Effects of ankle bracing on dynamic stabilization in subjects with chronic ankle instability

Brittany L. Taylor

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Effects of ankle bracing on dynamic stabilization in subjects with chronic ankle instability

By

Brittany L. Taylor

Submitted as partial fulfillment of the requirements for
The Master of Science degree in Exercise Science

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Committee Member: Dr. Charles Armstrong

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College of Health Science and Human Services

College of Graduate Studies

The University of Toledo

May 2008
An Abstract of

Effects of Ankle Bracing on Dynamic Stabilization in Subject with Chronic Ankle Instability

Brittany Taylor, ATC

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Objective: The purpose of this study was to compare a lace-up ankle brace with a no-brace condition on the ability to return an athlete with CAI to a stable state by measuring the TTS following a jump-landing task. Design: Repeated measures within-subject design. Setting: Athletic Training Research Laboratory. Patients or Participants: Ten subjects, five males and five females (18.5625±.814yr; 174.0963±7.191cm; 69.2937±8.277kg) that fit the criteria for chronic ankle instability participated in this study.
**Measurements:** Subjects participated in two separate testing sessions during which a jump-landing task was performed with one of two conditions: lace-up ankle brace or no ankle brace. The brace condition was randomized. During each session, five trials of a jump-landing task were performed on each leg. The jump-landing task consisted of a single-leg landing from a double-leg jump height equivalent to 50% of the subject’s maximum jump height. Subjects jumped off of both feet from a distance 70cm away from the center of the force plate, reached up and touched the indicated marker, and landed on the force plate on a single test limb. The landing leg was randomized. Ground reaction forces were used to calculate TTS in the medial/lateral (MLTTS) and anterior/posterior (APTTS) directions. The independent variables were Condition (brace, no brace) and Side (injured, non-injured). A separate two-within (Condition, Side) repeated measures ANOVA was performed for APTTS and MLTTS. **Main Outcome Measure(s):** APTTS and MLTTS. **Results:** For APTTS, the Side by Condition interaction was not statistically significant ($F_{1,9} = .004; p = .952$). For MLTTS, the Side by Condition interaction was not statistically significant ($F_{1,9} = .023; p = .884$). No measurements were found to be statistically significant in either direction. **Conclusion:** This study was designed to show if the use of an ankle brace, like the Swede-O Universal would assist those subjects with CAI in reducing the amount of time it takes for them to stabilize after a jump landing task. Although the results of this study do not support these conclusions with statistical significance, it may provide an important direction in examining the connection between TTS, ankle bracing, and those with CAI. There is a definite need for further testing on more subjects with CAI so we can make a better conclusion about the use of the Swede-O Universal and its ability to reduce time to stabilization after a jump-landing task.
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# Table of Contents

Abstract ii  
Acknowledgements iv  
Table of Contents v  
List of Tables vii  
List of Figures viii  
I. Introduction 1  
    Statement of the problem 3  
    Statement of purpose 3  
    Hypotheses 3  
    Operational Definitions 4  
II. Literature Review 5  
    Anatomy of the ankle 5  
    Mechanisms of ankle sprains 7  
    Muscle receptor physiology 8  
    Motor Control Terms 8  
    Repeated ankle injuries 10  
    Jump landing task 12
### III. Methods

- **Subjects**
- **Instrumentation**
- **Independent variables**
- **Dependant variables**
- **Procedures**
- **Data Processing**
- **Statistical analysis**
- **Potential Health risks**
- **Anticipated Outcomes**
- **Anticipated Timeline**

### IV. Results

- **Anterior/Posterior Time to Stabilization**
- **Medial/Lateral Time to Stabilization**

### V. Discussion
VI. References  

VII. Appendix  

A. Power Analysis Calculation  

B. Informed Consent for Participation  

C. Health History Questionnaire
List of Tables

Table 1. Subject Demographics 28

Table 2. Anterior/Posterior side by condition interaction 29

Table 3. Medial/Lateral side by condition interaction 29
List of Figures

Figure 1. Anterior/Posterior TTS side by condition interaction 30

Figure 2. Anterior/Posterior TTS side main effect 31

Figure 3. Anterior/Posterior TTS condition main effect 32

Figure 4. Medial/Lateral TTS side by condition interaction 33

Figure 5. Medial/Lateral TTS side main effect 34

Figure 6. Medial/Lateral TTS condition main effect 35
Chapter 1

Introduction

Ankle sprains are among the most common injuries suffered during athletic activities\(^1\). After initial injury, the rate of recurrence may be as high as 80% among active individuals\(^2\). Altered mechanical joint stability due to repeated disruptions to ankle integrity with resultant perceived and observed deficits in neuromuscular control has been described as chronic ankle instability (CAI)\(^3\). Chronic Ankle Instability might result from one or a combination of the following factors: (1) ligamentous damage, (2) ankle muscle strength deficits, (3) delayed muscle reaction time, and (4) proprioception deficits at the ankle joint. Researchers have speculated that these factors might cause individuals with ankle instability to land from a jump differently than individuals with stable ankles\(^4-12\).

Freeman et al\(^13\) suggested that alterations in postural control could be attributed to deficits in the afferent input arising from mechanoreceptors residing in the ankle ligaments and capsule (articular deafferentation). CAI has been reported to affect other components of the postural-control system besides the mechanoreceptors, such as strength, mechanical stability and range of motion\(^14\). Reimann\(^14\) reported that more consistent evidence in recent studies show that the way postural-control patterns are maintained are altered in patients with CAI.

The jump-landing task is selected as the criterion movement because many athletes perform jumping activities during competition\(^15\). In sports such as volleyball and basketball, ankle sprains are the
most common injuries due to the nature of jumping and landing with high ground reaction forces, resulting in these sports having 87% and 79% lateral ankle sprain injury rates, respectively\(^\text{16}\). Therefore, the jump-landing task is most commonly selected to study dynamic postural stability because it most closely replicates what an athlete does on a regular basis.

In order to measure the amount of dynamic stability in an unstable ankle, time to stabilization (TTS) measurement has been shown to be an effective way of measuring the amount of dynamic postural control in a joint during a jump-landing task. Using a TTS calculation originally reported by Ross, Guskiewicz, et al\(^\text{15}\) longer TTS values have been noted for subjects with chronic ankle instability than subjects with stable ankles\(^\text{17-19}\). The TTS offers a more functional method of assessing the effects of chronic ankle instability on neuromuscular control and dynamic stability.

Ankle supports such as bracing and taping are used by clinicians in order to stabilize the ankle or help prevent further injury to an already injured ankle. The objective of these support systems is to provide mechanical restriction of undesirable ankle joint motion and to relieve ankle joint ligaments of excessive strain while allowing for minimal hindrance to normal joint mechanics\(^\text{17}\). In a study by Eils et al\(^\text{20}\), they tested 10 different ankle braces and their effectiveness on restricting range of motion during passive and rapidly induced joint motion at the ankle for subjects with chronic ankle instability. They found all ten braces were more effective at restricting range of motion than the no brace condition and there were some significant differences between the ten braces. A recent project compared measures of TTS before and after functional fatigue among a group of collegiate volleyball players while they wore either a lace-up brace, Active Ankle semi-rigid brace, or no brace\(^\text{19}\). After fatigue was induced, the lace-up brace condition promoted improved TTS while the Active Ankle and no brace conditions suffered deficits in TTS\(^\text{19}\). Braces have been shown to be an effective way of controlling joint stability, but little
research has been conducted to show that a brace will improve the amount of TTS in an athlete with CAI during a jump-landing task.

**Statement of Problem**

In the clinical setting, a common practice for those with chronic ankle instability has been to apply an ankle brace to wear during any physical activity. These devices are used not only once an injury has occurred, but also for injury prevention. Specifically the Swede-o Universal (Swede-O Universal, Northbranch, MN, USA) is a common lace-up ankle brace used in athletics. One of the purposes of the use of ankle braces is to aid in recovery of balance, but there is a lack of evidence confirming the ability of an ankle brace, specifically the Swede-O Universal, to improve dynamic stability as measured with TTS in athletes with CAI.

**Statement of Purpose**

Therefore, the purpose of this study is to compare the Swede-O Universal brace with a no-brace condition on the ability to return an athlete with CAI to a stable state by measuring the TTS following a jump-landing task.

**Hypotheses**

1. In the medial/lateral direction the Swede-O Universal condition will gain stability more quickly than the no-brace condition.
2. In the anterior/posterior direction the Swede-O Universal condition will gain stability more quickly than the no-brace condition.
3. In the anterior/posterior direction the uninjured limb will gain stability more quickly than the injured limb during the no brace condition.
4. In the medial/lateral direction the uninjured limb will gain stability more quickly than the injured limb during the no brace condition.

5. In the anterior/posterior direction the Swede-O Universal will cause the uninjured limb to gain stability more quickly than the injured limb.

6. In the medial/lateral direction the Swede-O Universal will cause the uninjured limb to gain stability more quickly then the injured limb.

**Operational Definitions**

**Chronic Ankle Instability** – CAI; Alteration in ankle function due to repeated disruptions in the structural integrity of the ankle with resultant perceived and observed deficits in neuromuscular control\(^\text{13}\).  

**Time to Stabilization** – TTS; A quantitative forceplate measure that evaluates dynamic postural stability, by indicating how quickly one stabilizes after a jump-landing\(^\text{19}\).  

**Anterior/Posterior Time to Stabilization** – APTTS; a measure of TTS in the A/P plane  

**Medial/Lateral Time To Stabilization** – MLTTS; a measure of TTS in the M/L plane
Anatomy

Bones: There are three bones that come together to form the ankle complex, the tibia, fibula, and the talus. Also known as the ankle mortise the distal end of the tibia and the fibula and the body of the talus are what give the ankle its bony stability which is primarily on its lateral side due to the lateral malleolus. A fourth bone that sits underneath the talus, the calcaneus, provides another joint for allowing inversion and eversion. This joint is known as the subtalar joint and is commonly overlooked but can be the cause of symptoms in lateral ankle sprains.

Ligaments: The ligaments that provide the soft-tissue stability to the ankle joint can be divided into three groups: the lateral ligamentous complex, the syndesmosis ligaments, and the deltoid ligament. The lateral ligamentous complex consists of the anterior talofibular ligament (ATFL), the
posterior talofibular ligament (PTFL), and the calcaneofibular ligament (CFL). The ATFL runs from the anterior distal margin of the lateral malleolus to the body of the talus at 75 degree angle to the floor and the weakest ligament in its group. The PTFL however is the strongest in the group and runs from the posterior medial margin of the lateral malleolus to the posterior talus. The CFL is 2.5 times stronger than the ATFL and originates off the lateral wall of the calcaneous then following along it anteriorly and proximally it inserts on the lateral malleolus just anterior to its most distal tip\textsuperscript{21}.

Though the subtalar ligamentous complex is not often studied, it still plays a crucial role in lateral stabilization of the ankle. This complex includes the CFL, the inferior extensor retinaculum, the lateral talocalcaneal ligament, the cervical ligament, and the interosseous ligament\textsuperscript{21}. This entire complex sits laterally to the subtalar joint’s axis of rotation and provides stability during inversion stress. These ligaments, therefore, are often injured along with the lateral ligament complex and can further complicate an instability issue.

The deltoid ligament is a fan-shaped ligament that sits on the medial side of the ankle and it’s primary function is to limit abduction of the ankle. The deltoid has three insertion points at the navicular, the calcaneous, and the talus. Due to it’s large amount of strength it is the least frequently injured ligament in the ankle\textsuperscript{21}.

Muscles: The dynamic stabilizers of the medial ankle include the tibialis posterior tendon, flexor digitorum longus, and flexor hallucis longus tendons. Each of the these tendons pass behind the medial malleolus and provide a small but important stabilizing function for the ankle and hindfoot\textsuperscript{21}.

On the lateral side the peroneus brevis and longus muscles are the dynamic stabilizers. The peroneus brevis runs behind the fibula in a groove and attaches to the base of the fifth metatarsal. The peroneus longus also runs behind the fibula in the same groove but attaches on the plantar aspect of
the base of the first metatarsal and the medial cuneiform of the foot. These two muscles together provide eversion and pronation for the ankle and are frequently injured during a lateral ankle sprain. Other muscles that actively move the ankle are the gastrocnemius, the soleus, plantaris, and the tibialis anterior. The gastrocnemius originates on the posterior medial and lateral femoral condyles and inserts on the calcaneus and assists in ankle plantar flexion. The soleus muscle also plantar flexes the ankle and originates on the posterior fibular head and then joins the gastrocnemius to insert on the calcaneus. The plantaris plantar flexes the ankle as well and originates on the lateral supracondylar ridge of the femur and inserts on the calcaneus. The tibialis anterior which dorsiflexes and inverts the ankle originates on the lateral epicondyle and shaft of the tibia and inserts on the first cuneiform and metatarsal.

**Mechanisms of ankle sprains**

Ankle sprains are the most common injury in sports and therefore are the cause of a significant amount of time loss in competition for athletes, about 25%. The ankle is unique in that 85% of all sprains at the ankle joint involve damage to the lateral ligaments. The cause of this is due to two anatomical considerations: 1) the medial malleolus is shorter than the lateral malleolus, which allows the talus to further invert than it can evert; and 2) the lateral ligaments form as discrete fascicular bundles, making them weaker than the broad, deltoid ligament of the medial side.

The most common mechanism for ankle sprain can be caused after landing, or any movement associated with unanticipated foot placement on a sloped surface (e.g. landing in a hole) or inappropriate positioning of the foot in space before making contact with the ground that forces the ankle to invert and plantarflex. This puts a great amount of strain on the lateral ligamentous complex and the ligaments fail in order of their strength, weakest to strongest. Most commonly, the
ATF will fail first followed by the CF and then the PTF ligament. After this the muscle tendons will experience damage which would be the peroneous brevis and longus that suffer.\textsuperscript{23}

**Muscle receptor physiology**

Joint stability is a physiologically complex process that arises from components synonymous with the entire motor control system. In order for the joint to maintain stability there must be a flawless relationship between its static and dynamic components. The static components are made up of the ligaments, joint capsule, cartilage and bony articulations. The dynamic component is enabled by the muscles that cross over that joint and their neuromotor control. This control has two parts: the feedback controls, which is the stimulation of a corrective response within the corresponding system when the sensory receptors detect change; and the feedforward controls which are the anticipatory actions occurring before the sensory detection of a homeostatic disruption.\textsuperscript{25}

There are four types of mechanoreceptors which are located in muscles, tendons, ligaments, and capsules. The mechanoreceptors found in musculotendinous tissue are the Golgi tendon organs (GTOs) and are found throughout the junction and in the muscle spindles. GTOs have a very low threshold and high dynamic sensitivity in the sensory endings which enable the GTO’s to provide the CNS with feedback and signaling active muscle tension rather than passive tension. Ruffini receptors are found in the ligaments and capsular tissue and act as static and dynamic receptors. Pacinian corpuscles have such a low threshold they are exclusively classified as dynamic receptors. Muscle spindles are the
last of the four receptors and they are responsible for conveying information regarding muscle length and rate of changes in length\textsuperscript{25}.

**Motor Control Terms**

Kinesthesia is the sense of position and movement of the body\textsuperscript{26}. When described by McCloskey\textsuperscript{27} it is the 'perceived sensations about the static position or velocity of movement (whether imposed or voluntarily generated) of those parts of the body moved by skeletal muscles and perceived sensations about the forces generated during muscular contractions even when those contractions are isometric'. Muscle, skin, and joint receptors are the three different kinds of sensory receptors that aid in kinesthesia. The amount that each receptor is utilized depends on the joint, but research indicates that distal joints, such as the ankle, use skin and joint receptor input more than muscle receptor input, the opposite being true for proximal joints\textsuperscript{28}.

The plantar tactile receptor responsible for precise kinaesthetic sense is probably the slowly adapting mechanoreceptor with myelinated afferent fibers (SAIL mechanoreceptor), since it alone is capable of transducing plantar shear and stimulus direction, information essential to relating tactile information to position sense\textsuperscript{29}. Information provided by muscle receptors will not as precisely reflect actual foot position since discharge from muscle receptors is influenced by previous muscle contractions\textsuperscript{30, 31}. Following an intense muscle contraction or vibration of a muscle tendon there is what is called a postcontraction sensory discharge which is a persistent afferent discharge that can explain the increased error in foot position when tactile information is unavailable\textsuperscript{31, 32}.

Proprioception can be defined as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position (joint position sense)\textsuperscript{12}. Proprioception has been incorrectly used synonymously and interchangeably with kinesthesia, joint position sense, somatosensation, balance, and reflexive joint stability but proprioception describes
afferent information coming from internal peripheral areas of the body that contribute to postural control and joint stability\(^{25}\) where kinesthesia deals with the body’s position sense\(^{26}\).

Balance can be defined as the ability of one to maintain the vertical projection of the center of mass on the support surface, thus achieving a stable state\(^{33}\). Balance is actively controlled by the CNS which enables the necessary postural muscles to maintain balance. Balance and postural control can be synonymous, though postural control is complex and involves several parts\(^{34}\).

Postural control contains two divisions, static (attempting to maintain a base of support with little or no movement) and dynamic (attempting to maintain a base of support while performing a movement or task)\(^{35}\). A combination of physical and psychological functions including vestibular, visual and proprioceptive feedback as well as motivation and concentration are all used to create static or dynamic postural stability\(^{36}\). In order to maintain one’s center of gravity there is continuous muscle corrections including anticipatory control that must work properly. While standing, the center of gravity falls anterior to the axis of the talocrural joint, causing the calf muscles to play a central role as prime postural control muscles, making the ankle vital in regards to making postural corrections\(^{34}\).

During static standing, there is little postural muscle activity required because of the CNS ability to anticipate minimal body movements. Of course when movement does occur then the CNS must rely on the visual and vestibular input in order to maintain balance\(^{37}\). Increased postural sway during the static stance may imply damage to postural control in patients with conditions related to the effects of muscular inactivity due to ankle injuries and instability\(^{34}\).

**Repeated ankle injuries**

Lateral ankle sprains are one of the most common injuries in athletics and despite extensive clinical and basic science research, the reoccurrence rate remains high. The reoccurrence of ankle
Sprains can take its toll on the joint itself and cause altered joint mechanics. These altered joint mechanics are believed to occur during the tissue-repair phase of the healing process and may force tissues to heal in elongated positions (producing laxity), expose tissues to excessive forces, create altered afferent feedback to the neuromuscular control system, or result in chronic loss of motion⁴. Hertel et al³⁸ addresses some of the evidence or signs that a person has chronic ankle instability. The first sign being a balance deficit, numerous balance parameters have been found to be altered, most importantly one’s postural sway while balancing on the injured limb³⁸. Joint position sense has also been found to be affected following LAS. Glencross and Thornton³⁹ were the first to demonstrate that following a history of lateral ankle sprains subjects showed an impaired ability to actively replicate joint positions. Delayed muscle reaction times in the peroneus longus and brevis have also been reported. The peroneus muscles are the first muscles to contract in response to a sudden ankle inversion movement and are vital in controlling dynamic stability of the ankle complex³⁸. Injury to the peroneal nerve has been reported due to the traction placed on it during a LAS which is suspected to be the cause of the nerve injury and may play a role in CAI⁴⁰,⁴¹. Some authors have reported that a weakness in the muscles that evert and pronate the ankle may also be a factor contributing to CAI⁴²-⁴⁶ but the methods used did not replicate a functional movement and was at a much slower pace.

Diminished dorsiflexion following a LAS is thought to contribute to CAI because when the talocrural joint is not in closed packed position (like it would be in full dorsiflexion) this allows for more inversion and internal rotation at heel strike. The inflexibility of the triceps surae prevents the ankle from reaching full dorsiflexion leaving it in a more plantarflexed position throughout the gait cycle³⁸. Sinus tarsi syndrome and anterolateral impingement syndrome have also been reported and one cause is LAS.

**Jump landing task**
Athletes with CAI have been found to alter their joint mechanics and increase their postural sway during a dynamic task. A task most commonly used to test these deficits is the jump-landing task. Researchers have speculated that individuals with CAI may land from a jump differently than individuals with stable ankles\textsuperscript{15}. The jump landing task is a movement performed by a variety of athletes in competition and is replicated with ease when performing it in the lab because it allows the control of the jump height and distance for each subject\textsuperscript{19}. When landing from a jump the individual must successfully decelerate the body and absorb the GRF with the lower extremity by contracting muscles at each joint in the kinetic chain. It has been suggested that differences in landing-pattern strategies might cause an insufficiency in controlling the joint stability of individuals with CAI\textsuperscript{47, 48}.

Ross et al\textsuperscript{15} used the single leg jump landing procedure to compare ten subjects with CAI and ten subjects with stable ankles and the amount of time it took for them to stabilize on one ankle after jumping at 50\% of their maximum vertical jump height. They found that the amount of time it took for the ankle to stabilize was in fact longer in the CAI group than in the stable group.

**Ankle braces**

Ankle ligament injuries are the single most common injury and account for 19-23\% of all sports injuries, with 90\% of those being inversion sprains affecting the lateral ligament complex\textsuperscript{49}. Several different management strategies are used after the injury occurs including an elastic bandage, tape, and also some form of a brace. Elastic bandages are often applied to help control the swelling, tape is often used by athletic trainers as a form of stabilization and restriction of further inversion, and the brace is often used due to its convenience and ease of use but it's effectiveness still remains unclear. Several theories have been proposed to explain how an ankle brace works as a stabilizing support system for the ankle after it has experienced trauma. Robbins and Waken\textsuperscript{50} found that restricting the range of motion is not related to preventing injury because the amount of force caused by sprains is said to exceed that
of taping or bracing, but the taping and bracing provide adequate amounts of support to return the ankle to neutral position and avoid improper landing due to foot position. Some researchers think that applying a brace or tape may improve one's orientation and judgment of position of the plantar aspect of the foot with respect to the leg\textsuperscript{30, 51, 52}. Because shoes decrease plantar skin tactile receptor activity the use of ankle taping and bracing restores tactile sensory cues, thus re-establishing position and orientation of the foot\textsuperscript{50, 53}.

Ankle braces are becoming more popular in use due to the rise in cost of athletic tape and the need for personnel to apply it. Ankle braces come in various options from non-rigid-semi-rigid, lace-up, cloth material, plastic polymer material or thermoplastic material\textsuperscript{16, 54} and readjustable, and washable. Ankle braces are created with one ultimate goal in mind: to restrict the amount of inversion and eversion at the ankle joint in order to prevent ankle sprains. Still some controversy exists over whether braces actually reduce the incidence of ligamentous injury since the protection from the brace is needed only at the limits of the range of motion\textsuperscript{55}.

Ashton-Miller et al\textsuperscript{24} conducted a study to compare isometric eversion moments in low and three-quarter top shoes with and without three different ankle braces and athletic tape. The results showed that at 15 degrees of inversion at the ankle the evertor muscles provide roughly three times greater protection against inversion than any tape or ankle braces tested worn inside a three-quarter top shoe. The calculations also showed that there was virtually no difference with or without ankle brace or tape at increasing ankle resistance to inversion when the evertor muscles were inactive.

The use of ankle braces is reported to advance various measures of neuromotor function such as increased proprioception of the ankle joint, though the extent to which neutral receptors add to observed brace-related changes in neuromotor function of the ankle, and the conditions under which they contribute are not fully known. We do know that muscle mechanoreceptors play an important role,
but cutaneous receptors have been overlooked. It has been shown that cutaneous mechanoreceptors can contribute to proprioception, especially when the skin experiences a displacement. The peroneal muscle may also be affected by the application of tape and/or braces by increasing proprioception that causes the peroneal muscles to react more quickly to inhibit extreme inversion. Brace-related skin displacement and stimulation of cutaneous mechanoreceptors have been shown to increase motorneuron excitability, and it is thought that in addition to exciting articular and muscular mechanoreceptors by increasing local pressure after brace application, these conditions would be associated with increased peroneus longus motorneuron excitability.

In a more recent study done by Gribble et al., they tested the effects of lace-up braces on the activation of the peroneal muscles during lateral shuffle movement. This study tested the use of the brace at four different times 1) immediately prior to bracing 2) immediately after brace application 3) following two weeks of continued brace use 4) two weeks after discontinued use of the brace. There was a total of 4 testing sessions and 1,3,4 were performed with no brace in order to test the short-term effects of ankle bracing application. Session two had the subject wearing a brace on only their right ankle in order to determine if there was an immediate change in muscle activation related to the application of a brace. They found no significant differences between the braced conditions for both muscle groups, which means that the use of ankle braces did not produce immediate changes in muscle activation or changes in activation following short-term brace use.

In another study done by Nishikawa & Grabiner, they found conflicting results when compared to the Gribble study. When they test peroneal motorneuron excitability after the use of a semi-rigid brace they found that peroneal muscle reflex was significantly larger for the braced condition as compared to the non-braced condition. This result meant that the application of a semi rigid brace did increase peroneal muscle excitability. By using electrodes placed over the peroneus longus, lateral
gastrocnemius, and tibialis anterior muscles they were able to record the maximum voluntary isometric eversion force during the braced and non-braced conditions. The theory is that the brace stimulated mechanoreceptors in the skin, muscle, and possibly the ankle joint capsule, increasing peroneal motorneuron excitability.

The semi-rigid brace, along with the lace up brace and tape were compared in a meta-analysis among 17 different randomized controlled trials that used predominantly crossover designs. Differences between mean changes in treatment and control groups were computed as standardized effect sizes for sprint, agility, and vertical jump performance with their 90% confidence interval. The greatest effect that was found was a negative effect of the lace-up brace on sprint speed; all other effects of external ankle support were insubstantial. More research needs to be carried out to further reduce the uncertainty of the effects of external ankle support on lower-extremity functional performance measures. Ankle stabilization devices continue to be a viable option for injury prevention.

According to Cordova et al, although some question remains as to whether ankle stabilizers inhibit performance abilities there is still research that proves ankle stabilizers are a good support mechanism for people with CAI.

In a study by Eils et al, 10 different ankle braces were tested during passive and rapidly-induced inversion on 24 subjects with CAI. They tested five semi-rigid braces, four soft braces and one rigid that was intended to serve as a reference model along with the condition without brace. All the braces tested restricted range of motion during the passive and rapidly-induced conditions better than the no brace condition. Differences between semi-rigid and soft braces were significant in nearly all cases, so clear distinction between soft and semi-rigid braces was able to be made. The rigid brace showed a significantly higher stability compared to all other braces and the semi-rigid model showed a reduced stability compared to soft braces. Basing the tests on passive and rapidly-induced motion is
important in providing objective information about the ankle braces and making the decision of which brace is better to use in athletes with CAI.

Over the years numerous braces have been studied to measure stabilization ability as well has performance hindering. One brace in particular, the Swede-O Universal has gone through several research studies\(^{41, 64-68}\) including functional performance such as speed, agility, and vertical jump and more recent studies involving stability during functional tasks.

When testing the Swede-O Universal and its effects on one’s functional performance studies have showed varying results\(^{41, 66-68}\). Four different studies looked at the performance effect the Swede-O Universal has on vertical jump, speed, and agility. Three out of the four studies showed that the Swede-O Universal had no effect on a person’s vertical jump, speed, or agility\(^{41, 67, 68}\). Burks et al found a negative effect however, with the use of the Swede-O Universal on speed and vertical jump, but not agility. Another two studies only looked at the effects the brace had on agility with neither finding an effect\(^{64, 65}\).

In another functional assessment study, the Swede-O Universal was used on female basketball athletes during vertical jumps, jump shots, and a sprint drill\(^{67}\). Compared to the other braces used in the study, the Swede-O Universal demonstrated the greatest performance impairment. They found the Swede-O Universal to have the most significant impact on jump shots, all the ankle braces significantly affected the vertical jump and sprint time was not affected by any of the braces tested.

In a study performed by Shaw et al\(^{36}\), they tested two braces the Swede-O Universal and the Active Ankle on collegiate volleyball players during a jump-landing task. They used ten healthy female collegiate volleyball athletes and had them perform a fatigue protocol and then vertical jumps at 50% of their maximum vertical jump height. They then were asked to complete the task by landing on the designated limb and try to gain stabilization as quickly as possible. The forceplate beneath recorded
each jump and how long it took to stabilize. The results showed that the Swede-O Universal brace stabilized the ankle more quickly than the Active Ankle in the anterior-posterior direction.

**Time to Stabilization**

Time to stabilization (TTS) can be defined as the time needed to reduce the variation of a given ground reaction force component to the range of variation of the corresponding ground reaction force component in a stabilized position\(^6\). The TTS measurement has been used to compare subjects with stable ankles and those with unstable ankles. The benefit of a jump-landing maneuver is because it is most often used in sports and can be controlled with height and distance which reduces the variance of the TTS measurements\(^1\)

A technique reported by Ross, Guskiewicz, et al\(^1\) is used to calculate TTS when comparing subjects with CAI and those with stable ankles. The first step is to define the range of variation of a given ground reaction force component. The range of variation is defined as the smallest absolute range value of a ground reaction force component during the last 10 seconds of the single-leg stance portion of a jump landing task\(^1\). A horizontal range-of-variation line that represents the smallest absolute range value of a component of the ground reaction force is superimposed over the data. An unbounded third-order polynomial is fit to the data, and TTS is the point at which this polynomial transects the range-of variation line. Basically, TTS signifies when the ground reaction force range of variation at the beginning of a single-leg jump landing resembles the ground reaction force range of variation of a stabilized single-leg stance\(^1\)

Several studies have been performed using this TTS calculation and some have found varying results. All the studies had the subjects jump from a distance of 70 cm using their 50% maximum jump height. Shills et al\(^7\) found no significant difference when using subjects with and without functional
ankle instability. The subjects were tested on their TTS before and after a functional fatigue protocol. They did find faster TTS times pre-fatigue when compared to post-fatigue.

In a study by Ross, Guskiewicz et al\textsuperscript{69}, they had ten subjects with reported functional ankle instability and 10 subjects with stable ankles. They performed the jump-landing task at 50-55\% of their maximum jump height. The results showed that it took longer for the functionally unstable group to stabilize (1.98 \pm 0.81s) than the stable ankle group (1.45 \pm 0.30s). A main effect for direction was found and indicated that M/L TTS of 1.90 \pm 0.77s was longer than the A/P TTS of 1.54 \pm 0.50s.

In a similar study, Brown et al\textsuperscript{18} used 20 recreational athletes, 10 with FAI and ten with stable ankles were tested on TTS as well as joint position sense and electromyography of ankle musculature. Focusing on the TTS measurement, they found a significant difference between groups in the A/P direction with the FAI group taking longer to stabilize. They found no difference between groups in the M/L direction.

Wikstrom et al\textsuperscript{71} used healthy subjects to test TTS before and after isokinetic and functional fatigue. Functional fatigue results for M/L TTS were 1.547 \pm 0.360s pre-fatigue and 1.443 \pm 0.375s post-fatigue. The A/P TTS results were 1.679 \pm 0.344s pre-fatigue and 1.443 \pm 0.301s post-fatigue. Isokinetic fatigue results for M/L TTS were 1.547 \pm 0.427s pre-fatigue, and 1.520 \pm 0.453s post fatigue, while A/P TTS results were 1.444 \pm 0.332s pre-fatigue, and 1.258 \pm 0.393 s post- fatigue. All of these measurements showed a decrease in TTS for all directions after fatigue with a significant main effect in the AP direction.

The study by Shaw et al\textsuperscript{36}, used TTS to show the effects of two different ankle braces, the Active Ankle and Swede-O Universal during a jump landing task and their ability to stabilize the ankle. The results showed a significant difference between the braces in the AP direction. The Swede-O Universal
(2.492 ± 0.271s) stabilized the ankle more quickly than the Active Ankle (3.817 ± 0.263s) and control condition (3.341 ± 0.339s).

In a more recent study by Wikstrom et al\textsuperscript{72}, they test 28 subjects who met the criteria for CAI during a jump-landing task. They tested two different prophylactic ankle stabilizers (PASs), the McDavid Ultra (a semirigid brace) and the Meuller lace-up (a soft brace) and their ability to stabilize the ankle during a jump-landing task. They used a relatively new measure of postural stability, called the Dynamic Postural Stability Index (DPSI), that determines how well balance is maintained as the subject transitions from a dynamic to a static state\textsuperscript{73}. The results found no significant difference for the DPSI in the M/L direction or the A/P direction or the vGRF. They did find, however, that the soft (.0278 ± .006) and semirigid (.0280 ± .006) PAS conditions significantly improved (produced smaller) vertical stability index (VSI) scores in comparison with the no brace condition (.0311 ± .008).

Summary

According to previous research we know that the Swede-O Universal brace is capable of protecting the ankle before and after a functional fatigue protocol on healthy individuals\textsuperscript{36}. There has also been several studies on the effects of the Swede-O Universal on functional performance which have gained varying results. But to this authors knowledge no research has been done utilizing the Swede-O Universal ankle brace on subjects with CAI during a jump-landing task in order to measure the TTS as compared to the healthy ankle. Several studies have also been done on those with CAI and the amount of time it takes to stabilize after completing a task, such as the jump-landing task, where results have showed that CAI patients have longer TTS times than in patients with healthy ankles. The jump-landing task\textsuperscript{19} is proven to be a good task because it best replicates an athletic maneuver during competition and gives ability to measure TTS for the ankle.
Chapter 3
Experimental Design & Methods

Subjects

Ten physically active subjects between the ages of 18 and 22 years of age were recruited from the university community and volunteered for this study. Based on previous data, 20 subjects will produce a power level of 0.85 (Appendix A). We tested 23 subjects in the lab but after the data processing and due to not calculating the FADI and FADI sport scores prior to testing, 13 subjects did not meet the criteria for chronic ankle instability. All ten subjects had chronic ankle instability defined by at least 1 acute ankle sprain that resulted in swelling, pain, and temporary loss of function (but none in the previous 3 months); and a history of multiple episodes of the ankle “giving way” in the past 6 months. Prior to participating, all subjects read and signed an informed consent form that was approved by the university’s institutional review board.

Instrumentation

A Bertec 4060NC forceplate (Bertec, Inc., Columbus, OH) integrated with MotionMonitor software (Innovative Sports Technologies Inc., Chicago, IL) was used to collect ground reaction forces during the jump-landing task, sampled at 200Hz. A Vertec vertical jump tester (Sports Imports, Columbus, OH) was used to measure the subjects standing, maximum and 50% maximum jump height.
**Independent Variables**

1. Condition
   a. Control
   b. Swede-O Universal ankle brace

2. Side
   a. Injured
   b. Uninjured

**Dependant Variables**

1. TTS in the A/P direction (APTTS)
2. TTS in the M/L direction (MLTTS)

**Procedures**

Each subject was asked to report to the research laboratory for one session. Prior to being selected for the study, subjects were asked to fill out a questionnaire regarding the history of their ankle injuries. Once subjects were selected that fit the qualifications for chronic ankle instability they were then asked to meet in the laboratory to perform their testing.

The session started with recording the subjects age, height, weight and sex. In the next step we assessed their maximum vertical jump height. They were asked to stand next to the Vertec vertical jump tester (Sports Imports, Columbus, OH), reach up and touch the highest point possible while maintaining both feet flat on the ground. This measurement was recorded as their standing reach height. Next the subject was asked to perform a maximum jump off both feet and touch the highest point possible on the Vertec. There was three trials and the maximum height of those three was
recorded as the maximum jump height (Vert\textsubscript{max}). The 50% of their Vert\textsubscript{max} was determined as the difference between the maximum height reached during the jump and the standing-reach height.

During the testing session, both legs were assessed during a single-limb landing task to assess dynamic stability. The order of testing limb was randomized. When performing the jump-landing task, there were two different jumping conditions, one with the Swede-O Universal brace applied and one with no brace. The order of bracing condition was randomized. The jump-landing task began 70 cm away from the forceplate, they were instructed to perform the jump-landing task by landing on their injured limb from 50% of Vert\textsubscript{max}. They began the jump landing task with both feet on the ground, jumped towards the forceplate, reached up and touched the indicated marker (50% of each subject's Vertmax) on the Vertec and landed on the test leg on the forceplate. The subjects were instructed to stabilize as quickly as possible on the single testing leg and put both hands on their hips while facing forward.

The subjects were allowed practice trials to practice the jump-landing task and familiarize themselves with the procedures on the first designated testing leg. The first bracing condition was revealed for this leg and the practice trials took place. Subjects were allowed as many practices as needed to feel comfortable with the task. After the practice trials and a five minute rest period, subjects performed five test trials with one minute rest between trials. After the test trials, a 10 minute rest period was provided and the procedures were repeated on the same leg with the second bracing condition. After both bracing conditions are completed for the first testing limb, a 10 minute rest period was provided and then the procedures were repeated for the second testing limb. If the subject had to hop or touch down the non-testing limb during a trial, then the trial was thrown out and repeated.
Data Processing

We calculated TTS using the method originally reported by Ross, Guskiewicz, et al\textsuperscript{17-19}. The first step when performing the calculation is to define the range of variation of a given ground reaction force component. The range of variation values that come from a ground reaction force component are defined as the smallest absolute range value of a ground reaction force component during the 5 seconds of the single-leg stance portion of a jump landing task\textsuperscript{19}. In this particular study we used normalized range-of-variation reference variables that are not influenced by ankle instability in order to calculate TTS\textsuperscript{15}. Then a horizontal line that represents that smallest absolute range value was superimposed over the data. An unbounded third-order polynomial is fit to the data, and the TTS is the point at which this polynomial transects the range of variation line.

Statistical Analysis

For the 5 trials of each brace condition and limb, the means and standard errors were used for statistical comparison. Two separate Limb by Condition repeated measures ANOVA’s were performed for the dependent variables of APTTS and MLTTS. Significance was set at $p<.05$. All statistical analysis was performed using SPSS 14.0 (SPSS, Inc. Chicago, IL.).

Potential Health Risks

There is a risk of injury during the jump-landing task but subjects were given proper verbal and visual instructions. Subjects were also allowed to practice the jump-landing technique until they felt
comfortable. Subjects were continuously monitored throughout the testing for fatigue and were allowed adequate amount of rest time between conditions.

**Anticipated Outcomes**

We had hypothesized that the Swede-O Universal ankle brace would decrease the TTS for each subject when compared to the no-brace condition. We also hypothesized that the brace would reduce TTS in the uninjured limb when compared to the injured limb. This will help to address the question if the application of a brace to an athlete with CAI will help to improve stabilization and support when performing a jump-landing task. This will also help to determine if a brace is more effective than no brace at all when measuring TTS during a jump-landing task. The results of this study may influence clinician’s decision of whether or not the Swede-O universal would be an effective tool in helping to control postural stability during physical activity.

Several studies have tested the use of an external ankle support during functional activities and in a static position. In order to truly test the effectiveness of an ankle brace and its ability to prevent ankle injuries it is necessary to test using subjects with chronic ankle instability. This study looked to discover if an ankle brace would be an effective addition to the options clinician’s have in treating people with CAI.

**Anticipated Timetable**

- June 1, 2007: Project approval by Institutional Review Board
- June-July, 2007: Pilot testing
Chapter Four

Results

Anterior/Posterior Time to Stabilization

The means ± S.D. values may be found in Table 2. For APTTS, the Side by Condition interaction was not statistically significant (F₁,₉ = .004; p=.952) (Figure 1). While not significantly different, the
injured side took longer to stabilize when compared with the non-injured side in both the no braced (Inj: 1.195± .067s; Non: 1.185± .068s) and braced (Inj: 1.229± .101s; Non: 1.220± .092s) conditions.

The main effect for Side was not statistically significant (F_{1,9} = 2.390; p=.156) (Figure 2). While not significantly different, the injured side took longer to stabilize (1.212± .096 sec) compared to the non-injured side (1.203± .067 sec).

The main effect for Condition was not statistically significant (F_{1,9} = 1.952; p=.196) (Figure 3). While not significantly different, the braced condition was associated with a longer stabilization time (1.224± .084 sec) compared to the non-braced condition (1.190± .080).

**Medial /Lateral Time to Stabilization**

The means ± S.D. can be found in Table 3. For MLTTS, the Side by Condition interaction was not statistically significant (F_{1,9} = .023; p=.884) Figure 4. While not significantly different, the injured side took longer to stabilize compared to the non-injured side during both the no-braced (Inj: 1.198± .042s; Non: 1.176± .044s) and braced (Inj: 1.222± .077s; Non: 1.197± .815s) conditions.

The main effect for Side was not statistically significant (F_{1,9} = 1.233; p=.296) (Figure 5). While not significantly different, the injured side took longer to stabilize (1.210± .079 sec) compared to the non-injured side (1.187± .043 sec).

The main effect for Condition was not statistically significant (F_{1,9} = 1.394; p=.268) (Figure 6). While not significantly different, the braced condition was associated with a longer stabilization time (1.210± .060 sec) compared to the non-braced condition (1.187± .063 sec).
## Table 1. Subject Demographics

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Table 2. Anterior/Posterior Side by Condition Interaction

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Table 3. Medial/ Lateral Side by Condition Interaction

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<td>nonB vs nonNB: 0.31</td>
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$F_{1,9} = .004; p=.952$
Figure 2. APTTS Side Main Effect

$F_{1,9} = 2.390; p=.156$
Figure 3. APTTS Condition Main Effect
$F_{1,9} = 1.952; p=.196$
Figure 4. MLTTS Side by Condition Interaction

$F_{1,9} = .023; p = .884$
Figure 5. MLTTS Side Main Effect

$F_{1,9} = 1.233; p=.296$
Figure 6. MLTTS Condition Main Effect

$F_{1,9} = 1.394; p = .268$
Chapter 5
Discussion

The purpose of this study was to compare the Swede-O Universal brace with a no-brace condition on the ability to return an athlete with CAI to a stable state by measuring the TTS following a jump-landing task. It was hypothesized that the Swede-O Universal would allow the injured ankle to stabilize more quickly in both the A/P and M/L directions when compared to the no brace condition. Additionally, it was hypothesized that the ankle brace would cause the uninjured ankle to stabilize more quickly in both the A/P and M/L directions when compared to the injured ankle. Though these hypotheses proved to be incorrect, and no statistical significance was found for any relationship, there is still some clinical impact and need for further research from this study.
We feel that a possible contributing factor to our non-significant relationships is our low sample size. We initially tested twenty-three subjects. After reviewing the data, the faculty advisor determined that 13 of those subjects did not meet the intended inclusion criteria with scores on the FADI and FADI Sport Scale higher than the desired cut-off level (>90% and >80%, respectively). Therefore, the pool of subjects meeting all inclusion criteria was reduced to the ten subjects that are represented in the data in this current report. From the post-hoc observed power levels (range: 0.05-0.28), it is clear that we may be at risk for a Type II error. It is the intention of the faculty advisor to continue the testing procedures utilized in this thesis project to obtain a more complete data set so that conclusions may be made with more confidence.

As expected, none of the effect sizes are considered to be large, according to the classification of Cohen (large: >.80) and two of our reported effect sizes would not be considered even a small effect size (small: >.20). An encouraging observation is that several of our reported effect size values, in spite of the low sample size, are approaching the moderate level of effect size (moderate: >.50), ranging from .31-.41. We feel this lends additional support for the need to continue testing subjects that meet our intended inclusion criteria and achieve the a priori sample size of 20 subjects. In spite of the low power levels and effect sizes, we do feel there were some important observations that may be made from our data.

While not statistically significant in the AP and ML directions, the braced condition was associated with longer stabilization times compared to the no brace condition. This finding is similar to what Wikstrom et al. reported when testing a semi-rigid and soft brace using the same jump-landing protocol. They tested twenty-eight subjects that fit the criteria for Functional Ankle Instability (FAI), utilizing the same jump-landing task and procedures used in our current study. Two different ankle braces were used, the McDavid Ultra and the Mueller Lace up, and the authors used a variation on the
calculation of stabilization of ground reaction forces when landing from a jump called The Dynamic Postural Stability Index. They observed no significant difference between the braced and the no braced conditions for any of their measures of dynamic stabilization in subjects with functionally unstable ankles.

Surprisingly, it appears that bracing an unstable ankle during this jump landing task may not improve the dynamic stabilizing capabilities. While our current study and the results of Wikstrom et al did use different inclusion criteria (CAI vs FAI), the results in both studies seem to agree. Landing from a jump is an injurious mechanism implicated in ankle sprain pathology. Additionally, the application of an ankle brace has been shown to reduce initial ankle sprain injury rates in jumping sports. Perhaps the application of a brace does not have as great of an influence on ankles that have lingering instability. Another possibility is that the examination of the time to stabilize the ground reaction forces following a jump-landing may not be a sensitive enough measure to detect the influence of the application of a brace. Additional investigation will be needed to address these questions.

We do know that the measurement technique is sensitive at detecting deficits in dynamic stability of those with CAI when comparing to an uninjured side and to matched control subjects based on previously published work. We observed that the injured side took longer to stabilize compared to the uninjured side in the AP and ML directions; but without statistical significance and with a low level of observed power. However, our observed differences do coincide with a previous study conducted by Ross et al, reporting that it does take those subjects with CAI longer to stabilize when compared to the healthy group. In a similar study, Brown et al, comparing TTS measures between those with and without unilateral FAI, found a significant difference between groups in the A/P direction with the FAI group taking longer to stabilize. They found no difference between groups in the M/L direction. Finally, Gribble et al testing thirty two subjects, sixteen with and sixteen without CAI, reported significantly
increased TTS times in the injured sides of the CAI subjects. We feel that our results, with the addition of more subjects to the sample size, may produce relationships in agreement with these studies.

It is also possible that TTS may not be the best method to quantify the effects of the brace. By testing more subjects at a later time we will be able to better understand if TTS is an effective measurement. The fact that TTS detects ground reaction forces upon landing, its very possible that the brace is stabilizing the ankle but because the rest of the kinetic chain is not used to this type of fixation, the rest of the body maybe swaying while the ankle is staying fixed. The swaying and instability of the rest of the body could be what is detected on the force plate and then computed in the TTS calculation. This also leads to the discussion of whether TTS has practical significance. Since results show only millisecond differences and can be considered a significant difference, but an ankle injury can occur before that time lapse then is there any practical use for the results of TTS. It raises questions about how valuable the use of TTS is in determining if an ankle brace is an effective profilactic device in preventing injury to the ankle.

For both APTTS and MLTTS, within the injured and non-injured sides the brace condition was associated with longer stabilization times compare to the no brace condition, but without statistical significance. Our effect size of 0.41 was close to a moderate effect and may be an indication that there was a potential relationship of the brace actually increasing stabilization time. This proposed relationship would refute our associated hypothesis. One possible explanation is that during the testing, many subjects complained about the feeling of the brace and how they were not used to having a brace on their non-injured limb or that it has been a long time since they wore an ankle brace. This change in perception and peripheral sensation may have distracted them from the task. Others have suggested that a benefit of ankle bracing and taping is an increased activation of cutaneous receptors about the ankle and foot that may contribute to earlier activation of the gamma motor system to heighten the
muscle spindle activation in the stabilizers of the ankle, leading to an increase in dynamic stability and extrinsic stiffness of the ankle. Our results may not be supporting this theory. Additional testing will be necessary to address this relationship.

Building on this theory, there is some argument within the literature that prophylactic supports such as bracing may not be as vital for ankle stability as proper muscle activation. In a study conducted by Ashton-Miller et al they compared isometric eversion moments in low and three-quarter top shoes with and without three different ankle braces and athletic tape. The calculations also showed that there was virtually no difference with or without ankle brace or tape at increasing ankle resistance to inversion when the evertor muscles were inactive.

In a more recent study done by Gribble et al, they tested the effects of lace-up braces on the activation of the peroneal muscles during lateral shuffle movement. They found no significant differences between the braced conditions for both muscle groups, which mean that the use of ankle braces did not produce immediate changes in muscle activation or changes in activation following short-term brace use. This is related to the findings in our current study because each subject only wore the brace for a short amount of time and may have affected their comfort level with the brace potentially interrupting their dynamic stability.

In a study by Eils et al, they tested ten different ankle braces on twenty four subjects with CAI. Passive ankle range of motion measurements were performed in a custom-built fixture and simulated inversion sprains were elicited on a tilting platform. The study concluded that the main purpose of a brace is not to resist motion, but it is to position the ankle prior to landing and allow muscle activation to occur properly. In this current study we did not measure positioning of the ankle as the subjects were preparing to land. Future studies should examine this time period and the influence that brace may be having on ankle positioning to examine the theory that Eils et al proposes.
From a clinical aspect, this study raises several questions about the impact an ankle brace, specifically the Swede-O Universal, can have on a population with CAI. Further testing is needed on the CAI population with the Swede-O Universal brace as well as other types of braces from rigid to soft and with a larger sample size. The hope will be that these results will provide clinicians and researchers insight on the best prevention and treatment mechanism for those people that suffer from CAI.

Conclusion

This study was designed to show if the use of an ankle brace, like the Swede-O Universal would assist those subjects with CAI in reducing the amount of time it takes for them to stabilize after a jump landing task. Although the results of this study do not support these conclusions with statistical significance, it may provide an important direction in examining the connection between TTS, ankle bracing, and those with CAI. Because many of the subjects from this study had to be removed from the data due to an oversight in their FADI scoring, there was not enough statistical power in the results to make a strong argument one way or the other. There is a definite need for further testing on more subjects with CAI so we can make a better conclusion about the use of the Swede-O Universal and it’s ability to reduce time to stabilization after a jump-landing task.

References


36. Shaw M, Gribble P. Effects of ankle bracing and fatigue on time to stabilization among collegiate volleyball athletes. in review.


74. Gribble P, Robinson R. Chronic ankle instability creates deficits in time to stabilization and kinematic alterations at the knee. in review.

76. Gribble P RR. Chronic ankle instability creates deficits in time to stabilization and kinematic alterations at the knee. in review.

77. Shaw M GP. Effects of ankle bracing and fatigue on time to stabilization among collegiate volleyball athletes. in review.
Appendix A: Power Analysis Calculation

The sample size is based on recent data collected in the research laboratory of the faculty advisor and currently in review for consideration for publication\textsuperscript{76,77}. These studies report on dependent variables similar to what is presented in the current proposal (MLTTS, APTTS).

The means and standard deviations, F-values, and p-values for each relationship are provided in table format below. Using these data and the UCLA Department of Statistics online statistical calculator, sample size for with a desired level of statistical significance of $p<0.05$ and a Power level equal to or greater 0.85 was calculated.

MLTTS\textsuperscript{76}
Statistically Significant Group by Side Interaction ($F_{1,28}=7.80; p=0.009$)

Means ± Standard Deviation (seconds)

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<th>Group</th>
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<th>Non-injured side</th>
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<tr>
<td>CAI</td>
<td>1.56±0.31 s</td>
<td>1.43±0.27 s</td>
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<tr>
<td>Healthy</td>
<td>1.29±0.31 s</td>
<td>1.34±0.27 s</td>
</tr>
</tbody>
</table>

* Tukey's post-hoc testing revealed that the injured side of the CAI group took significantly longer to stabilize than the matched “injured” side of the Healthy group.

To achieve a Power level of 0.85 at a significance level of p<.05, 20 subjects would be needed.

**APTTS**

Statistically Significant Condition by Time Interaction ($F_{2,18}=5.55; p=0.013$)

Means ± Standard Deviation (seconds)

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<tr>
<th>Condition</th>
<th>Pre-fatigue</th>
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<tr>
<td>No brace</td>
<td>3.07±0.88 s</td>
<td>3.34±1.08 s</td>
</tr>
<tr>
<td>Ankle Brace</td>
<td>2.89±1.11 s</td>
<td># 2.49±0.85 s</td>
</tr>
<tr>
<td>Active Ankle</td>
<td>2.73±1.04 s</td>
<td>* 3.82±0.82 s</td>
</tr>
</tbody>
</table>

* Tukey’s post-hoc testing revealed that APTTS significantly increased after fatigue in the AA condition.  
  # Tukey’s post-hoc revealed that the APTTS during the post-fatigue testing was significantly less in the AB condition compared to the other two conditions.

Based on the observed post-fatigue Condition difference, to achieve a Power level of 0.85 at a significance level of p<.05, 11 subjects would be needed.
Appendix B: Informed Consent Form
ADULT RESEARCH SUBJECT INFORMATION AND CONSENT/AUTORIZATION FOR USE AND DISCLOSURE OF PROTECTED HEALTH INFORMATION FORM

THE EFFECTS OF ANKLE BRACING ON DYNAMIC POSTURAL CONTROL AMONG SUBJECTS WITH CHRONIC ANKLE INSTABILITY

Principal Investigator: Phillip Gribble, Ph.D., ATC

Sub-Investigator: Brittany Taylor, BS, ATC

Corey Monarch

Phone numbers: (419)530-2744, 530-2691

What you should know about this research study:

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

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

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

• You have the right to refuse to take part in this research, or agree to take part now and change your mind later.
• If you decide to take part in this research or not, or if you decide to take part now but change your mind later, your decision will not affect your routine care.

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

• Your participation in this research is voluntary.
PURPOSE (WHY THIS RESEARCH IS BEING DONE)

You are being asked to take part in a research study that will examine the relationship of ankle braces in the ability to land from a jump among people with chronic ankle instability (CAI). The angles of your joints and the ability to obtain a position of balance on one leg will be assessed as you land from a jump. The purpose of the study is to determine what movement patterns occur when one lands on an ankle with CAI and if it is different when an ankle brace is applied. If we are able to identify these patterns, researchers and clinicians may be able to determine if ankle braces are an effective way of managing CAI during dynamic tasks such as jumping and landing.

You were selected as someone who may want to take part in this study because you have suffered one or more previous ankle sprains and continue to experience feelings of instability or giving way in your affected ankle. We will be enrolling 20 participants ages 18 to 30 years old at the University of Toledo.

This research study will be conducted in the Biomechanics Research Laboratory in the Health Science and Human Services Building at The University of Toledo.

DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT

After consenting to participate in this study, you will be asked to fill out a questionnaire to allow us to better understand your ankle injury history. Then, your height and weight will be measured.

Your maximum vertical jump height will be assessed on a Vertec vertical jump tester, which has plastic targets aligned on top of one another, half an inch apart. First, you will be asked to stand under to the Vertec, reach up and touch the highest target possible while maintaining both feet flat on the ground. This measurement will be recorded as your standing reach height. Next, you will be asked to perform a maximum jump off both feet and touch the highest point possible on the Vertec. You will jump three times with a rest in between attempts. The highest of those three attempts will be recorded as your maximum jump height. Later in the procedures, you will be performing test trials during which you will be asked to jump to a height that will be set at 50% of your maximum vertical jumping height (Vert_{max}). This will be determined as the difference between your maximum height reached during the jump and the standing-reach height. This 50% mark will be designated and set by the associated plastic target on the Vertec.

Next, the investigator will demonstrate the jump-landing task for you. The jump-landing task will begin from a line marked on the ground 70 cm away from a forceplate, which is a device imbedded in the floor and will record landing forces during the testing procedures. The Vertec will be positioned
beside the forceplate and your target of 50% $V_{\text{Vert}}$ max will be set up so that the plastic target is hanging directly above the forceplate. The jump landing task begins with both feet on the ground behind the line, and then you jump towards the forceplate, while reaching up and touching the indicated target on the Vertec. You will be asked to attempt to land as close to the middle of the forceplate as you can using only one leg. You will be told prior to beginning the trials if you will be using the left or right leg first. You will be instructed to stabilize as quickly as possible on the single testing leg and put both hands on their hips while facing forward. This position you are trying to achieve is the same position as if you were trying to balance on one foot and remain as still as you can. While you are landing and attempting to gain your balance, you are to try and not hop or touch down with the non-testing limb. Instead, you are being asked to “stick the landing”. However, if you feel unstable during the task, you may step down or hop. If this happens, the trial will be repeated and you will have the chance to try to land in a balanced position again. As mentioned, the investigator will demonstrate this task to you and then ask you if there are any questions on how to perform the task.

When you are satisfied that you understand the task, you will be allowed to practice the task on both legs individually as many times as you need to feel comfortable with the task. An investigator will be standing next the landing area to assist you in the unlikely event if you feel unstable during the practice trials and the actual test trials. During the testing session, you will perform the task using your left leg and right leg as the landing leg. However, the order of that you perform the jump-landing task will be randomized, meaning that you will be told if you will use your left leg or right leg first. After you complete the test trials on the first leg, you will then perform the same number of trials on your other leg.

This study is examining the techniques used to perform a jump-landing task with and without a commonly used ankle brace. You are being asked to come to the lab for two testing sessions. During one of the testing sessions, you will perform the jump-landing task with an ankle brace on and during the other testing session, you will perform the task without an ankle brace on. The brace is a “lace-up” style ankle brace and the size of the brace that is appropriate for the size of your foot will be used. After you have practiced the task as described above, the investigator will reveal to you the bracing condition (brace or no brace) for that session.

Additionally, sensors will be placed on the skin of the top of your foot, lower leg, outer thigh, and low back. These sensors will record the positions of your ankle, knee and hip as you jump and land. The sensors will pick up a signal from an electromagnetic field that will be created from a transmitter placed about 3 feet from the landing area. The sensors will be secured on your skin with adhesive tape and Velcro straps. You will not feel anything from these sensors during testing. Additionally, you will not see or feel the electromagnetic field and it does not cause any harm to you. The information from
the sensors will be transmitted to a computer which will then be able to draw a stick-figure of your movements.

Next, you will be asked to perform five test trials of the jump landing task on each leg, for a total of 10 trials. You will be given a one minute rest period between each trial. After the test trials on the first landing leg, a 10 minute rest period will be provided to you and then you the procedures will be repeated so that you will be performing 5 trials on the other leg. During the 10 minute rest period, the sensors and the ankle brace will be switched to the second landing leg.

After you complete all 10 test trials, the first testing session will be complete. You will be asked to return one week later to the laboratory and wear the same shoes that you wore during the first testing session. During the second testing session, the procedures will be the same as during the first session, but the only difference is you will use the second bracing condition. For example, if during the first testing session, the test trials were performed with the ankle brace on, then during the second testing session, the test trials will be performed without an ankle brace.

The researchers encourage you to ask any questions you have prior to or during the study. If at any time you feel unable to participate in the study, for whatever reasons, please tell the researcher and you will be kindly dismissed from the study.

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH

When participating in any research study, you may encounter some risks. Although the risk for taking part in this study is very low, you may experience one or more of the following:

1. Because you are participating in functional activities, there is a chance that you could fall during testing. However, you will be given instruction on how to perform the task and as much practice as you need to become comfortable with the task. Additionally, the height to which you will be jump is only 50% of the maximum vertical jump you could attain, so this risk is minimal. Finally, an investigator will be standing nearby in the unlikely event that you do lose your balance and need assistance.
2. You may experience minor muscle soreness for two or three days following the study as you would after exercising. Having the rest periods between jumps should help to minimize this risk.
3. Double sided tape will be used to secure the sensors to your skin. If you have had a skin reaction (mild redness or itchiness) to adhesives before, there is a chance your skin may be sensitive to the adhesives used here.
If you are pregnant, it is advised that you remove yourself from the study during your pregnancy. Due to balance changes during pregnancy you may have an increased risk of falling. There are no known additional risks for pregnant women taking part in this study.

POSSIBLE BENEFIT TO YOU IF YOU DECIDE TO TAKE PART IN THIS RESEARCH
We cannot and do not guarantee or promise that you will receive any benefits from this research. The benefit of participating in this study is to help further research regarding ankle instability.

COST TO YOU FOR TAKING PART IN THIS STUDY
You are not directly responsible for making any type of payment to take part in this study. However, you are responsible for providing your own means of transportation to and from the Health Science and Human Services Building at The University of Toledo. You will not be compensated for gas for travel or any other expenses to participate in this study.

PAYMENT OR OTHER COMPENSATION TO YOU FOR TAKING PART IN THIS RESEARCH
No compensation including money, free treatment, free medications, or free transportation will be provided for this study.

PAYMENT OR OTHER COMPENSATION TO THE RESEARCH SITE
The University of Toledo is not receiving money or other benefits from the sponsor of this research as reimbursement for conducting the research.

ALTERNATIVE(S) TO TAKING PART IN THIS RESEARCH
There is no alternative to taking part in this research. Exclusion from the study, however, will not affect the quality of care you may receive at the sports medicine/physical therapy facility, doctor’s office, or other medical facilities.

CONFIDENTIALITY - (USE(S) AND DISCLOSURE(S) OF YOUR PERSONAL INFORMATION)
By agreeing to take part in this research study, you give to The University of Toledo, the Principal Investigator and all personnel associated with this research study your permission to use or disclose health information that can be identified with you that we obtain in connection with this study. We will use this information solely for the purpose of conducting the research study as described in the research consent/authorization form.
The information that we will use or disclose includes movement and balance/ground reaction force data from the functional activities listed in the previous section which will be recorded at the Athletic Training Research Laboratory in the Health Science and Human Services building at The University of Toledo. Your data and other information will remain confidential and will be used for research purposes only. Under some circumstances, however, the Institutional Review Board, Research and Grants Administration of the University of Toledo may review your information for compliance audits.

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

Your permission for us to use or disclose your personal health information as described in this section is voluntary. However, you will not be allowed to participate in the research study unless you give us your permission to use or disclose your personal health information by signing this document.

You have the right to revoke (cancel) the permission you have given to us to use or disclose your personal health information at any time by giving written notice to Phillip Gribble, PhD, ATC, 2801 W. Bancroft, Mail Stop #119, Toledo, OH 43606. However, a cancellation will not apply if we have acted with your permission, for example, information that already has been used or disclosed prior to the cancellation. Also, a cancellation will not prevent us from continuing to use and disclose information that was obtained prior to the cancellation as necessary to maintain the integrity of the research study.

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

A more complete statement of University of Toledo’s Privacy Practices is set forth in its Joint Notice of Privacy Practice. If you have not already received this Notice, a member of the research team will provide this to you. If you have any further questions concerning privacy, you may contact the person identified in the Notice.
Note: For sponsored research, the UT IRB may request additional information or request modifications to the “In the Event of a Research-Related Injury” section of the Consent/Authorization Form following its review of indemnification language after it has been reviewed and approved by the sponsor and the University of Toledo Research and Grants Administration.

IN THE EVENT OF A RESEARCH-RELATED INJURY

In the event of injury resulting from your taking part in this study, treatment can be obtained at a health care facility of your choice. You should understand that the costs of such treatment will be your responsibility. Financial compensation is not available through the University of Toledo, or the University Medical Center. By signing this form you are not giving up any of your legal rights as a research subject.

In the event of an injury, contact Phillip Gribble, PhD, ATC (419) 530-2691.

VOLUNTARY PARTICIPATION

Taking part in this study is voluntary. If you decide not to take part in this study, your decision will not affect your future relations with the University of Toledo, their personnel, and The University of Toledo Medical Center. If you do decide to take part in this research, you are free to withdraw your consent and to discontinue your participation at any time without a penalty.

NEW FINDINGS

You will be notified of new information that might change your decision to be in this study if any becomes available.

OTHER IMPORTANT INFORMATION

There is no additional information.

ADDITIONAL ELEMENTS

There are no additional elements to the study.
Appendix C: Health History Questionnaire

Name__________________________  M   F

1. Have you ever had an ankle injury where you experienced great pain, limited and/or were immobilized for more than one day?  
   How many times?
   Y     N
   When was the 1st time?
   When was the most recent time?

2. Which is the involved ankle?
   L     R     Both

3. Is the involved ankle chronically weak or “looser” compared to the uninvolved ankle?  
   Y     N

4. Is the involved ankle more painful than the uninvolved ankle?  
   Y     N

5. Is the involved ankle less functional than the uninvolved ankle?  
   Y     N

6. Have you experienced your ankle “giving way” in the last 6 months?  
   Y     N
   If yes, how many times? _______
7. Do you attribute your current instability to previous injury?  Y  N

8. Have you ever broken/fractured your ankle?   Y  N

9. Have you ever had a significant injury to one of your legs besides your ankle?
   Y  N
   If yes, please describe.

10. Do you have any balance or vestibular disorders?  Y  N

11. Are you currently in supervised or unsupervised rehabilitation?  Y  N
   If yes, please describe.