased mean amplitude EMG of the tibialis anterior during the preparatory phase during the post-test when compared to the pre-test. There were no other significant between or within group comparisons.

Means and standard deviations for the mean amplitude EMG of the tibialis anterior during the loading phase are presented in Table 5. There was a significant main effect for Group ($F_{(2,25)}=5.504$, p=0.01). Overall, subjects in the FRT and PT group demonstrated a decreased mean amplitude EMG of the tibialis anterior during the loading phase when compared to subjects in the control group, but were not different from each other.
Peroneus Longus

Means and standard deviations for peroneus longus onset time are presented in Table 4. There were no significant main effects for Group or Test as well as no significant Group x Test interactions (p>0.05).

Means and standard deviations for mean amplitude EMG of the peroneus longus during the preparatory phase are presented in Table 6. There was a significant main effect for Test (F(1,25)=8.752, p=0.007). Subjects demonstrated a decreased mean amplitude values for the peroneus longus in the preparatory phase during the post-test when compared to the pre-test. There was no significant Group main effect or Group x Test interaction.

Means and standard deviations for the mean amplitude EMG of the peroneus longus during the loading phase are presented in Table 6. There was a significant main effect for Test (F(1,25)=28.013, p<0.0005). Subjects demonstrated a decreased mean amplitude EMG value of the peroneus longus in the loading phase during the post-test when compared to the pre-test.
CHAPTER 5

Our principal findings in this study were that the FRT alters ankle kinematics in the sagittal plane and lower extremity muscle activity. Specifically, the FRT caused subjects to have a decreased plantarflexion angle at initial ground contact when compared to a control group as well as less activation of the tibialis anterior muscle during the preparatory phase as measured by mean amplitude EMG. Additionally, the PT also caused a smaller plantarflexion angle at initial ground contact, but to a lesser extent than the FRT group, suggesting that cutaneous stimulation may play a role in altering ankle kinematics. These results suggest that FRT could have beneficial effects on ankle joint landing mechanics and potentially could decrease the rate of ankle sprains.

**Ankle Kinematics**

The most vulnerable position of the ankle for injury to the lateral ligament complex is when the ankle is plantarflexed, inverted, and internally rotated.\(^1\) Several previous studies have demonstrated that subjects with CAI have potentially detrimental alterations in ankle kinematics, such as an increased inversion angle at initial contact, when compared to healthy ankles that may lead to repetitive ankle sprains.\(^{13-16,19}\) Our results indicate that intervention through FRT may restore proper joint arthrokinematics that allow the ankle to be in a less vulnerable position for injury by decreasing the plantarflexion angle of the ankle at initial ground contact. This causes more of the wider
anterior portion of the talus to fit inside the ankle mortise and increases joint congruency and thus, stability. Comparison of our results to previous studies is extremely limited because, to our knowledge, there is only one other study examining the effects of FRT, which was a prospective pilot study to examine the incidence of ankle sprains in recreational basketball players and the potential prophylactic use of FRT. However, preliminary data from that pilot study indicated that subjects who wore the FRT were five times less likely to sustain an ankle sprain compared to a control group. Although there were substantial limitations to that study, including not randomizing groups or controlling for wearing other external ankle supports, our findings of a lesser plantarflexion angle at initial ground contact could help explain why FRT reduced the rate of ankle sprains.

Previous research examining other forms of external ankle supports, such as bracing and taping, has reported reduction in sagittal plane motion during tasks. McCaw et al. used a drop landing task to examine changes in ankle kinematics measured while wearing either ankle tape or an ankle brace and found a reduction in ankle plantarflexion angle at initial ground contact and maximum dorsiflexion angle during impact. A meta-analysis of ankle bracing literature found that ankle taping and bracing reduced sagittal plane motion at the ankle joint. While our results agree with the reduction in plantarflexion angle during initial ground contact, we did not find a significant difference in the maximum amount of dorsiflexion achieved during loading as previous studies have indicated. Although not statistically significant, our results show a trend toward a greater maximum dorsiflexion angle during loading in subjects with FRT as shown in Figure 2.
Lower Extremity EMG

Lower extremity musculature around the ankle joint plays a key role in providing dynamic stability and restraining excessive motion.\textsuperscript{18, 25} Several studies have documented decreased activity of the peroneus longus during various tasks in subjects with chronic ankle instability.\textsuperscript{14, 15, 17, 18} We hypothesized that there would be an increase in muscle activity because of a decreased plantarflexion angle at initial ground contact and a greater maximum dorsiflexion angle during loading due to the FRT.

However, our results showed the opposite, as there was actually a decrease in mean amplitude EMG of the two muscles during post-tests. The FRT group demonstrated a decreased mean amplitude EMG of the tibialis anterior during post-test compared to the pre-test in both the preparatory and loading phases. This may potentially be explained due to the length of the moment arm of the tibialis anterior through the range of motion of the ankle joint. As the ankle moves from plantarflexion to dorsiflexion the moment arm of the tibialis anterior increases in length.\textsuperscript{70} As this is a more mechanically efficient position, less force (therefore EMG activity) is needed to produce the same amount of torque around the joint center.

In the peroneus longus muscle, however, there was only a main effect for test. In both the preparatory and loading phases, subjects had lesser mean amplitude EMG during the post-test in all three groups. This might suggest a potential learning effect. Because the conditions were not randomized it is possible subjects needed less activation of their musculature as motor learning occurred. This effect was consistent across all groups, as the Group x Test interaction was not significant.
Following visual inspection of the data, we noted trends suggesting an effect of FRT which may have been masked by our relatively small sample size in each group. Exploratory post hoc analyses were conducted on all non-significant interaction effects to evaluate differences between groups in each test and between tests within each group. These analyses revealed a significant decrease in mean amplitude EMG of the peroneus longus during the preparatory phase in the FRT group from pre-test to post-test (p=0.044). Although not significant, there was a trend for a decrease in mean amplitude EMG of the tibialis anterior during the loading phase in the FRT group from pre-test to post-test, but not the PT or control groups (p=0.06). A relatively low power of 41 may explain why this was not significant. In order to achieve a power of 80, we would have needed 26 subjects per group.

Limitations and Future Research

A limitation of this study is that we did not definitively know if each subject had an anterior fibular fault. Although Hubbard et al. found that subjects with CAI had significant anterior displacement of their fibulas, the authors acknowledged that not all subjects possessed a fault (13 out of 30 did not show a fault). Without x-ray imaging for all subjects, we do not know how many of the nine subjects in the FRT group actually possessed the fault.

A related limitation is we did not know if the FRT actually changed any existing fibular positional faults. Mulligan theorizes that the taping technique will re-position the fibula, but it has never been scientifically proven. Therefore, we do not know to what extent, if any, the fibula’s position is actually changed due to the taping procedure.
Although not all variables showed significant differences, we were able to visually detect trends in the data that suggest FRT may induce more changes than our study noted. A small sample size in each group led to low power in most of our variables.

This study was unique because, to our knowledge, it was the first study to examine the effects of FRT on ankle kinematics and lower extremity EMG. Future research should aim to eliminate our limitations by using x-ray imaging on all subjects before and after application of the FRT to determine its effect on fibular positioning. Analyzing similar variables in a variety of tasks such as during gait and jump landings may help further clarify and explain the effect that FRT has on lower extremity kinematics and muscle activity in those with CAI.

Additionally, new research has shown that individuals suffering from acute ankle sprains may also possess an anterior fibular fault. Therefore, the effect of FRT on acute ankle sprains should also be examined.

**Clinical Applications**

This study has demonstrated that the FRT technique has positive effects on ankle kinematics during landing in subjects with CAI. Subjects were able to land from a specified height with a significantly decreased plantarflexion angle. Since the most common mechanism of injury for a lateral ankle sprain is having the ankle in a plantarflexed, inverted, and internally rotated position, the FRT could potentially reduce the risk of ankle sprain by promoting better ankle positioning during dynamic tasks. Additionally, the trend of the FRT allowing a greater maximum dorsiflexion angle during loading allows the ankle to achieve a closed-pack position for a longer duration during
loading, which may help attenuate ground reaction forces and promote joint congruency, thus stability.

It is important to note that traditional ankle taping and FRT have distinct indications for clinical use. Ankle taping is a mechanical restraint to extreme ranges of motion, particularly in the sagittal plane, and controls foot position before initial ground contact. In contrast, the purpose of FRT is to restore proper arthrokinematics at the distal tibiofibular joint. Although they function through different mechanisms, the results of this study indicate that they have similar effects on foot position before initial ground contact (reduction in plantarflexion angle).
APPENDIX A: TABLES
Table 1. Means and standard deviations for subject characteristics (age, height, and weight) N=28

<table>
<thead>
<tr>
<th>Variables</th>
<th>FRT Mean (SD)</th>
<th>PT Mean (SD)</th>
<th>Control Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>20.78 2.05</td>
<td>22.56 4.28</td>
<td>19.70 1.77</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.44 12.35</td>
<td>176.67 10.46</td>
<td>174.20 7.61</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.33 21.49</td>
<td>86.22 31.94</td>
<td>75.30 15.87</td>
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</tbody>
</table>
Table 2. Means and standard deviations for sagittal plane joint angles (°). Plantarflexion angles are (-), dorsiflexion angles are (+).

<table>
<thead>
<tr>
<th>Group</th>
<th>Angle at Initial Contact Pre-Test</th>
<th>Mean (SD)</th>
<th>Post-Test</th>
<th>Mean (SD)</th>
<th>Maximum Angle Pre-Test</th>
<th>Mean (SD)</th>
<th>Post-Test</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT</td>
<td>-31.80 8.70</td>
<td>-27.21</td>
<td>8.79</td>
<td>19.82</td>
<td>6.28</td>
<td>22.40</td>
<td>7.63</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>-38.11 5.13</td>
<td>-37.34</td>
<td>5.13</td>
<td>20.48</td>
<td>2.62</td>
<td>20.12</td>
<td>2.59</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Means and standard deviations for frontal plane joint angles (°). Inversion angles are (-), eversion angles are (+).

<table>
<thead>
<tr>
<th>Group</th>
<th>Angle at Initial Contact</th>
<th>Maximum Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test Mean (SD)</td>
<td>Post-Test Mean (SD)</td>
</tr>
<tr>
<td>PT</td>
<td>-14.97 11.35</td>
<td>-14.79 12.44</td>
</tr>
<tr>
<td>Control</td>
<td>-9.37 10.20</td>
<td>-9.03 11.39</td>
</tr>
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</table>
Table 4. Means and standard deviations for onset time (ms).

<table>
<thead>
<tr>
<th>Group</th>
<th>Tibialis Anterior Pre-Test Mean (SD)</th>
<th>Post-Test Mean (SD)</th>
<th>Peroneus Longus Pre-Test Mean (SD)</th>
<th>Post-Test Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRT</td>
<td>129.20 (14.14)</td>
<td>125.60 (15.74)</td>
<td>129.20 (25.14)</td>
<td>120.78 (32.67)</td>
</tr>
<tr>
<td>PT</td>
<td>146.24 (27.07)</td>
<td>133.54 (16.33)</td>
<td>162.64 (48.71)</td>
<td>143.53 (25.21)</td>
</tr>
<tr>
<td>Control</td>
<td>136.78 (11.07)</td>
<td>143.38 (22.00)</td>
<td>146.30 (17.60)</td>
<td>155.62 (22.10)</td>
</tr>
</tbody>
</table>
Table 5. Means and standard deviations for normalized EMG mean amplitudes of the tibialis anterior muscle.

<table>
<thead>
<tr>
<th>Group</th>
<th>Preparatory Phase</th>
<th>Loading Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test Mean</td>
<td>Post-Test Mean</td>
</tr>
<tr>
<td>FRT</td>
<td>0.40 (SD 0.15)</td>
<td>0.29 (SD 0.14)</td>
</tr>
<tr>
<td>PT</td>
<td>0.27 (SD 0.14)</td>
<td>0.24 (SD 0.12)</td>
</tr>
<tr>
<td>Control</td>
<td>0.37 (SD 0.14)</td>
<td>0.37 (SD 0.16)</td>
</tr>
</tbody>
</table>
Table 6. Means and standard deviations for normalized EMG mean amplitudes for the peroneus longus muscle.

<table>
<thead>
<tr>
<th>Group</th>
<th>Preparatory Phase</th>
<th></th>
<th>Loading Phase</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
<td>Pre-Test</td>
<td>Post-Test</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>FRT</td>
<td>0.42 (0.19)</td>
<td>0.35 (0.19)</td>
<td>0.67 (0.30)</td>
<td>0.55 (0.28)</td>
</tr>
<tr>
<td>PT</td>
<td>0.37 (0.12)</td>
<td>0.36 (0.14)</td>
<td>0.67 (0.28)</td>
<td>0.59 (0.24)</td>
</tr>
<tr>
<td>Control</td>
<td>0.58 (0.23)</td>
<td>0.52 (0.19)</td>
<td>0.86 (0.28)</td>
<td>0.75 (0.24)</td>
</tr>
</tbody>
</table>
APPENDIX B: FIGURES
Sagittal Plane Angle at Initial Ground Contact

Figure 1.
Maximum Sagittal Plane Angle

Figure 2.
Figure 3.
Figure 4.
Figure 5.
Figure 6.
Figure 7.
Figure 8.

Peroneus Longus Mean Amplitude EMG during Preparatory Phase

- FRT
- PT
- Control
Figure 9.
Figure 10.
Figure 11.

![Graph showing GRFv over time with标注“1st Local Minimum.”](image)
APPENDIX C: MANUSCRIPT
ABSTRACT
Megan East
Fibular repositioning tape alters ankle kinematics and lower extremity muscle activity in those with chronic ankle instability
(Under the direction of Dr. Troy Blackburn)

Objective: To evaluate the immediate effects of fibular repositioning tape on ankle kinematics and muscle activity during a single-leg drop landing in subjects with chronic ankle instability. Design and Setting: An experimental research design was used to compare a fibular repositioning tape group (n=10), placebo tape group (n=10), and control group (n=10) before and after a taping intervention. Subjects: Thirty subjects with chronic ankle instability volunteered to participate. Measurements: Ankle kinematics and lower extremity EMG data were recorded. A mixed-model ANOVA was used for statistical analyses for each dependent variable. Post-hoc testing was done with independent and dependent t-tests. Results: The fibular repositioning tape group landed with a decreased plantarflexion angle at initial contact (p<0.0005) and had decreased mean amplitude EMG of the tibialis anterior during the preparatory phase (p<0.0005). Conclusion: Fibular repositioning tape may cause beneficial changes in landing kinematics that may lead to a decreased rate of ankle sprains.
Introduction

Lateral ankle sprains are among the most common injuries in athletic activities.\(^1\) The most common mechanism of injury for a lateral ankle sprain involves a plantarflexed, inverted, and internally rotated position of the ankle, and typically occurs after initial contact of the rearfoot during gait or landing from a jump.\(^1,2\) Approximately 85% of all ankle sprains are due to inversion, and cause subsequent damage to the lateral ligament complex.\(^3\) Many individuals experience residual symptoms, and up to 70% will suffer recurrent sprains.\(^4\) Typical residual symptoms include pain during activity, recurrent swelling, feeling of “giving way,” and weakness.\(^5\) The development of lingering symptoms and repetitive ankle sprains has been termed chronic ankle instability (CAI).

Several studies have examined changes in ankle joint kinematics and lower leg electromyography (EMG) during static stances, gait, and jump landings in subjects with CAI.\(^13-17\) The results of these studies indicate that subjects with CAI demonstrate a significantly more inverted ankle position and decreases in peroneus longus activity during the tasks when compared to control subjects.\(^13-17\) The peroneal musculature is the primary eccentric control to resist ankle inversion, thus serving as a protective mechanism to lateral ankle sprains, and adding to the dynamic stability of the ankle joint.\(^18\) Peroneal activity alterations coupled with the vulnerable ankle position of inversion may explain why individuals with CAI suffer repetitive ankle sprains.\(^14,15\)

Recently, the role of positional faults at the ankle complex has become a topic of much debate. Mulligan first proposed that an anterior fault of the distal fibula on the tibia occurs in some individuals after lateral ankle sprains.\(^19\) During the plantarflexion and inversion mechanism of lateral ankle sprain, the anterior talofibular ligament (ATFL)
places tension on the distal fibula, causing it to move anteriorly. With a more anteriorly positioned fibula, the ATFL has less tension on it, thereby allowing further ranges of inversion before restraint is provided, and potentially leading to repetitive sprains and instability. It has been hypothesized that individuals with CAI maintain anterior positional faults due to changes in peroneal muscle tone from alterations in the neuromuscular control system.

Manual repositioning of the fibula either by rigid tape or manual therapy has been shown to have positive effects on ankle joint pain, range of motion, and disability. Fibular repositioning tape (FRT) is used clinically as a treatment following ankle sprains. Mulligan proposed that fibular repositioning tape can correct an anterior positional fault and maintain normal fibular alignment, however there is no research evidence to support this method. FRT is believed to prevent fibular forward displacement, and may be effective in ankle injury prevention. An early pilot study indicated that the prophylactic use of FRT may decrease the rate of ankle sprains in basketball players. Despite the growing use of fibular repositioning techniques clinically for athletic competition, there is little evidence in the literature as to why these methods are effective or what mechanisms result in improved function. Therefore, the purpose of this study was to investigate the immediate effects of FRT on ankle kinematics and lower extremity electromyography (EMG) in subjects with CAI while performing a single-leg drop landing task.
Methods

Experimental Design

We used a randomized, single-blinded, repeated measures design to investigate the effects of fibular repositioning tape on ankle joint kinematics and muscle activity. Subjects were randomly assigned into one of three groups: fibular repositioning tape (FRT) group, the placebo tape (PT) group, or the control group (no tape). Data were collected twice during one testing session, before and after an intervention (taping) period.

Subjects

Thirty subjects volunteered to participate in this study. Subjects were eligible for participation if they were between the ages of 18-30 and were identified as having unilateral chronic ankle instability. Chronic ankle instability criteria included: 1) a self-reported previous history of at least one inversion ankle sprain that required a period of protected weight-bearing and/or immobilization; 2) the subject reported a tendency for the ankle to “give way” during activity; 3) the involved ankle was subjectively reported to be less functional compared to uninvolved ankle at the time of testing. Exclusion criteria included any previous history of lower extremity fracture, ankle surgery, or acute ankle sprain within the six weeks prior to data collection. Signs and symptoms of acute ankle sprain were any pain, redness, swelling, or self-reported loss of typical function at the time of testing. Prior to testing, all subjects read and signed an approved informed consent document.
Experimental Procedures

All subjects reported to the laboratory for one testing session lasting approximately one hour. Upon arriving at the lab, subjects completed a questionnaire to ensure they met the inclusion criteria and to screen for any of the exclusion factors. Subject assignment occurred through random assignment without replacement. The subject was blinded to group assignment.

Electromagnetic sensors (Ascension Technologies, Burlington, VT) were placed on the limb with the chronically unstable ankle of each subject over the shank, posterior calcaneus, and the lateral dorsum of the foot. The sensor on the tibia was placed in an area consisting of the least amount of muscle mass to minimize potential artifact induced by muscle contraction. Sensors were attached by double-sided tape and secured to the body with prewrap and athletic tape. Kinematic data were sampled at 100 Hz.

Preamplified EMG electrodes from a surface electromyography (EMG) system (Delsys Bagnoli-8, Boston, MA: interelectrode distance = 10 mm; amplification factor = 1,000 (20 – 450 Hz); CMRR @ 60 Hz > 80 dB; input impedance > 10^{15}/0.2 ohm/pF) were then secured to the subject’s lower leg. The area where the electrodes were placed was shaved to remove any hair, lightly abraded with an abrasive pad, and cleansed using isopropyl alcohol to reduce impedance of the EMG signal. Electrodes were placed over the muscle bellies of the peroneus longus and tibialis anterior. A reference electrode was placed over the tibial tuberosity. Electrodes were secured to the skin with prewrap and athletic tape. A manual muscle test was performed to ensure proper positioning of the electrodes and the absence of cross talk. EMG data were sampled at a rate of 1000 Hz.
The subject’s injured limb was then digitized after sensor and electrode application while subjects stood in a neutral and relaxed stance. A segment-linkage model of the lower extremity was constructed by digitizing the following landmarks: medial and lateral epicondyle of the femur, medial and lateral malleoli of the ankle, and the most distal portion of the 2nd phalanx. Knee and ankle joint centers were defined as the midpoint of the digitized femoral condyles and malleoli, respectively.

Ankle kinematic and EMG data were collected during a single leg drop landing task. The primary investigator explained the drop landing task and subjects practiced the task a maximum of three times or until they felt comfortable with the task. All subjects performed this task barefoot to control for any differences in shoe type. The drop landing task required the subject to stand on his/her unaffected limb on a box 30 centimeters high placed 10 centimeters from the edge of a force plate with affected limb relaxed and non-weightbearing. Subjects then dropped from the box using the unaffected limb, and landed with the affected limb on the middle of the force plate. A nonconductive force plate (Bertec Corporation, Columbus, OH) was used to collect vertical ground reaction force data to determine the instant of initial contact during the single leg drop landing task. Data were synchronized with ankle kinematic data and sampled at a rate of 1000 Hz.

Each subject performed five trials of the single leg drop landing task with 30 seconds of rest between trials to minimize the risk of fatigue. Trials with incorrect landings were considered invalid, and a new trial was performed. Incorrect landings were those in which the subject’s tested limb did not land completely on the force plate, or if the untested limb touched down during the trial.
After recording the first five drop landings, subjects received the FRT, the PT, or no tape as determined by group assignment. All taping procedures were performed by the same trained clinician. For the FRT, the subject was seated with the foot in a relaxed position. The subject’s skin was prepared with adhesive. A 20 centimeter length of non-stretch tape (leukotape) was applied obliquely starting at the distal end of the lateral malleolus. A pain-free posterolateral force was applied to the distal fibula while tape was applied. A second reinforcing strip was then applied in the same manner. For the placebo tape, the same process as the FRT was followed without a posterolateral force applied during application. The control group received no tape and rested quietly during the treatment period. The time between testing sessions for all subjects was 10 minutes. After the treatment period, an additional five single leg drop landing trials were performed as described previously.

A five-second maximal voluntary isometric contraction (MVIC) against a manual resistance was then performed for each muscle to normalize muscle activity. For the peroneus longus muscle, the tester stabilized the tibia and resisted eversion and plantarflexion manually by placing her hand on the lateral dorsal aspect of the foot. The tibialis anterior muscle was tested manually by stabilizing the tibia and providing resistance to dorsiflexion and inversion.

Data Sampling and Reduction

Data sampling was synchronized by The Motion Monitor (Innovative Sports Training, Inc., Chicago, IL) data acquisition computer software. Electromagnetic sensor data were sampled at 100 Hz, while EMG and force plate data were sampled at 1,000 Hz.
Kinematic data were time synchronized with EMG and force plate data, and re-sampled at 1,000 Hz.

Raw kinematic data were converted to the aligned anatomical coordinate axes. The three dimensional global and local coordinate systems were defined as follows: the positive x-axis was the direction the subject faces, the positive y-axis was to the left of the subject, and the positive z-axis was directed upward. Kinematic data were low pass filtered at 10 Hz (4th order, zero phase lag).

Ankle angles in the frontal and sagittal planes at initial ground contact and maximum ankles angles in the frontal and sagittal planes during the loading phase of the drop landing task were then determined through customized software in MatLab (The Mathworks, Inc., Natick, MA). The loading phase was defined as the time period from initial ground contact to the first local minimum of the vertical ground reaction force (see Figure 11).

Raw EMG data were passively demeaned, band-pass filtered (20-350 Hz; 4th order Butterworth) and smoothed using a 20 ms sliding window function. We then determined the mean EMG amplitude of the peroneus longus and tibialis anterior for the preparatory and loading phases of the drop landing as well as the onset time for each muscle. The preparatory phase was defined as the time period between EMG onset and initial ground contact. The loading phase for EMG was the same as used for kinematic data. The onset time was defined as the time at which the EMG was three standard deviations above baseline EMG.
Statistical Analyses

A 3 (Group: FRT, PT, Control) x 2 (Test: Pre, Post) mixed-model repeated measures ANOVA was used to compare the groups and testing sessions for each of the dependent variables. Dependent and independent samples t-tests were then conducted as post-hoc tests after a Bonferroni adjustment for Type I error rate. All data were analyzed with SPSS Version 13.0 statistical software (SPSS, Inc., Chicago, IL) with an a priori alpha level set at 0.05.

Results

Of the original 30 subjects recruited and randomly assigned to the FRT (n=10), PT (n=10), or control (n=10) group, the data for one subject in the FRT group and one subject in the PT group were not used for statistical analyses due to data reduction errors. Specifically, the algorithms used in data processing were unable to detect EMG onset. Therefore, data from 9 FRT group subjects, 9 PT subjects, and 10 control group subjects were used for data analyses. Additionally, the algorithms used for data reduction were unsuccessful for 4 trials (within 3 subjects) out of 280 total trials included in data analyses. These trials were discarded, and in those subjects, averages were calculated across four trials instead of five in that test condition. Subject demographics are presented in Table 1 for the 28 subjects included in the analysis.

Ankle Kinematics

Means and standard deviations for ankle angle at initial ground contact in the sagittal plane are presented in Table 2. A significant main effect for Test ($F_{(1,25)}=73.942,$
p<0.0005) was found. Overall, subjects had a smaller plantarflexion angle at initial contact during the post-test compared to the pre-test. There was also a significant main effect for Group (F(2,25)=4.979, p=0.015). Subjects in the FRT and the PT groups demonstrated smaller plantarflexion angles at initial contact when compared to the control group, but were not different from each other. There was a significant Group x Test interaction (F(2,25)=17.492, p<0.0005). Pairwise comparisons indicated that subjects in both the FRT and PT groups demonstrated smaller plantarflexion angles at initial contact during the post-test when compared to the control group during post-test, but were not different from each other. There were no differences between groups during the pre-test. Additionally, the FRT and PT groups demonstrated lesser angles in the sagittal plane at initial contact during the post-test when compared to the pre-test.

Means and standard deviations for the maximum ankle angle in the sagittal plane are presented in Table 2. There was a significant main effect for Test (F(1,25)=5.405, p=0.028). Subjects demonstrated greater maximum angles in the sagittal plane in the post-test when compared to the pre-test. There was no significant main effect for Group or Group x Test interaction.

Means and standard deviations for ankle angle at initial contact in the frontal plane and maximum angle in the frontal plane are presented in Table 3. There were no significant main effects for Group or Test as well as no significant Group x Test interactions for either variable (p>0.05).
Lower Extremity EMG

Means and standard deviations for tibialis anterior and peroneus longus onset times are presented in Table 4. There were no significant main effects for Group or Test as well as no significant Group x Test interactions for either muscle (p>0.05).

Means and standard deviations for the tibialis anterior mean amplitude EMG during the preparatory phase are presented in Table 5. There was a significant main effect for Test ($F_{(1,25)}=24.279$, p<0.0005). Subjects demonstrated decreased mean amplitude EMG values of the tibialis anterior in the preparatory phase during the post-test when compared to the pre-test. There was also a significant Group x Test interaction ($F_{(2,25)}=11.082$, p<0.0005). Pairwise comparisons indicated that subjects in the FRT group demonstrated a decreased mean amplitude EMG of the tibialis anterior during the preparatory phase during the post-test when compared to the pre-test. There were no other significant differences between or within group comparisons.

Means and standard deviations for the mean amplitude EMG of the tibialis anterior during the loading phase are presented in Table 5. There was a significant main effect for Group ($F_{(2,25)}=5.504$, p=0.01). Overall, subjects in the FRT and PT group demonstrated a decreased mean amplitude EMG of the tibialis anterior during the loading phase when compared to subjects in the control group, but were not different from each other.

Means and standard deviations for mean amplitude EMG of the peroneus longus during the preparatory phase are presented in Table 6. There was a significant main effect for Test ($F_{(1,25)}=8.752$, p=0.007). Subjects demonstrated a decreased mean amplitude values for the peroneus longus in the preparatory phase during the post-test when
compared to the pre-test. There was no significant Group main effect or Group x Test interaction.

Means and standard deviations for the mean amplitude EMG of the peroneus longus during the loading phase are presented in Table 6. There was a significant main effect for Test ($F_{(1,25)}=28.013, p<0.0005$). Subjects demonstrated a decreased mean amplitude EMG value of the peroneus longus in the loading phase during the post-test when compared to the pre-test.

**Discussion**

Our principal findings in this study were that the FRT alters ankle kinematics in the sagittal plane and lower extremity muscle activity. Specifically, the FRT caused subjects to have a decreased plantarflexion angle at initial ground contact when compared to a control group as well as less activation of the tibialis anterior muscle during the preparatory phase as measured by mean amplitude EMG. Additionally, the PT also caused a smaller plantarflexion angle at initial ground contact, but to a lesser extent than the FRT group, suggesting that cutaneous stimulation may play a role in altering ankle kinematics. These results suggest that FRT could have beneficial effects on ankle joint landing mechanics and potentially could decrease the rate of ankle sprains.

**Ankle Kinematics**

The most vulnerable position of the ankle for injury to the lateral ligament complex is when the ankle is plantarflexed, inverted, and internally rotated. Several previous studies have demonstrated that subjects with CAI have potentially detrimental
alterations in ankle kinematics, such as an increased inversion angle at initial contact, when compared to healthy ankles that may lead to repetitive ankle sprains.\textsuperscript{13-16, 19} Our results indicate that intervention through FRT may restore proper joint arthrokinematics that allow the ankle to be in a less vulnerable position for injury by decreasing the plantarflexion angle of the ankle at initial ground contact. This causes more of the wider anterior portion of the talus to fit inside the ankle mortise and increases joint congruency and thus, stability. Comparison of our results to previous studies is extremely limited because, to our knowledge, there is only one other study examining the effects of FRT, which was a prospective pilot study to examine the incidence of ankle sprains in recreational basketball players and the potential prophylactic use of FRT.\textsuperscript{22} However, preliminary data from that pilot study indicated that subjects who wore the FRT were five times less likely to sustain an ankle sprain compared to a control group.\textsuperscript{22} Although there were substantial limitations to that study, including not randomizing groups or controlling for wearing other external ankle supports, our findings of a lesser plantarflexion angle at initial ground contact could help explain why FRT reduced the rate of ankle sprains.

Previous research examining other forms of external ankle supports, such as bracing and taping, has reported reduction in sagittal plane motion during tasks. McCaw et al.\textsuperscript{68} used a drop landing task to examine changes in ankle kinematics measured while wearing either ankle tape or an ankle brace and found a reduction in ankle plantarflexion angle at initial ground contact and maximum dorsiflexion angle during impact.\textsuperscript{68} A meta-analysis of ankle bracing literature found that ankle taping and bracing reduced sagittal plane motion at the ankle joint.\textsuperscript{69} While our results agree with the reduction in plantarflexion angle during initial ground contact, we did not find a significant difference
in the maximum amount of dorsiflexion achieved during loading as previous studies have indicated. Although not statistically significant, our results show a trend toward a greater maximum dorsiflexion angle during loading in subjects with FRT as shown in Figure 2.

Lower Extremity EMG

Lower extremity musculature around the ankle joint plays a key role in providing dynamic stability and restraining excessive motion.\textsuperscript{18, 25} Several studies have documented decreased activity of the peroneus longus during various tasks in subjects with chronic ankle instability.\textsuperscript{14, 15, 17, 18} We hypothesized that there would be an increase in muscle activity because of a decreased plantarflexion angle at initial ground contact and a greater maximum dorsiflexion angle during loading due to the FRT.

However, our results showed the opposite, as there was actually a decrease in mean amplitude EMG of the two muscles during post-tests. The FRT group demonstrated a decreased mean amplitude EMG of the tibialis anterior during post-test compared to the pre-test in both the preparatory and loading phases. This may potentially be explained due to the length of the moment arm of the tibialis anterior through the range of motion of the ankle joint. As the ankle moves from plantarflexion to dorsiflexion the moment arm of the tibialis anterior increases in length.\textsuperscript{70} As this is a more mechanically efficient position, less force (therefore EMG activity) is needed to produce the same amount of torque around the joint center. The FRT group demonstrated a decreased plantarflexion angle (therefore increased the moment arm length of the tibialis anterior) at initial ground contact when compared after tape application, which could have led to the decrease in tibialis anterior activity.
In the peroneus longus muscle, however, there was only a main effect for test. In both the preparatory and loading phases, subjects had lesser mean amplitude EMG during the post-test in all three groups. This might suggest a potential learning effect. Because the conditions were not randomized it is possible subjects needed less activation of their musculature as motor learning occurred. This effect was consistent across all groups, as the Group x Test interaction was not significant.

Following visual inspection of the data, we noted trends suggesting an effect of FRT which may have been masked by our relatively small sample size in each group. Exploratory post hoc analyses were conducted on all non-significant interaction effects to evaluate differences between groups in each test and between tests within each group. These analyses revealed a significant decrease in mean amplitude EMG of the peroneus longus during the preparatory phase in the FRT group from pre-test to post-test (p=0.044). Although not significant, there was a trend for a decrease in mean amplitude EMG of the tibialis anterior during the loading phase in the FRT group from pre-test to post-test (p=0.06). A relatively low power of 41 may explain why this was not significant. In order to achieve a power of 80, we would have needed 26 subjects per group. These findings suggest that significant effects of the FRT may be masked by the small sample sizes used in this study.

Limitations and Future Research

A limitation of this study is that we did not definitively know if each subject had an anterior fibular fault. Although Hubbard et al.\textsuperscript{35} found that subjects with CAI had significant anterior displacement of their fibulas, the authors acknowledged that not all
subjects possessed the fault (13 out of 30 did not). Without x-ray imaging for all subjects, we do not know how many of the nine subjects in the FRT group actually possessed the fault.

A related limitation is we did not know if the FRT actually changed any existing fibular positional faults. Mulligan theorizes that the taping technique will re-position the fibula, but it has never been scientifically proven. Therefore, we do not know to what extent, if any, the fibula’s position is actually changed due to the taping procedure.

Although not all variables showed significant differences, we were able to visually detect trends in the data that suggest FRT may induce more changes than our study noted. A small sample size in each group led to low power in most of our variables.

This study was unique because, to our knowledge, it was the first study to examine the effects of FRT on ankle kinematics and lower extremity EMG. Future research should aim to eliminate our limitations by using x-ray imaging on all subjects before and after application of the FRT to determine its effect on fibular positioning. Analyzing similar variables in a variety of tasks such as during gait and jump landings may help further clarify and explain the effect that FRT has on lower extremity kinematics and muscle activity in those with CAI.

Additionally, new research has shown that individuals suffering from acute ankle sprains may also possess an anterior fibular fault. Therefore, the effect of FRT on acute ankle sprains should also be examined.
Clinical Relevance

This study has demonstrated that the FRT technique has positive effects on ankle kinematics during landing in subjects with CAI. Subjects were able to land from a specified height with a significantly decreased plantarflexion angle. Since the most common mechanism of injury for a lateral ankle sprain is having the ankle in a plantarflexed, inverted, and internally rotated position, the FRT could potentially reduce the risk of ankle sprain by promoting better ankle positioning during dynamic tasks. Additionally, the trend of the FRT allowing a greater maximum dorsiflexion angle during loading allows the ankle to achieve a closed-pack position for a longer duration during loading, which may help attenuate ground reaction forces and promote joint congruency, thus stability.

It is important to note that traditional ankle taping and FRT have distinct indications for clinical use. Ankle taping is a mechanical restraint to extreme ranges of motion, particularly in the sagittal plane, and controls foot position before initial ground contact. In contrast, the purpose of FRT is to restore proper arthrokinematics at the distal tibiofibular joint. Although they function through different mechanisms, the results of this study indicate that they have similar effects on foot position before initial ground contact (reduction in plantarflexion angle).
University of North Carolina-Chapel Hill
Consent to Participate in a Research Study
Adult Subjects
Biomedical Form

IRB Study # 07-1589
Consent Form Version Date: 10/30/07

Title of Study: The immediate effects of fibular repositioning tape on ankle kinematics and muscle activity

Principal Investigator: Megan East
UNC-Chapel Hill Department: Exercise and Sport Science
UNC-Chapel Hill Phone number: 919-962-2067
Email Address: east21@email.unc.edu
Co-Investigators: Lindsay Strickland, MA, ATC
Marc Norcross, MA, ATC
Steven Zinder, PhD, ATC
Faculty Advisor: Troy Blackburn, PhD, ATC
Funding Source: N/A

Study Contact telephone number: 727-463-6112
Study Contact email: east21@email.unc.edu

What are some general things you should know about research studies?
You are being asked to take part in a research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

Research studies are designed to obtain new knowledge that may help other people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Deciding not to be in the study or leaving the study before it is done will not affect your relationship with the researcher, your health care provider, or the University of North Carolina-Chapel Hill. If you are a patient with an illness, you do not have to be in the research study in order to receive health care.

Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about being in this research study. You will be given a copy of this consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.
What is the purpose of this study?
The purpose of this research study is to learn about the effects of fibular repositioning tape on ankle movement and muscle activity. Fibular repositioning taping is a relatively new form of ankle taping being used clinically to reduce ankle pain and improve function. Clinicians use this taping technique on individuals who have suffered from ankle sprains and/or chronic ankle instability. Despite the growing use of this technique clinically, we do not have a complete understanding of why this method is effective. This study will attempt to detect changes in ankle movement and muscle activity after application of the fibular repositioning tape.

You are being asked to be in the study because you meet the following criteria for unilateral chronic ankle instability:
- You have a history of at least one inversion ankle sprain that required a period of protected weight-bearing and/or immobilization
- Your affected ankle has a tendency to “give way” during activity
- Your affected ankle is currently more painful and less functional than the healthy ankle

Are there any reasons you should not be in this study?
You should not be in this study if:
- you have a history of any fracture of the lower extremity (hip, thigh, knee, leg, ankle, and/or foot)
- you have ever had ankle surgery of any kind
- you have suffered an acute ankle sprain in the last 6 weeks (injury to your ankle causing any pain, redness, swelling, or loss of function)

How many people will take part in this study?
If you decide to be in this study, you will be one of approximately 45 people in this research study.

How long will your part in this study last?
You will be enrolled in this study for one session lasting approximately one hour. There are no follow-up sessions required for this study.

What will happen if you take part in the study?
If you agree to take part in the study, you will report to the Sports Medicine Research Laboratory located in Room 06F in Fetzer Gymnasium at The University of North Carolina at Chapel Hill for one testing session lasting approximately one hour.

Upon your arrival the following information will be collected and recorded:
- General demographic information such as age, height, and weight
- A questionnaire to ensure you meet the inclusion criteria of the study
- The Foot and Ankle Disability Index (a survey indicating your current level of function of your affected ankle)
*For all questionnaires, you may choose not to answer a question for any reason.*

Motion sensors that will measure your ankle range of motion will then be attached to parts of your leg and ankle. These are secured using double-sided tape and athletic tape. Next, you will have electromyographic (EMG) sensors placed on the skin over two muscles of your lower leg to measure the electric activity of your muscles. These will be secured in the same fashion as the motion sensors.

A drop landing task will then be described and demonstrated by the investigator. This task involves standing on your unaffected leg on a box 30 centimeters high and dropping down to land on your affected ankle onto a force plate. You will be allowed to have practice trials of the drop landings to get used to the task. Once you are comfortable with the task, you will then perform five trials in which data will be collected for the study. You will then be randomly assigned to one of three groups: two of which involve the fibular repositioning taping, or a control group (no taping involved). At the time of testing, you will not be aware of your group assignment. If you are assigned to a taping group, two strips of tape will be applied to the ankle with chronic instability and you will perform another set of five drop landings in the same manner as the previous five. If you are in the control group, no tape will be applied and you will perform another set of five drop landings in the same manner as the previous five.

**What are the possible benefits from being in this study?**
Research is designed to benefit society by gaining new knowledge. The benefits to you from being in this study may be to determine if fibular repositioning taping has a positive outcome to your ankle pain or function.

**What are the possible risks or discomforts involved with being in this study?**
While performing the drop landing task, there is a small risk of injury to the lower extremity. This risk will be minimized by allowing practice trials to familiarize yourself with the task. Skin irritation at the site of the EMG electrodes and motion analysis sensors may occur. In addition, there may be uncommon or previously unknown risks that might occur. You should report any problems to the researchers.

**What if we learn about new findings or information during the study?**
You will be given any new information gained during the course of the study that might affect your willingness to continue your participation.

**How will your privacy be protected?**
Measures will be taken to ensure that your privacy is maintained. All records will be kept in a locked filing cabinet and on a secure computer requiring a password. Only the primary and co-investigators will have access to these records. After the initial interview, only subject identification numbers will be used for identification purposes.

Participants will not be identified in any report or publication about this study. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal
information. This is very unlikely, but if disclosure is ever required, UNC-Chapel Hill will take steps allowable by law to protect the privacy of personal information. In some cases, your information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies for purposes such as quality control or safety.

**What will happen if you are injured by this research?**
All research involves a chance that something bad might happen to you. This may include the risk of personal injury. In spite of all safety measures, you might develop a reaction or injury from being in this study. If such problems occur, the researchers will help you get medical care, but any costs for the medical care will be billed to you and/or your insurance company. The University of North Carolina at Chapel Hill has not set aside funds to pay you for any such reactions or injuries, or for the related medical care. However, by signing this form, you do not give up any of your legal rights.

**What if you want to stop before your part in the study is complete?**
You can withdraw from this study at any time, without penalty. The investigators also have the right to stop your participation at any time. This could be because you have had an unexpected reaction, or have failed to follow instructions, or because the entire study has been stopped.

**Will you receive anything for being in this study?**
You will not receive anything for taking part in this study.

**Will it cost you anything to be in this study?**
There are no costs for being in this study.

**What if you are a UNC student?**
You may choose not to be in the study or to stop being in the study before it is over at any time. This will not affect your class standing or grades at UNC-Chapel Hill. You will not be offered or receive any special consideration if you take part in this research.

**What if you are a UNC employee?**
Taking part in this research is not a part of your University duties, and refusing will not affect your job. You will not be offered or receive any special job-related consideration if you take part in this research.

**What if you have questions about this study?**
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, or if a research-related injury occurs, you should contact the researchers listed on the first page of this form.

**What if you have questions about your rights as a research subject?**
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject, you have the right to ask, and have answered, any questions you may have about this research.
subject you may contact, anonymously if you wish, the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

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**Subject's Agreement:**

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree to participate in this research study.

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