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EFFECTS OF ANKLE SUPPORT ON TIME TO STABILIZATION OF SUBJECTS  
WITH STABLE ANKLES

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of  
Science at Virginia Commonwealth University.

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## Abstract

### EFFECTS OF ANKLE SUPPORT ON TIME TO STABILIZATION OF SUBJECTS WITH STABLE ANKLES

By Raquel Elise Martin

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science at Virginia Commonwealth University.

Virginia Commonwealth University, 2007

Major Director: Dr. Scott Ross  
Assistant Professor  
Department of Health & Human Performance

The purpose of this study was to determine if prophylactic ankle tape and/or ankle braces improve dynamic stability in TTS measure. All subjects were healthy and had no prior history of ankle injuries. Data collection consisted of each subject performing a single leg jump-landing with ankle tape, ankle brace, combination of the two, and control (no tape or brace) conditions. Dynamic stability was assessed with time to stabilization force plate measure. Significant plane by ankle tape interaction ( $p=0.045$ ) was found. No significant plane by ankle tape by ankle brace interaction ( $p=0.637$ ), no significant ankle tape by ankle brace interaction ( $p=0.483$ ), or plane by

ankle brace interaction ( $p=0.697$ ) were found. A notable finding was that subjects took longer to stabilize in the anterior/posterior direction than medial/lateral direction. In conclusion ankle tape, ankle brace, and the combination of ankle tape and ankle brace did not statistically improve dynamic stability in healthy ankles.

## CHAPTER I

### STATEMENT OF THE PROBLEM

The lateral area of the ankle has been called “the most frequently injured single structure in the body”.<sup>5</sup> Ankle sprains are thought to result in more time lost by athletes than any other single injury.<sup>20</sup> Ankle sprains frequently occur and the lateral ligaments are involved 85% of the time.<sup>5, 20, 25, 59</sup>

The effectiveness of prophylactic ankle tape and braces has been continually researched. Prophylactic ankle tape and braces are used to prevent initial ankle sprains and to prevent future ankle sprains in individuals with a history of ankle sprains.<sup>13, 51</sup> Both ankle tape and braces are designed to prevent excessive inversion of the foot and minimize ankle range of motion, especially plantar flexion and inversion. Many different test measures have been used to determine the effectiveness of ankle tape and brace on limiting motion and improving proprioception.

The incidence of ankle sprains is increased with a history of ankle problems. Ankle bracing has been shown to decrease the incidence of sprains among those with previous problems.<sup>48, 51</sup> The other method shown to significantly reduce the risk of reinjury is coordination training on a disk.<sup>51</sup> Ankle tape and the combination of tape and brace have not been as effective as bracing alone.<sup>48</sup>

Postural sway is a component of proprioception used to measure proprioception. Proprioception is thought to be disrupted after ankle trauma. Postural sway has been shown to increase with functional ankle instability and shown to be a predictor of future injuries.<sup>31, 51, 52, 53</sup> Researchers have speculated that postural sway improvements with the application of ankle supports might indicate that an individual's risk of injury is reduced.<sup>3, 28, 31, 39</sup> However, researchers have reported conflicting results on the effects of ankle support on postural sway, with the majority of researchers reporting no significant difference between bracing and non-bracing conditions.<sup>3, 28, 39</sup>

Time to stabilization (TTS) is a dynamic postural stability measure that quantifies how quickly an individual can stabilize a single leg after a jump landing.<sup>7, 46, 47, 56</sup> Time to stabilization is thought to be a more functional measure of muscular strength, neuromuscular coordination, and joint stability.<sup>7, 46, 56</sup> Improving dynamic postural stability with the application of ankle support might have implications for decreasing ankle sprain injuries. Currently, no studies have examined the effects of prophylactic ankle tape, ankle braces, or a combination of the two on dynamic postural stability. Therefore, the purpose of this study was to determine if prophylactic ankle tape and/or ankle braces improve dynamic stability in TTS measure.

## Research Questions

- R<sub>1</sub>: Does prophylactic ankle tape decrease TTS compared to a control condition:
- In the Anterior/Posterior direction?
  - In the Medial/Lateral direction?
- R<sub>2</sub>: Does a prophylactic braces decrease TTS compared to a control condition:
- In the Anterior/Posterior direction?
  - In the Medial/Lateral direction?
- R<sub>3</sub>: Does a combination of prophylactic tape and brace decrease TTS compared to a control condition:
- In the Anterior/Posterior direction?
  - In the Medial/Lateral direction?
- R<sub>4</sub>: Does TTS differ between prophylactic ankle tape and brace conditions:
- In the Anterior/Posterior direction?
  - In the Medial/Lateral direction?
- R<sub>5</sub>: Does a combination of prophylactic ankle tape and brace decrease TTS compared to tape and braces conditions:
- In the Anterior/Posterior direction?
  - In the Medial/Lateral direction?

### Research Hypotheses

- H<sub>1</sub>: Anterior/Posterior and Medial/Lateral TTS values will be lower with prophylactic ankle tape than control condition values.
- H<sub>2</sub>: Anterior/Posterior and Medial/Lateral TTS values will be lower with prophylactic ankle braces than control condition values.
- H<sub>3</sub>: Anterior/Posterior and Medial/Lateral TTS values will be lower with a combination of prophylactic ankle tape and brace compared to control condition values.
- H<sub>4</sub>: Anterior/Posterior and Medial/Lateral TTS values will be lower with prophylactic ankle tape compared to prophylactic ankle brace values.
- H<sub>5</sub>: Anterior/Posterior and Medial/Lateral TTS values will be lower with a combination of prophylactic ankle tape and brace condition compared to prophylactic ankle tape or ankle brace conditions.

### Operational Definitions

Time to Stabilization (TTS): point in time when the ground reaction forces of a single leg jump landing resemble the ground reaction forces of stabilized single leg stance.

Dynamic Stability: maintaining a moving center of gravity within a fixed base of support.

### Clinical Significance

Clinically, ankle tape and braces are effectively used to prevent sprains. However, no definite conclusion is reported demonstrating the effectiveness of a combination of ankle tape and brace support. We are unaware of any studies showing the effect of prophylactic ankle tape, ankle braces, or a combination of the two on TTS. Perhaps prophylactic ankle tape or braces could improve dynamic postural stability, which might have implications for decreasing ankle sprain incidence.

## CHAPTER II

### REVIEW OF LITERATURE

Ankle sprains are thought to result in more time lost by athletes than any other single injury.<sup>20</sup> The lateral area of the ankle has been called “the most frequently injured single structure in the body”.<sup>5</sup> Ankle sprains most commonly occur to the lateral ligaments because of excessive supination to the subtalar joint.<sup>5, 20, 25, 32, 59</sup> The two static protectors of the ankle most commonly associated with lateral ankle sprains are the anterior talofibular ligament (ATF) and the calcaneofibular ligament (CF), which are lateral ligaments of the ankle.<sup>25</sup> Dynamic protection of the lateral ankle is composed of peroneus longus and brevis muscles, anterior tibialis, extensor digitorum longus, extensor digitorum brevis, and the peroneus tertius.<sup>25, 29</sup> Both static and dynamic stabilizers work together to protect the ankle.

#### Static Stabilizers of the Ankle

Static protection of the lateral ankle is composed of the talocrural joint ligaments, the subtalar joint ligaments, and the joint capsule. The lateral ligaments of the talocrural joint include the ATF, the CF, and the posterior talofibular ligament (PTF). The subtalar joint ligaments are divided into three groups: deep ligaments, peripheral ligaments, and retinacula. These include the cervical and interosseous as

deep ligaments; and the lateral talocalcaneal, the CF, and the fibulotalocalcaneal as the peripheral ligaments.<sup>25</sup> The lateral ligaments are the most commonly injured.<sup>5, 25</sup> The two lateral ligaments most commonly associated with lateral ankle sprains are the ATF and the CF. The ATF limits talar tilt throughout the sagittal plane, especially in plantar flexion. The CF limits excessive supination of the talocrural and the subtalar joint.<sup>25, 36</sup> The PTF resists inversion and internal rotation, although this is the least commonly sprained ligament.<sup>25</sup>

### Dynamic Stabilizers of the Ankle

Dynamic stabilizers are the active muscular defense that protects against excessive motion.<sup>29</sup> When contractions of the muscles occur, the musculotendinous units produce stiffness.<sup>25</sup> Dynamic protection of the lateral ankle is composed of peroneus longus and brevis muscles, anterior tibialis, extensor digitorum longus, extensor digitorum brevis, and the peroneus tertius.<sup>25, 29</sup> The peroneus longus and brevis are believed to be an essential part preventing supination and protecting the lateral complex.<sup>25</sup> Overall, the muscles associated with dynamic stabilization at the ankle are thought to slow the plantar flexion component of supination to prevent ankle sprains.<sup>25</sup>

### Reduction of Incidence of Ankle Sprains

Tropp et al<sup>53</sup> investigated the effectiveness of semirigid ankle orthosis and ankle-disk training on reducing the incidence of ankle sprains. Subjects were placed in a coordination training program group, a control group, or a group with semirigid

orthosis. Subjects were followed for 6 months through preseason and spring season; attendance and ankle injuries were recorded by the coach. Within the control group, 19 of the 75 with a history of ankle problems sustained an ankle sprain and 11 of the 96 with no history sustained a sprain. The ankle orthosis group had 2 sprains. The training program groups had 7 ankle sprains. The authors concluded both ankle orthosis and the training program lowered the incidence of ankle sprains in players with previous history of ankle problems. There were no significant differences within the three groups in players with no history of ankle problems.<sup>53</sup>

Sharpe et al<sup>48</sup> examined ankle sprain recurrences in athletes with different ankle supports. All subjects had a previous ankle sprain in one or both ankles. The supports offered were taping, bracing, a combination of tape and brace, or no intervention. The tape method was a modified basketweave with two medial and lateral heel locks and two figure-8 strips. The brace offered was a Swede-O Universal Ankle Support. The results showed all interventions had similar exposure time with practice and game sessions. Ankle bracing was the most effective modality in reducing ankle sprain recurrence; ankle tape alone was less effective. The combination group and the tape group had equal risk of reinjury, which was not statistically significant from no treatment. The combination group, however, had a small sample size most with a history of multiple ankle sprains. Ankle tape was not thought to be as effective because of its loosening after activity.<sup>48</sup>

The incidences of ankle sprain injuries are increased with a history of ankle problems. Ankle bracing has been shown to decrease the incidence of sprains among

those with previous problems.<sup>48, 53</sup> The other method shown to significantly reduce the risk of reinjury is coordination training program on a disk.<sup>53</sup> Ankle tape and the combination of tape and brace have not been proven as effective as bracing alone.<sup>48</sup>

### Time to Stabilization

Time to stabilization is a dynamic measure, studying how quickly an individual can stabilize on a single leg after a jump landing.<sup>8, 45, 46, 47, 56</sup> This measure is thought to quantify postural control during a dynamic task.<sup>8, 45, 46, 47, 56</sup> Volleyball or basketball for example, both are highly demanding sports on the ankle because of jump landings from a rebound or a spike.<sup>46</sup> Quicker stabilization might be an important factor for prevention of injury. To stabilize the body while landing, the lower extremity is required to decelerate quickly.<sup>46</sup> Quick deceleration is done by contraction of the muscles at each joint starting at the ankle and working its way up the body.<sup>8</sup> Quick and efficient deceleration can provide greater ankle joint stability during a dynamic task.<sup>46</sup>

The point in time when the ground reaction forces from a single leg jump landing resemble ground reaction forces of stabilized single leg stance is defined as the TTS.<sup>8, 46, 47</sup> Time to stabilization can be measured following single-leg jump-landings at half the maximum jump height of the subject. This jump is performed with both legs producing enough force to reach the 50% mark. Subjects land on a single leg on a top of a force plate. The amount of time taken to stabilize the ankle is the TTS measure; calculated from anterior/posterior and medial/lateral ground reaction forces.

Brown et al<sup>8</sup> compared TTS and electromyography (EMG) in athletes with stable ankles to athletes with functional ankle instability. The EMG assessed the tibialis anterior, peroneals, lateral gastrocnemius, and the soleus muscles prior to and after landing on a single leg. Brown et al<sup>8</sup> revealed no difference between ankle groups in medial-lateral TTS and EMG pre-landing. They showed that functional ankle instability increased TTS in the anterior-posterior direction, as well as a significant decrease in EMG in unstable ankles with the soleus after landing.<sup>8</sup>

Wikstrom et al<sup>56</sup> used TTS to examine fatigue in the ankle. Fatigue was brought on after the pretest in two ways, isokinetic using the KinCom isokinetic dynamometer and continuous concentric contraction of the plantar flexors and the dorsiflexors. They found vertical TTS increased following exercise. No increase was observed in medial-lateral and anterior-posterior TTS. Anterior-posterior TTS was found to decrease after exercise.<sup>56</sup>

Wikstrom et al<sup>55</sup> continued to look at dynamic postural stability using the same single leg jump landing method, but they used a dynamic postural stability index to test if prophylactic ankle stabilizers improved dynamic stability in functional ankle instability (FAI). Twenty-eight subjects with FAI were tested with a semirigid and soft brace. Semirigid and soft braces improved the vertical stability index compared to the control condition. However, dynamic postural stability index showed no improvement on dynamic postural stability using prophylactic ankle stabilizers.<sup>55</sup>

Ross et al<sup>45</sup> studied static and dynamic postural stability in functionally stable and unstable ankles. Subjects were required to perform a single leg stance and a jump-

landing task. They found no statistical difference for anterior-posterior and medial-lateral mean sway between the stable and functionally unstable ankles. The anterior-posterior and medial-lateral TTS measure showed significant differences between groups. The functionally unstable group took significantly longer to stabilize after a landing compared to the stable group. The authors concluded jump-landings may be more challenging to an individual with functional ankle instability than single leg stance; this may in turn allow fewer differences between stable and unstable ankles to go overlooked.<sup>45</sup>

Continuing TTS research, Ross et al<sup>47</sup> compared single-leg jump landings in functionally stable ankles and functionally unstable ankles. Ten subjects with stable ankles were matched with ten subjects with unstable ankles; additionally, twelve subjects separate from the previously mentioned with stable ankles were used in the reliability study. Subjects performed a single-leg jump landing as mentioned earlier in this section. The researchers used a vibration magnitude curve-fit TTS calculation to analyze the data. They found that functionally unstable ankles took longer to stabilize than the stable ankle group in both medial-lateral TTS and anterior-posterior TTS, which agreed with previous findings from Ross et al<sup>45</sup>. They also showed medial-lateral TTS took longer than anterior-posterior TTS. They concluded that establishing stabilization time deficits could decrease the risk of reinjury following an ankle sprain.<sup>47</sup>

Time to stabilization has been studied with functional ankle instability and ankle fatigue. Fatigue showed to increase vertical TTS but have no effect on medial-lateral or anterior-posterior TTS.<sup>56</sup> Functional ankle instability showed no difference in the

medial-lateral, but increased anterior-posterior TTS.<sup>8</sup> However Ross et al<sup>45,47</sup> showed functionally unstable ankles took significantly longer to stabilize after a landing compared to the stable ankles. Improving dynamic postural stability with the application of ankle support might have implications for decreasing ankle sprain injuries. Currently, no studies have examined the effects of prophylactic ankle tape or ankle braces using TTS on dynamic postural stability. Wikstrom et al<sup>55</sup> used dynamic postural stability index and found ankle braces did not improve dynamic postural stability.<sup>55</sup> Perhaps the study conducted by Wikstrom et al<sup>55</sup> did not find results that TTS measure may find on ankle braces. Possibly prophylactic ankle tape or ankle braces could improve dynamic postural stability of the ankle joint.

### The Effect of Tape and Brace

Researchers have studied the effectiveness of prophylactic ankle tape and bracing. Previous studies have investigated range of motion, proprioception (postural sway, joint position sense), and neuromuscular response (including peroneal latency, H-reflex, and EMG activity).<sup>1, 2, 3, 6, 12, 19, 26, 40, 49</sup> Few similarities are found throughout the literature with regards to the effectiveness of prophylactic ankle tape and brace.

### Range of Motion

Ankle tape and brace significantly reduces range of motion of the joint.<sup>19, 22, 23, 30, 40, 41, 42, 43</sup> Ankle tape and braces are designed to prevent the ankle from moving into inversion and plantar flexion.<sup>19, 42</sup> Lohrer et al<sup>30</sup> used EMG and goniometry to test the neuromuscular adaptation with the ankle in two different tape techniques. One tape

technique solely used crossed dorsoventral and mediolateral straps; the other techniques added figure-8 over the straps. The trap door was used to simulate sudden inversion to measure the neuromuscular response with EMG; active range of motion was measured with the goniometer. Range of motion and five sprain simulations were recorded before application of tape, after application, and 10 and 20 minutes of exercising. Subjects returned after 24 hours to be retested and the final test was after removal of the ankle tape. The exercise consisted of ten minutes of treadmill running and 2 minutes of slope jumping. The researchers showed prophylactic ankle tape with mean maximum inversion using the inversion simulator to restrict from 32 degrees to 18 degrees. After 10 and 20 minutes of exercise, inversion was restricted about 21 degrees. Final removal increased degrees of inversion to between 29 and 31 degrees. With goniometry measures, inversion was significantly reduced in all situations. Plantar flexion was significantly reduced only immediately after application. Overall, prophylactic ankle tape was shown significantly reduce range of motion; and significantly reduce after 20 minutes of exercise.<sup>30</sup>

Fumich et al <sup>19</sup> compared tape versus untaped before and after exercise. The exercise was 2.5 to 3 hours of football practice; 16 subjects from a football team were used. The Inman ankle machine was used to measure active range of motion before, immediately after taping, and after football practice. They found initially prophylactic ankle tape restricted the greatest range of motion in three directions, plantar flexion, plantar flexion inversion, and inversion neutral. Eversion neutral, inversion neutral, and plantar flexion inversion decreased less than 50% after ankle tape and exercise. Plantar

flexion, dorsiflexion, and plantar flexion eversion loosened more than 50% after ankle tape and exercise. Loosening occurred most with these three directions during and after exercise, but provided residual restriction compared to absolute value after exercise.<sup>19</sup>

Paris et al<sup>40</sup> compared prophylactic ankle tape to prophylactic ankle brace in plantar flexion, dorsiflexion, inversion, and eversion. Thirty healthy males were tested on the Inman ankle machine to measure passive range of motion. The supports tested were Swede-O, SubTalar support, and ankle tape (Gibney closed basketweave technique). Prior to activity all support conditions were found to significantly reduce range of motions in all directions. Exercise was performed for 60 minutes to simulate sports activity; data was recorded after 15, 30, 45, and 60 minutes. Exercise consisted of treadmill speed walking, treadmill walking broken down into different parts; forward, left facing crossover strides, right facing crossover strides. They showed prophylactic ankle tape and SubTalar brace to steadily increase plantar flexion following 15 minutes of exercise; ankle tape further increased each 15-minute interval. An increase in plantar flexion was shown at 30 minutes with Swede-O braces. Inversion motion in all three supports (tape, SubTalar, and Swede-O) showed an increase following 15 minutes of activity and a further significant increase in SubTalar support between 15 and 30 minutes. Swede-O brace provided the most support in inversion range of motion and subtalar support brace provided the least support in inversion.<sup>40</sup>

Gross et al<sup>23</sup> compared ankle tape and semirigid orthosis in limiting ankle motion before and after exercise. Passive inversion-eversion was measured using the

Cybex II Isokinetic Dynamometer. Brief period of exercise consisted of 10 minutes of running on a figure-eight course and twenty toe raises. They showed ankle tape and semirigid orthosis both significantly restrict ankle range of motion. Semirigid orthosis provided a significantly greater restriction in inversion-eversion due to the restriction in eversion. After exercise both conditions were shown to significantly restrict all measures. However, tape was shown to loosen greater than semirigid orthosis, while semi-rigid orthosis maintained stability.<sup>23</sup>

DonJoy ankle ligament protector and subtalar sling ankle tape was compared with passive range of motion in a study by Gross et al <sup>22</sup>. Sixteen subjects had no history of injury were tested on the biodex dynamometer and the biodex eversion-inversion angular displacement. Both conditions tested passive range of motion before application, immediately after application, and following a short 10-minute exercise session (same exercise protocol as mentioned in Gross et al <sup>23</sup>). They concluded both conditions significantly reduced eversion in all three test positions; a loss of eversion occurred following exercise although significant reduction in eversion was still shown. The same was found for inversion, both conditions significantly restricted inversion. The subtalar sling ankle tape provided greater resistance following application. Following exercise the sling ankle tape lost some restriction, reporting both conditions to have significant restriction and equal support.<sup>22</sup>

Myburgh et al <sup>35</sup> measured range of motion before, during, and after a squash match. They compared two ankle tape materials (elastic and non-elastic) with the same technique and two ankle braces. The two braces were Ace guard and Futuro guard; the

two tape materials used were Zinc oxide tape and Elastic tape. The ankle tape was applied using a combination of a basketweave, stirrup, and heel lock applied to skin. Two matches were played with the ankle brace on the right foot and ankle tape on the left. Testing was done on the Inman ankle goniometer, the same method used by Fumich et al <sup>19</sup> to compare results. They showed ankle braces to provide no significant support before, during or after.<sup>35</sup> With the two types of ankle tape, both provided significant resistance before the squash match. Elastic tape loosened significantly more during the match than non-elastic. After 1 hour of play, neither tape provided significant support.<sup>35</sup>

Pederson et al <sup>41</sup> examined ankle tape and spinting on inversion before and after exercise. Ankle tape, ankle tape combined with spat, and spat were all tested on the trap door platform simulated sudden inversion. The exercise consisted of 30-minute rugby drills, mainly consisting of lateral cutting and forward running. All three methods significantly reduced inversion before and after exercise compared to the control. Before exercise the ankle tape reduced range of motion by 35% and after exercise range of motion was decreased by 20%. Taping and spinting before exercise reduced range of motion by 53% and after exercise 46%. Spat alone reduced range of motion before by 39% and after by 33%. The most efficient was the tape and spat combined, spat was the second most efficient, and ankle tape the least efficient.<sup>41</sup>

Ricard et al <sup>43</sup> studied the effects of ankle tape over prewrap on restricting dynamic weightbearing inversion. An inversion trap door platform was used to mimic sudden ankle inversion, and a goniometer was used to measure inversion. The exercise

consisted of treadmill running, figure eight running, shuttle runs, and toe raises. They found no difference between prewrap and taping to the skin; they did find both conditions significantly reduced inversion compared to the control ankle. After exercise they showed taped ankles to restrict inversion in the simulator by about 10 degrees.<sup>43</sup>

Braces and tape were compared in a study by Eils et al<sup>17</sup> in combination with two different shoe conditions. Two different braces, a semirigid and a soft brace, as well as tape were tested in combination with a cutout shoe (simulated barefoot) and a normal shoe. Twenty-five healthy subjects were used to test passive range of motion. Passive range of motion was tested in 3 planes including plantarflexion/ dorsiflexion, inversion/ eversion, and internal rotation/ external rotation. Results showed that all the devices tested significantly restricted range of motion. There was no significant difference between the brace conditions; however, the semirigid brace showed higher passive stability in plantarflexion inside the shoe. Both brace conditions limited range of motion compared to no brace conditions.<sup>17</sup>

Range of motion has been tested in various ways with different methods and supports. Overall, similar results were shown despite the different supports and methods used. Immediately following application, significant reduction of inversion, eversion, and plantar flexion was shown.<sup>17, 19, 22, 23, 30, 40, 41, 43</sup> Results vary after periods of exercise. Inversion has been shown to still be significantly reduced following exercise<sup>22, 23, 30, 41</sup> others have found residual support greater than the control.<sup>19, 43</sup> Eversion was found to still provide support following exercise.<sup>22, 23</sup> Plantar flexion was the one range of motion found to loosen the most, but still provides significant

support.<sup>19,40</sup> Despite loosening, ankle tape and brace have reported effective in restricting range of motion before and after application.<sup>22, 23, 41</sup>

### Neuromuscular control

Neuromuscular control is associated with the pathways that dictate how the muscle reacts.<sup>1</sup> Afferent and efferent pathways are linked to higher centers of the central nervous system. Afferent pathways travel to the higher centers; this information is processed and responded to through efferent pathways. The peroneus longus, for example, activates group Ia afferent fibers of the muscle spindle located in the muscle belly, which responds with an efferent motor response and the peroneus longus is contracted.<sup>14</sup> In relation to ankle stability, these pathways are necessary to protect the ankle from excessive inversion by maintaining joint stiffness and stability through muscle contractions.<sup>1,8</sup>

A factor in reinjury can be a longer peroneal latency.<sup>2</sup> The peroneal muscles, mainly the peroneus longus and brevis, are the primary muscle group studied at the ankle due to the large role they play in dynamic stability of the lateral ankle.<sup>12, 14</sup> Peroneal latency is the common measure of neuromuscular control; which is thought of as the time from the start of perturbation to the first increase in EMG level.<sup>2</sup> Longer peroneal latency causes a slower reaction to unexpected perturbation.<sup>1, 2, 30</sup>

In a review by Wilkerson<sup>57</sup>, he suggested the research proposes that ankle tape is most beneficial in deceleration of inversion velocity and aiding in dynamic neuromuscular protective mechanisms. Arnold et al<sup>2</sup> suggested in his review that

deceleration could be improved with prophylactic ankle tape or lace-up braces by a decrease in the angle of supination during heel strike. He suggests that it would take a greater amount of inversion to produce an ankle sprain.<sup>2</sup>

Alt et al<sup>1</sup> measured the stabilizing effects of ankle tape before and after exercise. Two different tape techniques were used at two different lengths; the short technique was about one tape strip shorter on the proximal and distal ends. A trap door platform was used to simulate sudden inversion. The results were measured with a goniometer, EMG, and thermally. Subjects were measured before application, after application, and after exercise. The exercises consisted of 10-minute treadmill run and 2 minutes of jump exercises. They showed that prophylactic ankle tape reduced peroneus muscles EMG by an average of 18%. They found about 35% of maximum inversion amplitude was decreased with ankle tape. Exercise significantly loosened the ankle tape, more in one technique. Overall, they showed improved joint stability after application because ankle tape showed to reduce the extent of inversion and to be capable of reacting fast enough to protect the joint from inversion trauma.<sup>1</sup>

Karlsson and Andreasson<sup>27</sup> measured mechanical stability on the ankle joint with ankle tape. Twenty subjects were used, all with instability in one ankle and a stable contralateral ankle. Anterior talar translation and talar tilt were examined, as well as the reaction time for the peroneus muscles. The trap door was used to simulate sudden inversion. EMG signal was measured for the reaction time. They found an increase in peroneal latency with adhesive tape in patients with unilateral ankle instability compared to the stable ankle. They concluded the peroneal latency was

significantly increased with ankle tape, still not as quick as normal reaction time before instability.<sup>27</sup>

Cordova et al<sup>12</sup> measured peroneus longus latency before a period of extended use and after long-term application of prophylactic ankle braces. Active Ankle training brace, McDavid 199, and no brace (control) were the groups the subjects were divided into. Subjects were tested before application of the ankle brace. They were then assigned to groups; subjects with the braces wore them 8 hours a day for 5 days a week for 8 weeks. Immediately after the 8 weeks, subjects returned and performed the same testing done prior to wearing the brace. They found there was no difference in peroneus longus latency in subjects who were braced than the subjects with no brace. In other words, those athletes who wear prophylactic ankle braces are not at risk for loss of peroneus longus response.<sup>12</sup> Cordova et al<sup>13</sup> furthered his study on lace up and semirigid braces by comparing initial and chronic application of bracing on the peroneus longus stretch reflex. Five test trials were performed on each subject in all support conditions (control, semirigid brace, lace up brace). After testing, subjects were assigned to one of the three support conditions. Conditions for wearing the brace were consistent with Cordova's previous study.<sup>12</sup> Post testing was performed immediately after the eight-week period. They showed initial application of the lace-up braces facilitated the peroneus longus amplitude. Chronic application showed to increase peroneus longus amplitude after 8 weeks of the semirigid ankle brace.<sup>13</sup>

Konradsen et al<sup>29</sup> showed peripheral and central reaction to perhaps be too slow to protect the ankle against sudden inversion. Stable and unstable ankles have shown

little to no difference in terms of peroneal latency.<sup>8, 54</sup> Studies with prophylactic ankle tape and brace show that ankle supports do not harm the individual, and improve response time of the dynamic defense mechanism.<sup>12, 13</sup> Karlsson and Andreasson<sup>27</sup> concluded the peroneal latency was significantly increased with ankle tape. Alt et al<sup>1</sup> showed ankle tape to reduce the extent of inversion and to be capable of reacting fast enough to protect the joint from inversion trauma. Therefore, ankle tape and brace are reported to be effective in dynamic responses to protect the ankle.

### Proprioception

Proprioception is explained, from Refshauge et al<sup>42</sup>, as “a group of sensations including the sensation of movement and position of the joints and those related to muscle force”.<sup>42</sup> As cited by Wilkerson and Nitz<sup>57</sup> it is the mechanoreceptors in the joint capsule, ligaments, muscles, tendons, and skin that send a cumulative neural input to the central nervous system.<sup>57</sup> After an initial ankle sprain, proprioception can be disrupted.<sup>6, 25, 42</sup> Two common ways proprioception is measured are postural sway and joint position sense.

### Postural Sway

Tropp et al<sup>52</sup> studied stabilometry, a quantitative measure of postural control. A healthy group was used as the reference group and a test group was compiled over time from a male 12-team senior soccer division. The force plate was used to measure medial-lateral and anterior-posterior directions of sway during a single leg stance. Each subject completed three tests, each test lasting 60 seconds. They found an increase risk

of injury was higher with players who had stabilometry values that exceeded the reference group by 2 standard deviation.<sup>52</sup> Those players with previous injury found no increased incidence compared to those who had no previous injury. Therefore, Tropp et al<sup>51</sup> found that impaired postural sway had a significantly greater impact on reinjury than previous history of ankle sprains.<sup>52</sup> Tropp et al<sup>53</sup> continued stabilometry measures by comparing the postural sway of functional instability to mechanical instability. Each subject performed two tests, standing on the right leg and standing on the left leg; each test lasting 60 seconds. Functionally unstable players showed higher stabilometry measures than players that were functionally stable. Mechanical instability showed different results than functional instability; mechanical stability and instability did not differ in stabilometry measures. However, 42% of the ankles that were functionally unstable were found to also be mechanically unstable. Due to this finding, the authors believe stabilometry is a good predictor of functional instability.<sup>53</sup> Based on Tropp et al's studies<sup>52,53</sup> it can be hypothesized that functional instability has a greater limitation due to the increased risk of reinjury.

McGuine et al<sup>31</sup> found poor balance was a predictor for future ankle sprains. They expanded on previous research, primarily Tropp et al<sup>52,53</sup>, by testing a different population. They measured postural sway in 210 high school basketball players. The 210 subjects were monitored for two years, none used prophylactic taping or bracing throughout the season. Prior to the season, balance and prior injuries were recorded. The New Balance Master Version 6.0 was used to record center of gravity sway velocity. Each subject was to perform a modified Romberg test lasting 10 seconds.

Poor balance was a high center of gravity sway velocity scores and good balance was low center of gravity sway velocity scores. It was shown that players who had poor balance had almost seven times as many ankle sprains as players with good balance.<sup>31</sup> It can be concluded that individuals with poor postural sway scores, including functionally unstable ankles, may be at an increased risk of reinjury. Postural sway can perhaps become a predictor of future injuries.<sup>31,52</sup>

Kinzey et al<sup>28</sup> examined different ankle braces on postural control. A modified Romberg test was performed on a force plate. Three ankle braces (Active ankle trainer, AirCast sport stirrup, and the McDavid A-101) were tested. Each test went through six conditions; eyes open and normal floor, eyes closed and blindfolded and normal floor, a visual-conflict dome and normal floor, eyes open with subject standing on foam, eyes closed and blindfolded with subject standing on foam, and visual-conflict dome with subject standing on foam. Investigators showed that wearing a brace increased anterior and lateral center of pressure values. They determined that postural control was only affected if no other sensory modalities were affected. In other words, this study did not support or oppose ankle braces improving postural control.<sup>28</sup>

Palmieri et al<sup>39</sup> recorded the effects of wearing ankle braces on postural sway. Twenty-eight healthy subjects were tested on a force platform system. The force platform was used to measure center of gravity in the medial-lateral and anterior-posterior directions. Subjects were pre-tested without an ankle brace and tested in a lace-up ankle brace. After testing was complete the brace group was to leave the brace on. They were instructed to wear the lace-up brace every day for 8 hours the next 4

days. Every day subjects returned for testing; the control group applied the ankle brace only for the test. They found no significant difference between the brace and control group. This, showed long periods of ankle bracing did not have adverse effects, but also did not additionally benefit the subject.<sup>39</sup>

Baier and Hopf<sup>3</sup> used previous studies and expanded by researching the ankle orthosis (rigid and flexible) on postural sway. This was performed in a single-limb stance with both functional instability and healthy ankles. Anteroposterior sway and mediolateral sway were measured. They showed that mediolateral sway velocity was reduced in either ankle orthosis with the functionally unstable group. No significant difference was shown with the healthy group when comparing ankle orthosis to no orthosis, which agreed with Palmieri et al's<sup>38</sup> findings.<sup>3</sup>

Friden et al<sup>18</sup> studied stabilometry in the frontal plane only. The thought was this approach would improve the sensitivity of the one leg stabilometry test compared to total sway amplitudes. All subjects had acute ankle injuries; the injured leg was compared to the non-injured leg. The ankle brace tested was the Air-Stirrup. Different variables were used to test sway in the frontal plane. Four of the variables showed a significant difference between the injured and uninjured leg. With the application of ankle braces, none of the variables differed from the uninjured side. It can be concluded the ankle brace allowed the injured ankle to be back in an uninjured state when looking at frontal plane sway. This could in turn be concluded that ankle braces can decrease differences between injured and uninjured ankles.<sup>18</sup>

Postural sway has been shown to increase with functional ankle instability and shown to be a predictor of future injuries.<sup>31, 52, 53</sup> Ankle tape and braces have been studied to determine if they decrease the risk of future ankle injuries and improve ankle stability based on postural sway. Kinzey et al<sup>28</sup> revealed bracing to increase anterior and lateral center of pressure values. Baier and Hopf<sup>3</sup> showed a decrease in medial-lateral sway velocity with ankle orthosis in the functionally unstable ankle. Friden et al<sup>18</sup> showed ankle braces decreased the differences between injured and uninjured ankles in the frontal plane. Palmieri et al<sup>39</sup> did show individuals who wear ankle braces frequently are not in a greater risk of losing postural sway due to continuous application of an ankle brace. Kinzey et al<sup>28</sup> and Baier and Hopf<sup>3</sup> showed little effect with bracing and orthosis, where as Friden et al<sup>18</sup> showed bracing to be effective. Overall, studies differ in determining the effectiveness of ankle tape and brace.

### Joint Position Sense

Joint position sense, another component of proprioception, is commonly used to measure proprioception.<sup>58</sup> Simoneau et al<sup>49</sup> tested the effect of strips of athletic tape applied directly on the skin of the ankle. This study was based on the belief that athletic tape may stimulate cutaneous mechanoreceptors and increase proprioception. Twenty healthy males were tested on the ankle joint movement and position perception apparatus. Joint position perception was consisted the difference between the preset angular position and the position the subject returned the ankle. Joint movement perception threshold was the subject's ability to perceive angular movement. Two 12.7

cm long strips of tape were placed on the anterior and posterior aspect of the ankle. Test position for joint position perception was 10 degrees plantar flexion and 5 degrees dorsiflexion. The subject was passively moved through the range of motion and pushed the stop button when they believed the position was reached. For joint movement perception threshold, the subject was passively moved in dorsiflexion or plantar flexion at 0.25 degrees/second. The subject was to use the stop button to stop the platform when the direction of movement of the ankle was recognized. Subjects were tested before and after application of tape strips in both weight bearing and non-weight bearing. Joint position perception with tape in weight bearing was shown to improve accuracy in returning the ankle to the desired position in dorsiflexion. As for the non-weight bearing position, tape was found to significantly improve the ability for the subject to perceive ankle joint position for plantar flexion. Athletic tape did not change the subject's ability to perceive movement at the ankle in weight bearing or non-weight bearing conditions. This study showed on healthy individuals that increased cutaneous sensory feedback from athletic tape could improve joint position perception with non-weight bearing situations, particularly in the midranges of plantar flexion.<sup>49</sup>

Robbins et al<sup>44</sup> studied improvements in proprioception with and without ankle tape, before and after exercise in healthy subjects. The ankle tape technique used was the Gibney basket weave with double heel locks applied directly to the skin. Subjects were tested on a series of blocks; in full weight bearing position. The blocks varied in slope between 0 degrees and 25 degrees. Perceived slope direction and estimated slope amplitude was indicated. There were two test sessions, exercise and no exercise; with

two groups, tape and untaped. Exercise session consisted of basketball and running for 30 minutes, the no exercise session was 30 minutes of rest in non-weight bearing position. Active foot position sense was tested before and after exercise/no exercises. They showed tape to influence foot position sense, primarily with slope greater than 10 degrees. They also showed ankle tape to have the greatest benefit to joint position sense after exercise.<sup>44</sup>

Kaminski et al<sup>26</sup> looked at neoprene ankle support and ankle tape on proprioception by measuring joint position sense. Joint position sense was measured with an isokinetic dynamometer. Each subject went through three days of testing, each day consisted of a different test condition (no tape, neoprene ankle support, ankle tape). Inversion and eversion was tested both actively and passively at four angles. They found no link between neoprene ankle supports or ankle tape and joint position sense; both active and passive range of motion had no significant difference on either condition.<sup>26</sup>

Refshauge et al<sup>42</sup> investigated if joint position sense would change from healthy ankle to an ankle with recurrent ankle sprains with ankle tape. Twenty-five ankles with recurrent ankle sprains and eighteen healthy ankles were used. Passive dorsiflexion and plantar flexion movements were tested. Subjects were tested before and after tape application. Each subject was tested at three velocities (0.1, 0.5, and 2.5 degrees/second); at each velocity there was a random mix of 10 plantar flexion and 10 dorsiflexion movements. No significant difference was found in joint position sense between healthy and sprained ankles, in all velocities between taped and untaped. In

other words, the ability to detect passive plantar flexion and dorsiflexion was negatively affected by tape.<sup>42</sup>

Proprioception is thought to be disrupted after ankle trauma. Ankle tape was investigated in the same way strength was, to see if ankle tape would improve joint position sense results. From the studies cited, Kaminiski et al<sup>26</sup> and Refshauge et al<sup>42</sup> showed no correlation between ankle tape/brace and frequent ankle sprains on joint position sense. Simoneau et al<sup>49</sup> showed healthy ankles to increase joint position perception mostly in plantar flexion with ankle tape in non-weight bearing conditions. Robbins et al<sup>44</sup> showed with a slope of greater than 10 degrees, joint position sense to be influenced by ankle tape. Half the studies have shown positive influence of ankle tape/brace and the other half showed no improvement. No definite conclusion is shown to prove ankle tape or brace are effective due to proprioception changes.

## CHAPTER III

### METHODS

#### Overview

Thirty-two subjects with functionally stable ankles were recruited for this study. Subjects reported to the Virginia Commonwealth Sports Medicine Research Laboratory for data collection. Data collection consisted of each subject performing a single leg jump-landing under four test conditions. The conditions included no tape or brace, close basket weave (Gibney) ankle tape technique, ankle brace, and close basket weave (Gibney) ankle tape technique and ankle brace.

#### Subjects

The inclusion criteria for the subjects were as follows: 1) age ranging from 18 to 30 years old; 2) no previous history of ankle, hip, or knee injuries 3) no history of functionally unstable ankles (this was defined as a sensation of “giving way” in the ankle, knee, or hip joint during activity); and 4) be able to perform the single leg jump-landing.

The exclusion criteria for the subjects were as follows: 1) any signs and symptoms of an acute injury in the lower extremity (swelling, redness, heat, pain, and loss of function); 2) any musculoskeletal injury that occurred 6-weeks prior to the

study; 3) functionally unstable ankles; 4) any symptoms of dizziness, tinnitus, headaches, or known vision deficits; and 5) any history of lower extremity surgery.

## Instrumentation

### Force Plate

The Bertec NC strain gauge force plate (Bertec Corp., Columbus, Ohio) was used to collect the GRF data at a sampling rate of 180 Hz. Analog signals from the force plate were not amplified. Data was then transferred to a personal computer for processing.<sup>46</sup>

### Vertec

The Vertec (Sports Imports, Columbus, OH) is an athletic performance tool that allowed subjects to jump and reach for horizontal moveable plastic rods. The maximum jump height was assessed according to the highest plastic rod reached during the jump. The Vertec could be adjusted to a height of twelve feet.<sup>46</sup>

## Procedure

Subjects received an orientation to the testing protocol and read a consent form that was approved by The Committee for the Protection of the Rights of Human Subjects at Virginia Commonwealth University. Any potential subject who did not meet the inclusion criteria was excluded from participation. Subjects meeting the inclusion criteria signed the consent form and the testing session continued. The subject's height, weight, and age were all recorded.

### Jump Stabilization Maneuver

Maximum vertical jump height was assessed with the Vertec. Subjects stood 70 cm away from the Vertec, and performed a two-legged jump. The maximal vertical jump height was performed three times, and the highest jump obtained was recorded as the maximum. The plastic rods on the Vertec were then set at minimum height of 50% and a maximum height of 55% of the subject's maximum jump height. Subjects stood 70 cm away from the Vertec and performed a two-legged jump at a minimum of 50% of their maximum jump height and a maximum of 55% of their maximum jump height. They were instructed to use a jumping technique that allows them to generate enough jumping force to reach between the 50-55% mark with their fingertips. The subjects were instructed to land one-legged on the force plate. They were instructed to maintain this position for 20 seconds. Three test trials were provided for practice before beginning testing. Three test trials were recorded for each testing condition. Thirty seconds of rest was given between trials and five minutes was given between test conditions. Testing order was counterbalanced (Table 1). Subjects were retested if they hopped on their test foot or touchdown with their non-weight bearing limb during the landing or stance part of testing.<sup>47</sup>

### Ankle Taping Protocol

Johnson and Johnson (J&J) athletic tape (1.5" x 15yd) was used. A closed basket weave (Gibney) technique was used as the ankle taping technique. This consisted of 2 anchors at each end of the ankle, 3 stirrups, 3 Gibney strips, 2 heel locks,

and 2 figure eights. The anchors were applied first, followed by 1 stirrup and 1 Gibney strip until all three are applied. The Gibney strips continued up the ankle followed by 2 figure eights and 2 heel locks. The same licensed certified athletic trainer performed all ankle taping. After the three test trials, the ankle tape was removed and redone if needed for the next set of test trials.

#### Ankle Brace Protocol

The Ankle Stabilizing Orthosis or ASO (Medical Specialties, Charlotte, NC) was chosen due to its popularity in clinical use and access to the researchers. The ASO was custom fit to each ankle using manufacturer's guidelines. A chart from the manufacturer was used to determine which size brace the subject will wear (Table 2). The chart was based on the circumference of the ankle.

#### Data Collection and Reduction

Time to stabilization was calculated using methods reported by Ross et al<sup>45,47</sup>. Analog signal was converted to digital signals, and smoothed using second order recursive low-pass Butterworth digital filter with an estimated optimum cutoff frequency of 12 Hz. A TTS program written in LabVIEW 8.5 (National Instruments, Corp, Austin, TX) was used to calculate anterior/posterior TTS and medial/lateral TTS using a normalization method reported by Ross et al.<sup>47</sup> Time to stabilization for each component of the ground reaction force essentially determined the time point where the beginning ground reaction force resembled the ground reaction force of stabilized single leg stance.<sup>47</sup>

### Statistical Analysis

Means (SD) were calculated for subject demographics, anterior/posterior TTS, and medial/lateral TTS. The mean of 5 trials for anterior/posterior TTS and medial/lateral TTS were used for statistical analyses. A 2 x 2 x 2 repeated measures ANOVA with 3 within factor with 2 levels was used for statistical analyses. The first within factor was plane of motion with 2 levels (anterior/posterior, medial/lateral). The second within factor was ankle tape with 2 levels (no brace, brace). The third within factor was ankle brace with 2 levels (no brace, brace). Simple main effects test was also performed for significant F statistics. Effect size (ES) values were calculated using Cohen's effect size  $d$ .<sup>10</sup> Alpha level was set a priori at 0.05 to indicate statistical significance for all tests. SPSS 13.0 (SPSS Inc., Chicago, IL) statistical software package was used for statistical analyses.<sup>47</sup>

**Table 1. Counterbalance Testing Order**

TO 1 = Subject 1	TO 2 = Subject 2	TO 3 = Subject 3	TO 4 = Subject 4
TO 1 = Subject 5	TO 2 = Subject 6	TO 3 = Subject 7	TO 4 = Subject 8
TO 1 = Subject 9	TO 2 = Subject 10	TO 3 = Subject 11	TO 4 = Subject 12
TO 1 = Subject 13	TO 2 = Subject 14	TO 3 = Subject 15	TO 4 = Subject 16
TO 1 = Subject 17	TO 2 = Subject 18	TO 3 = Subject 19	TO 4 = Subject 20
TO 1 = Subject 21	TO 2 = Subject 22	TO 3 = Subject 23	TO 4 = Subject 24
TO 1 = Subject 25	TO 2 = Subject 26	TO 3 = Subject 27	TO 4 = Subject 28
TO 1 = Subject 29	TO 2 = Subject 30	TO 3 = Subject 31	TO 4 = Subject 32

\*TO = Testing Order

TO 1 = no tape or brace, close basket weave (Gibney) ankle tape technique, ankle brace, close basket weave (Gibney) ankle tape technique and ankle brace

TO 2 =, close basket weave (Gibney) ankle tape technique, ankle brace, close basket weave (Gibney) ankle tape technique and ankle brace, no tape or brace

TO 3 = ankle brace, close basket weave (Gibney) ankle tape technique and ankle brace, no tape or brace, close basket weave (Gibney) ankle tape technique

TO 4 = close basket weave (Gibney) ankle tape technique and ankle brace, no tape or brace, close basket weave (Gibney) ankle tape technique, ankle brace

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**Table 2. ASO Braces Custom Fitting Chart**

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<b><u>SIZE</u></b>	<b><u>Circumference</u></b>
XX-Small	9"-10"
X-Small	10"-11"
Small	11"-12"
Medium	12"-13"
Large	13"-14"
X-Large	14"-15"
XX-Large	15"-16"

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**LEGENDS TO FIGURES**

Figure 3.1-Closed Basket Weave (Gibney) Ankle Tape technique

Figure 3.2-Ankle Stabilizing Orthosis (ASO)

Figure 3.3-Combination of Ankle Tape and Ankle Brace

Figure 3.1



Figure 3.2



Figure 3.3



## CHAPTER IV

### RESULTS

Data were collected from thirty-two subjects. All subjects recruited had no prior history of ankle injuries. Subjects were tested on their dominant foot in each of the four conditions. Six of the subjects had corrupted force plate data. Consequently, their data were excluded from the analysis. Thus, twenty-six subjects were analyzed for TTS data.

Table 3 reports the subject characteristics including age, gender, height, weight, activity level, and if tape and/or brace have previously been used. Table 4 reports maximum jump height and 50% of maximum jump height. Table 5 reports practice trials and test trials that subjects repeated for each test condition.

Table 6 reports the means, standard deviations, and effect sizes for AP TTS and ML TTS. No significant plane by ankle tape by ankle brace interaction ( $F_{(1,25)}=0.23$ ,  $p=0.637$ ), no significant ankle tape by ankle brace interaction ( $F_{(1,25)}=0.51$ ,  $p=0.483$ ), or plane by ankle brace interaction ( $F_{(1,25)}=0.16$ ,  $p=0.697$ ) were found. However, a significant plane by ankle tape interaction ( $F_{(1,25)}=4.45$ ,  $p=0.045$ ) was found (Table 7). Simple main effects testing indicated AP TTS in the no tape condition was significantly longer than ML TTS ( $F_{(1,200)}=156.12$ ,  $p<0.001$ ). Additionally, simple main effects testing indicated AP TTS in the tape condition was significantly longer than ML TTS

( $F_{(1,200)} = 121.08, p < 0.001$ ). A significant main effect for plane was found ( $F_{(1,25)} = 112.87, p < 0.001$ ). No main effects for ankle tape ( $F_{(1,25)} = 1.04, p = 0.318$ ) or ankle brace ( $F_{(1,25)} = 2.43, p = 0.132$ ) were found.

**Table 3. Subject Characteristics.**

	Age (yr)	Height (cm)	Mass (kg)	Gender	Test Foot	Activity Level	Ankle Support History
Subjects Analyzed (N=26)	24.10 (2.50)	170.20 (10.82)	71.70 (11.96)	Male = 12 Female = 14	Right = 23 Left = 3	LA = 3 MA = 11 VA = 12	N = 14 C = 6 T = 5 B = 1
Subjects Deleted (N=6)	24.50 (3.78)	165.75 (7.10)	65.85 (9.20)	Male = 2 Female = 4	Right = 5 Left = 1	LA = 2 MA = 4 VA = 0	N = 4 C = 0 T = 1 B = 1

# Age, Height and Mass are reported in mean ( $\pm$  SD)

\*LA: Low activity  
\*MA: Moderate activity  
\*VA: Very active

‡N= No prior use  
‡C = Used brace and tape  
‡T = Used tape  
‡B = Used brace

^Gender, Test Foot, Activity Level, and Ankle Support History are reported in number of subjects

**Table 4. Means ( $\pm$ SD) for Maximum Jump Height and 50% of Maximum Jump Height.**

	Maximum Jump Height (cm)	50% of Maximum Jump Height (cm)
Subjects Analyzed (N=26)	38 (4.26)	20.4 (2.14)
Subjects Deleted (N=6)	33.9 (4.10)	16.8 (1.96)

**Table 5. Means ( $\pm$ SD) for Practice Trials and Repeated Test Trials.**

	Practice Trials				Test Trials			
	No Tape		Tape		No Tape		Tape	
	No brace	Brace	No brace	Brace	No brace	Brace	No brace	Brace
Subjects Analyzed (N=26)	4.73 (2.54)	5.19 (4.20)	4.77 (1.84)	5.15 (2.20)	2.73 (3.08)	3.35 (2.88)	3.23 (3.60)	3.27 (2.69)
Subjects Deleted (N=6)	4.17 (1.17)	5.17 (3.71)	4.67 (1.97)	4.33 (1.03)	1.33 (0.82)	1.83 (1.33)	4.5 (4.72)	6.33 (5.28)

**Table 6. Means ( $\pm$ SD) and Effect Sizes for A/P TTS (s) and M/L TTS (s) for Plane x Tape x Brace Interaction.**

	Time to Stabilization					
	No Tape			Tape		
	No brace	Brace	Within ES	No brace	Brace	Within ES
A/P Plane	1.77 (0.37)	1.74 (0.21)	0.07	1.75 (0.23)	1.73 (0.22)	0.09
M/L Plane	1.26 (0.13)	1.20 (0.11)	0.50	1.29 (0.14)	1.28 (0.17)	0.06
Between ES	1.84	3.22		2.41	2.28	

**Table 7. Means ( $\pm$ SD) and Effect Sizes for A/P TTS (s) and M/L TTS (s) for Plane x Tape Interaction.**

Time to Stabilization			
	No Tape	Tape	Within ES
A/P Plane	1.75* (0.29)	1.74* (0.20)	0.04
M/L Plane	1.23 (0.13)	1.28 (0.16)	-0.34
Between ES	2.31	2.54	

\*  $p < 0.05$ . A/P TTS was significantly longer than ML TTS for both no tape and tape conditions.

## CHAPTER V

### DISCUSSION

The most important finding in this study was both no tape and tape conditions caused subjects to take longer to stabilize in the anterior/posterior direction than the medial/lateral direction. However, this finding was not related to our research questions or hypotheses. We rejected our first hypothesis that anterior/posterior and medial/lateral TTS values would be lower with prophylactic ankle tape than control condition values. Secondly, we rejected our hypothesis that anterior/posterior and medial/lateral TTS values would be lower with prophylactic ankle braces than control condition values. Thirdly, we rejected our hypothesis that anterior/posterior and medial/lateral TTS values would be lower with prophylactic ankle tape and brace combination condition compared to control condition values. Fourthly, we rejected our hypothesis that anterior/posterior and medial/lateral TTS would be lower with prophylactic ankle tape compared to prophylactic ankle brace values. Lastly, we rejected our hypothesis that anterior/posterior and medial/lateral TTS would be lower with a combination of prophylactic ankle tape and brace condition compared to prophylactic ankle tape or ankle brace condition.

Our results indicated that prophylactic ankle brace did not improve anterior/posterior or medial/lateral TTS compared to the control condition. However, a

slight treatment effect (effect size = 0.50) was present for the medial/lateral TTS, indicating that brace may have slightly improved stability. One of the main reasons the results were not statistically significant was because of our test subjects; healthy, active ankles. Greater benefit has been shown with bracing ankles that have a prior history of ankle sprains compared to ankles with no prior history.<sup>38</sup>

### Ankle Brace

Several different measures have been used to test the effectiveness of ankle bracing on ankles with no history of injuries and ankles with a history of injuries.<sup>3, 26, 35, 48, 55</sup> The literature is equivocal showing ankle bracing is an effective method in supporting the ankle joint.<sup>3, 17, 22, 23, 26, 35, 40, 48, 55</sup> Wikstrom et al<sup>55</sup> used both soft and semirigid orthosis with functionally unstable ankles. They used a single leg jump landing to assess dynamic balance, but used a slightly different measure than TTS. The researchers found a slight improvement with the both soft and semirigid orthosis using the vertical stabilizing index. However, no significant difference was reported using other dynamic stability indices.<sup>55</sup> Myburgh et al<sup>35</sup> found soft ankle braces to have not significantly restricted active range of motion; however, the ankle braces used are currently outdated.<sup>35</sup> Additionally, Kaminski et al<sup>26</sup> did not find a significant difference using a soft ankle brace testing proprioception with joint position sense.<sup>26</sup> In examining static balance, Baier and Hopf<sup>3</sup> did not find a treatment effect for bracing in healthy ankles. However, they also tested functionally unstable ankles, and found mediolateral sway velocity was improved with bracing compared to no brace conditions.<sup>3</sup>

Positive findings have been seen using soft ankle braces with functionally unstable and healthy ankles. Sharpe et al<sup>48</sup> showed soft ankle brace to be the most effective ankle support to reduce the recurrence on ankle sprains. This was in functionally unstable ankles comparing ankle braces to no support, tape, and a combination of tape and brace.<sup>48</sup> Eils et al<sup>17</sup> tested both soft and semirigid braces, along with tape in combination with two different shoe conditions in healthy individuals. They also found both braces to significantly restrict passive range of motion.<sup>17</sup> Our statistical results agreed with the majority of the literature that ankle bracing has no significant effect on healthy ankles. However, our slight treatment effect suggests that bracing might have implication in improving medial/lateral TTS. Future research should be conducted to confirm this finding.

Paris et al<sup>40</sup>, Gross et al<sup>23</sup>, and Gross et al<sup>22</sup> all looked at the effectiveness of ankle braces before and after activity. All three studies showed ankle bracing to decrease range of motion before activity. Paris et al<sup>40</sup> tested soft ankle braces and Gross et al<sup>22 and 23</sup> tested semirigid ankle braces. Even though the brace loosened after activity, all three studies found range of motion to still be restricted. Although there is not an abundance of literature on ankle brace, Sharpe et al<sup>48</sup>, Paris et al<sup>40</sup>, Gross et al<sup>23</sup>, and Gross et al<sup>22</sup> all found positive effects of ankle bracing. No studies have used the same measures used in our study on ankle braces. Even though some of these studies agree with finding a positive effect in ankle braces, they still do not help explain why we found a medium treatment effect (improvement) with medial/lateral TTS. One potential theory could be the comfort level. The majority of subjects mentioned that the

ankle brace was the most comfortable condition tested. The ankle braces gave support, but may have not completely restricted movement. Conversely, one of the most common complaints was the change of jump techniques that subjects used due to the brace restricting range of motion. This may be a reason why anterior/posterior or medial/lateral TTS were not statistically different between conditions.

#### Ankle Tape

Our results indicated that prophylactic ankle tape did not improve anterior/posterior or medial/lateral TTS compared to the control condition. However, a slight treatment effect (effect size = -0.34) was present for the medial/lateral TTS, indicating that tape might slightly impair stability. Some possible theories for our insignificant findings could be that individuals' jump techniques were altered due to the tape restricting the range of motion, inhibiting the ankle muscles to perform as needed due to the restriction of ankle tape. The research agrees with ankle tape restricting range of motion.<sup>17, 19, 22, 23, 30, 35, 40, 41, 42, 43</sup> To prove either theory with the restriction or decrease in range of motion, further studies would need to be conducted.

A large amount of the literature agrees with the ankle tape reducing range of motion at the ankle joint.<sup>17, 19, 22, 23, 30, 35, 40, 41, 42, 43</sup> Fumich et al<sup>19</sup> and Myburgh et al<sup>35</sup> both tested ankle tape using team practice as the exercise. Fumich et al<sup>19</sup> studied tape versus no tape on healthy individuals at football practice. They found initially ankle tape restrict range of motion.<sup>19</sup> Myburgh et al<sup>35</sup> tested squash players using two different types of tape, but the same tape technique. They found initially ankle tape significantly restricted range of motion.<sup>35</sup>

Lohrer et al <sup>30</sup>, Paris et al <sup>40</sup>, Gross et al <sup>23</sup>, Gross et al <sup>22</sup>, Pederson et al <sup>41</sup>, Ricard et al <sup>43</sup>, and Eils et al <sup>17</sup> all tested healthy individuals. All studies used different methods and different tape techniques. However, they all found range of motion to be significantly restricted with the application of ankle tape. Lohrer et al <sup>30</sup> used two different tape techniques, the first being crossed dorsoventral and mediolateral straps and the second same as the first plus adding figure-8's. Overall, they found both tape techniques to significantly reduce range of motion.<sup>30</sup> Paris et al <sup>40</sup> used the same tape technique used in our study, Gibneys closed basketweave. They compared this to ankle braces and found tape to significantly reduce range of motion.<sup>40</sup> Gross et al <sup>22</sup> used a subtalar sling ankle tape versus ankle brace. They found both before and after exercise ankle tape significantly reduced range of motion, even though ankle tape lost some restriction.<sup>22</sup> Pederson et al <sup>41</sup> tested ankle tape and spitting. They found tape to significantly reduce range of motion. However, the combination of ankle tape and spitting was the most effective.<sup>41</sup> Ricard et al <sup>43</sup> wanted to know if prewrap changes the effectiveness of ankle tape. They found prewrap to have no difference on the effectiveness, and ankle tape to significantly reduce inversion before and after exercise.<sup>43</sup>

Ankle tape has significantly reduced range of motion; however, the biggest challenge with ankle tape is how quickly it loosens after activity. Myburgh et al <sup>35</sup>, Paris et al <sup>40</sup>, Fumich et al <sup>19</sup>, and Sharpe et al <sup>48</sup> found ankle tape to loosen significantly after activity. Myburgh et al <sup>35</sup> studied ankle tape during squash practice. They found tape began to loosen after 10 minutes of exercise, and provided no support after one

hour of practice.<sup>35</sup> Paris et al<sup>40</sup> showed ankle tape to loosen after fifteen minutes of activity. This was found with both plantar flexion and inversion.<sup>40</sup> Fumich et al<sup>19</sup> agreed with Paris et al<sup>40</sup> in finding plantar flexion and inversion to increase after activity. Fumich et al<sup>19</sup>, however, found plantar flexion, dorsiflexion, and plantar flexion with eversion to loosen more than 50% with activity; eversion neutral, inversion neutral, and plantar flexion with inversion to loosen less than 50%.<sup>19</sup> Sharpe et al<sup>48</sup> used a similar tape technique used in this study, minus the stirrups, on ankles with a previous history of ankle instability. They tested tape, brace, and a combination of both. They found tape to be the least effective method of reducing ankle sprains due to how significant tape loosens after exercise.<sup>48</sup>

Tape has also been studied using neuromuscular control and joint position sense. Within neuromuscular control, Alt et al<sup>1</sup> tested healthy ankles with two different tape techniques using the trap door. They showed tape to improve joint stability and be capable of reducing the extent of inversion; be able to protect the ankle from inversion trauma.<sup>1</sup> Researchers also found tape to significantly loosen after activity. Karlsson and Andreasson<sup>27</sup> tested neuromuscular control as well. They tested individuals who had one unstable and one stable ankle using the trap door. They found tape to increase peroneal latency in the unstable ankle. However, they concluded the unstable ankle with tape was still not as quick as normal reaction time in the stable ankle.<sup>27</sup>

Joint position sense research found tape to be beneficial, as well as to have no effect. Simoneau et al<sup>49</sup> and Robbins et al<sup>44</sup> both found tape to have positive effects on

healthy ankles. However, Kaminski et al <sup>26</sup> and Refshauge et al <sup>42</sup> found tape to have no effect on both healthy and recurrent unstable ankles.

In summary, our prophylactic ankle tape may have impaired medial/lateral TTS. Since the literature indicates that ankle tape restricts range of motion, our ankle tape condition may have reduced range of motion in the ankle joint, causing individuals to change their jump technique enough to impair the results. Restricting range of motion on healthy ankles could have played a big part on impacting the results. This could have changed the jump technique, as well as inhibited the ankle muscles that stabilize the ankle joint to act as they needed to. The jump technique was notably changed through the tape, brace, and combination conditions. Some individuals had difficulty jumping. With the restriction of the tape, for example, individuals had trouble pushing off with the involved ankle; although, most of the complaints came with landing. Many individuals soften their landing by plantar flexing and landing on their toes first. Subjects anecdotally reported that both ankle tape and ankle brace restricted plantar flexion. Due to this being their normal technique for landing they changed the way they landed during these conditions. This could have changed the results.

#### Combination of Ankle Tape and Brace

Tape and brace combined was our fourth condition tested. We thought testing the combination would explain current clinical practices and add to the minimal literature available. We found no significant results with ankle tape and brace on TTS. Perhaps this could be due to the same reasons tape was not found to be effective. Ankle tape and brace possibly had the same effect on jumping techniques and the ankle

muscles as ankle tape alone did. Ankle tape and brace was the most commonly complained about condition due to its bulkiness and restriction on range of motion. The research agrees with ankle tape and ankle brace restricting range of motion individually.<sup>17, 19, 22, 23, 30, 35, 40, 41, 42, 43</sup> Therefore, the combination of ankle tape and brace should have the same effect on the ankle joint.

Little research has been published on the combination of ankle tape and ankle brace. Sharpe et al<sup>48</sup> tested ankle sprain recurrence using ankle tape, ankle brace, and the combination of ankle tape and brace. As similar tape technique as used in this study, as well as a soft ankle brace. The results showed the combination of ankle tape and brace had the same results as ankle tape alone. Due to the little research on the combination of ankle tape and brace, there is no evidence indicating that this combination treatment is effective.

### Healthy Subjects

Our study tested healthy ankles for various reasons. No published articles have shown any effects of ankle tape or brace on TTS. We wanted to first test healthy subjects to find any treatment effects that they may have on this measure. From that data further studies can be conducted.

If individuals with functional ankle instability or with acute ankle sprains were tested the results probably would have shown different findings. The greater part of the literature agrees with functional ankle instability and healthy ankles reacting different. Baier and Hopf<sup>3</sup> looked at both functional ankle instability and healthy ankles. They showed no significant difference with the healthy group. However, they showed

mediolateral sway velocity to be reduced in functionally unstable ankle with the use of ankle orthosis.<sup>3</sup> Tropp et al<sup>53</sup> examined semirigid ankle orthosis and ankle disk training on reducing incidence of ankle sprains. No significance was found with healthy ankles, while ankle sprain injury incidence rates were lowered in functionally unstable individuals.<sup>53</sup>

### Time to Stabilization

Time to stabilization has examined the difference between healthy and unstable ankles. Brown et al<sup>8</sup> found that functional ankle instability was associated with longer TTS in the anterior/posterior direction, while the medial/lateral TTS was not affected by ankle instability. The authors believed this was due to the injured anterior talofibular ligament not being able to prevent anterior displacement of the talus. However, this same rationale does not hold true for healthy ankles. Our finding of a longer anterior/posterior TTS could be caused by either the changes in landing techniques or the way the other joints affected the ankle.

Most TTS literature published have examined the difference between stable ankles and functionally unstable or acutely injured ankles. No published TTS articles to date have assessed the measure using ankle tape or ankle brace. Wikstrom et al<sup>55</sup> set in motion research on different ankle supports using the same jump-landing method; however, a different measure was used to find their results. They studied dynamic postural stability using both soft and semirigid ankle braces. Another difference, besides the measure, compared with this study is the population used was functionally unstable ankles. They found no improvement using dynamic postural stability index,

but an improved result using vertical stability index.<sup>55</sup> Our study had major differences from Wikstrom et al's<sup>55</sup> study; however, Wikstrom et al's<sup>55</sup> also showed ankle braces to have a positive effect on dynamic postural stability. Therefore, our study agrees with Wikstrom et al<sup>55</sup> on showing ankle braces to have a medium treatment effect (effect size = 0.50) on dynamic postural stability.

In examining the literature, a likely hypothesis would be that functionally unstable ankles and acute injured ankles would respond different to TTS than healthy ankles. Ross et al<sup>45</sup> concluded jump-landing may be more challenging with functionally unstable ankles than single leg stance. Perhaps the same is true with all different measures in the literature. Even though no statistically significant difference was found in this study with ankle tape, ankle brace, and the combination of ankle tape and brace, there still is a possibility that a difference will be found looking at either functionally unstable ankles or acute injured ankles.

A limitation to our study was that the jump landing method used is not a common movement for athletes outside of volleyball and basketball. The ability to decelerate the body and stabilize on one leg is a complex movement that takes time to master. None of our subjects were volleyball or basketball athletes. The majority of our subjects had either a harder time jumping or landing due to the restriction of plantar flexion. This may hold true for brace, tape, and combination conditions.

#### Clinical Significance

This study was chosen due the clinical use of ankle tape and ankle brace. Clinically, ankle tape and ankle brace is thought to prevent injury or further injury to

both stable and unstable ankles. The literature supports the use of both ankle tape and brace on ankles with a history of ankle sprains<sup>38</sup>; however, the literature does not support what is clinically practiced on healthy ankles. The literature does support the use of ankle tape or ankle brace individually on unstable ankles. Conversely, the literature does not support the use of ankle tape or ankle brace individually on stable ankles, or the use of the combination of ankle tape and ankle brace on either stable or unstable ankles. This study was conducted to provide literature support for clinical practice.

Based on the results found in this study a couple clinical recommendations can be made. Clinical recommendations that can be made are for healthy, stable ankles. Ankle tape or the combination of ankle tape and brace will not affect dynamic stability. Ankle brace alone, however, could possibly play some role in aiding the ankle joint with support in the medial/lateral plane. Future research is needed to determine if this finding holds true.

### Conclusion

Based on the results found in this study it can be concluded that future studies need to be conducted to confirm or deny any possible theories. It can also be concluded that ankle tape and the combination of ankle tape and ankle brace have little effect on healthy ankles. Ankle brace alone may be the only ankle support that can provide positive results for healthy ankles. Further studies could examine the effect of ankle tape, ankle brace, and the combination of ankle tape and ankle brace on functionally unstable ankle and acute injured ankles using TTS. Future studies can also look at the

effect of TTS method on the knee and hip joints. Lastly, jump techniques and the effect on the ankle muscles using TTS methods could show different results or confirm findings.

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