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Heavy elastic vs. white tape: the effect of ankle taping on ankle range of motion

Laura B. Grambo
Western Washington University

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HEAVY ELASTIC VS. WHITE TAPE: THE EFFECT OF ANKLE TAPING ON ANKLE RANGE OF MOTION

A Thesis
Presented to
The Faculty of
Western Washington University

In Partial Fulfillment
Of the Requirements for the Degree
Master of Science

by
Laura B. Grambo
May, 2010
Abstract

Previous research has found that with exercise, athletic tape loses some of its restricting properties. Different kinds of tape have been developed in order to decrease this change in restriction. The effects of heavy elastic tape were compared with white tape after fifteen minutes of multi-directional exercise. Twenty-seven volunteers participated in the study. Subject’s ankle range of motion (ROM) was measured with a manual goniometer before the application of the tape, immediately after application of tape and after 15 minutes of multi-directional exercise. Range of motion was measured in four directions: plantar flexion, dorsiflexion, eversion, and inversion. Data collected was analyzed using SPSS in a two-way repeated measures ANOVA for the main effects of Time and Condition, as well as an interaction effect of Time by Condition. If these effects were found to be significant ($p < .05$), then a paired t-test was performed within the effect. White tape and heavy elastic tape both restricted ankle range of motion immediately after application in a similar manner. After 15 minutes of exercise, both tapes restricted ankle motion in a comparable manner across three of the four ranges of motion (plantar flexion, dorsiflexion, eversion), but heavy elastic tape restricted inversion ROM greater than the white tape (mean change = $1.77 \pm 2.96^\circ$, $p < .001$, $r = 0.52$). Therefore, heavy elastic tape maintained a greater restriction in inversion ROM at the end of exercise, and may therefore be a better choice than white tape for an athlete recovering from an inversion ankle sprain and/or lateral instability, at least during a short term (15 minute) exercise session.

Keywords: ankle taping; heavy elastic tape
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Chapter I

The Problem and Its Scope

Introduction

The sports medicine staff plays a critical role in an athletes’ success, specifically when returning to play following an injury. While the structural help is there, the mental reassurance an athlete can have from an ankle taping allows for them to focus on their task and not their injury.

Tape is no longer just the white-cotton material it once was. There are various types of tape, including a light-elastic, stretchy, tape that is ideal for covering band-aids or cuts. Powerflex tape is also a stretchy tape, however it is not as sticky as light-elastic. This tape is used for covering tapings that could potentially be pulled apart (shin tapings), but does not need to add any extra restriction. Heavy-elastic tape is a strong, elastic material. It is more restrictive than light-elastic tape, but has more “give” than the traditional white tape. It is commonly used for athletes who are returning to play after an ankle sprain to help increase stability. With an increase in specialty of the tape, however, also comes an increase in cost.

A cost-benefit analysis performed by Olmsted, Vela, Denegar, and Hertel (2004) found that, during a thirteen-week season, an individual athlete would have a single ankle taped 78 times. Olmsted and company allowed for six practice sessions and one game session per week. This number, however, did not include pre-season practices or potential postseason activities. The total cost-benefit analysis determined that ankle taping would be 3.05 times as expensive as ankle bracing over a typical competitive season (Olmsted, Vela, Denegar, & Hertel, 2004). Despite the considerable cost, athletes...
still have their ankles taped on a regular basis. The amount of tape used in an ankle taping will vary based on the size of the athlete’s leg. A common rule is to allow an entire roll of white tape to be used when taping a college football player’s ankle. In 2004, to tape twenty-six athletes an entire season with white tape would cost close to $2,778 (Olmsted et al., 2004). A sports medicine supply company, Medco (http://www.medco-athletics.com/), lists the current price of basic athletic tape at close to $1.50/roll ($48.95 for 32 rolls of tape). Heavy elastic tape is priced at $5.25/roll causing the season cost of taping an ankle to increase a sizeable amount.

While a standard ankle taping has been commonly compared with the use of prophylactic braces in research, only a handful of studies have been done to analyze the effectiveness of different types of tape. There is a need to evaluate whether this more expensive tape provides more support, since it is used by certified athletic trainers (ATCs) in situations where they intend to provide increased support to athletes who have sustained an injury.

**Purpose of the Study**

The purpose of this study was to compare the range of motion of the ankle following a 15 minute multi-directional exercise intervention under two taping conditions: non-elastic white tape and heavy elastic tape in a modified Gibney closed basket weave ankle taping.

**Hypothesis**

Heavy elastic tape will result in a greater restriction than non-elastic white tape of ankle range of motion after fifteen minutes of multi-directional exercise.
**Significance of the Study**

Ankle sprains are a frequent injury within athletics. The classic procedures of an ankle taping are not always enough for an athletic trainer to help a player return to play quickly and with confidence that the athlete will not be reinjured. If new technology and techniques are found to be effective, they should be incorporated into an athletic trainer’s repertoire in an effort to maintain the athlete’s health. It is necessary to identify whether one method is superior over another.

**Limitations of the Study**

The following limitations were recognized for this study:

1. The basket weave technique is a standard technique for basic ankle protection and prevention. It is also commonly used in previous research studies (Alt, Lohrer, & Gollhofer, 1999; Firer, 1990; Laughman, Carr, Chao, Youdas, & Sim, 1980; Lindley & Kernozek, 1995; MacKean, Bell, & Burnham, 1995; McCaw & Cerullo, 1999; McCluskey, Blackburn, & Lewis, 1976; Purcell, Schuckman, Docherty, Schrader, & Poppy, 2009; Ricard, Sherwood, Schulthies, & Knight, 2000; Robbins, Waked, & Rappel, 1995; Verbrugge, 1996). However, taping procedures and patterns will vary depending on the clinician performing the taping. Therefore, these results can only be generalized to the taping techniques used in this study.

2. In the current study, subjects were not required to be clean-shaven. This was done in order to provide standardization between the clinical findings and a typical athlete who may or may not shave their leg before being taped.
3. Manual goniometry is not as precise as electric goniometry, but is a method that is commonly used in athletic training, and the reliability of the measurements is high when a single trained athletic trainer conducts the measurements (Elveru, Rothstein, & Lamb, 1988; Menadue, Raymond, Kilbreath, Refshauge, & Adams, 2006).

4. The exercises that the subjects performed are general and therefore the results cannot be linked with any one specific sport.

5. The type of tape may influence the way an ATC tapers an ankle, since one can pull harder on heavy elastic tape compared to white cloth tape.

**Definition of Terms**

**Abduction:** Movement of a body part away from the middle of the body (Prentice, 2003).

**Adduction:** Movement of a body part towards the middle of the body (Prentice, 2003).

**Active Range of Motion (AROM):** Motion that occurs because of a muscle contraction (Prentice, 2003).

**Analysis of Variance (ANOVA):** A statistical procedure that uses the F-ratio to test an overall fit of a linear model. This linear model tends to be defined in terms of group means and is a test of whether group means differ (Field, 2005).

**Anatomical Position:** A reference position where the body is in a supine position and viewed from the anterior surface with the palms facing forward (Martini, Timmons, & Tallitsch, 2003).

**Anterior:** On or near the front (Martini et al., 2003; Prentice, 2003).
Anterior Drawer Test: A manual test of the ankle used to determine the extent of injury to the anterior talofibular ligament (Hoppenfeld, 1976; Prentice, 2003).


Ankle Joint: see Talocrural Joint

ATC: Certified athletic trainer (Prentice, 2003).

Avulsion: Forcible tearing away of a portion of a structure (Prentice, 2003).

Calcaneofibular Ligament (CF): A ligament that begins at the tip of the lateral malleolus distally and inserts slightly posterior to the peroneal tubercle of the calcaneus, and restrains inversion of the calcaneus (Anderson et al., 1962; Percy et al., 1969; Prentice, 2003).

Crepitus: The noise produced by rubbing bone or irregular cartilage surfaces together; popping or grinding within a joint (Prentice, 2003).

Deltoid Ligament: A ligament originating at the medial malleolus and fans out to insert at the calcaneus, talus, and navicular bone that limits eversion and anterior displacement of the talus (Brostrom, 1964; Prentice, 2003).

Distal: Farthest from the trunk (Prentice, 2003).

Dorsal: Posterior or towards the back (Martini et al., 2003).

Dorsiflexion: Ankle flexion, opposite of plantar flexion (Martini et al., 2003; Prentice, 2003).
Eversion: Where the plantar surface moves away from the midline of the body in the frontal plane (Prentice, 2003).

Eversion Sprain: Caused by an excessive amount of eversion at the foot; results in injury to the medial ligaments/structures (Prentice, 2003).

Fracture: A break or crack in bone (Martini et al., 2003).

Inferior: Directional reference meaning below (Martini et al., 2003).

Inversion: Where the plantar surface moves toward the midline of the body in the frontal plane (Prentice, 2003).

Inversion Sprain: The mechanism of an inversion ankle sprain involves inversion resulting in injury to lateral ligaments (Prentice, 2003).

Isokinetic Exercise: Resistance is given at a constant velocity of movement (Prentice, 2003).

Isometric Exercise: Tension is produced without a change in length occurring (Prentice, 2003).

Isotonic Exercise: Segment moves a specified weight through a range of motion (Hamill & Knutzen, 2009).

Lateral: Referring to the outer side, away from the midline (Martini et al., 2003).

Medial: Referring to a position toward the midline of the body (Martini et al., 2003).

Mortise: The space formed by the medial and lateral malleoli, where the talus fits and creates the ankle joint (Hoppenfeld, 1976).

Palpate: To inspect through touch (Martini et al., 2003).

Palpation: Feeling structures with the fingers (Prentice, 2003).
Passive Range of Motion (PROM): Movement performed solely by the examiner (Prentice, 2003).

Plantar: Referring to the sole of the foot (Martini et al., 2003).

Plantar Flexion: Ankle extension, to “point” ones toes (Martini et al., 2003).

Posterior: On or toward the back (Martini et al., 2003; Prentice, 2003).

Posterior Talofibular Ligament (PTF): Ligament that originates at the posterior, inferior portion of the lateral malleolar fossa and inserts at the upper surface of the posterior tubercle of the talus. Aids in restricting posterior displacement of the talus Restrains posterior displacement of the talus (Anderson et al., 1962; Brostrom, 1964; Callaghan, 1997; Percy et al., 1969; Prentice, 2003).

Prone: Lying with face down (Martini et al., 2003)

Proprioception: The ability to determine the position of bones, joints and muscles in space (Martini et al., 2003).

Proprioceptor: A sensory receptor that responds to stimuli elicited from within the body (Prentice, 2003).

Proximal: Nearest to the trunk (Prentice, 2003).

Strength: Ability of a muscle to generate force against resistance (Prentice, 2003).

Superior: Directional reference meaning above (Martini et al., 2003).

Supine: Lying face up (Martini et al., 2003).

Sprain: Forceful distortion of an articulation that produces damage to the capsule, ligaments, or tendons but does not cause a dislocation (Martini et al., 2003).

Talocrural Joint: The talocrural joint is formed by medial and lateral malleolus, roof of the tibia, and dome of the talus, creating the ankle joint (Prentice, 2003).
Chapter II

Review of Literature

Introduction

This chapter presents a review of ankle anatomy, including the role the anatomy plays in stabilizing the joint. A description of the various grades of ankle sprains and how injuries affect strength and proprioception, as well as the rate of occurrence of injury in specific sports will be presented. Aides for ankle injuries, such as braces and taping, are examined as they affect strength, proprioception, range of motion and their overall effectiveness in reducing the risk of recurring injuries. As the purpose of this study was to compare two types of tape utilized in the same taping method, an in depth look will be taken at common techniques and a review of different materials used and their efficiency on restricting range of motion.

Anatomy of the Ankle

To appreciate the ankle and the complexity of its injuries, an understanding of what composes the ankle joint must first be established. Both rigid and soft tissues play an important role in the stability and functional abilities of the ankle. The ankle is susceptible to injury because of poor ligamentous stabilization, muscular support, and bony stability (Anderson, 1996).

Bony Anatomy. Anatomy books (such as Human Anatomy by Martini, Timmons, and Tallistch (2003)), and athletic training books that are staples in the profession (including Physical Examination of the Spine and Extremities, by Hoppenfeld (1976) and Arnheim’s Principles of Athletic Training: A Competency-Based Approach Eleventh Edition by Prentice (2003)), describe the gross anatomy in a very complete manner. The tarsal
bones of the foot consist of the calcaneus, talus, navicular, cuboid and three cuneiforms. The calcaneus, or “heel” bone, is the largest tarsal bone and is inferior to the talus. It conveys the body weight to the ground and serves as the attachment site for the Achilles tendon and several structures on the plantar, medial and lateral surfaces. The talus bone is irregularly shaped and is the most superior of the tarsal bones. The most superior part of the talus is the trochlea, which articulates with the lateral and medial malleolus to form the ankle joint (talocrural joint). The talus fits principally into the space formed by the medial and lateral malleolus, which restricts the amount of lateral movement due to the length of the fibula. This space is referred to in the literature as the “mortise” (Hoppenfeld, 1976). The talus has a broader anterior portion than posterior portion which prevents the tibia from slipping forward during locomotion. The broad anterior portion also increases bony stability, as it provides a tighter fit within the mortise, decreasing excessive movement. The navicular bone is on the medial aspect of the foot and anterior to the talus. The cuboid is on the lateral aspect of the foot. It lies anterior to the calcaneus and articulates with the fourth and fifth metatarsals. There are three cuneiforms in the foot. They are labeled as medial, intermediate, and lateral cuneiforms and are located between the navicular and base of the first three metatarsals. Distal to the tarsal bones are the metatarsals. Metatarsal bones are described as having a base, shaft and head. The base is proximal, the head distal, and the shaft between the two. The most medial metatarsal is labeled as the first metatarsal, while the most lateral, the fifth metatarsal bone. The digits are made of three phalanx bones: proximal, middle and distal phalanx, where the proximal phalanx
articulates with the head of the fifth metatarsal bone. The phalanx of the first metatarsal bone, or great toe, however, only has two sections: the proximal and distal phalanx.

**Talocrural Joint.** The talocrural joint is formed by the medial and lateral malleolus, the articular surface of the distal end of the tibia, and dome of the talus (Prentice, 2003). The shape of the talocrural joint allows for torque to be transmitted from the leg to the foot during weight bearing motions. This joint is also called the “mortise” joint (Hertel, 2002). It is considered a hinge joint as it allows for plantar flexion and dorsiflexion. The axis of rotation passes through the medial and lateral malleolus. The average range of motion (ROM) of an ankle is about 33 degrees of inversion, 18 degrees of eversion, 48 degrees plantar flexion and 18 degrees of dorsiflexion as estimated from The American Academy of Orthopaedic Surgeons and presented by Boone and Azen (1979).

**Subtalar Joint.** The subtalar joint is formed by the articulations between the talus and calcaneus and, much like the talocrural joint, it converts torque between the lower leg and the foot. This joint allows for inversion and eversion to occur. The joint is also complicated by two separate joint cavities. The posterior subtalar joint is formed between the talus and the inferior posterior facet and the superior posterior facet of the calcaneus. The anterior subtalar joint is formed by the head of the talus, sustentaculum tali of the calcaneus, and concave proximal surface of the tarsal navicular. This is similar to a ball and socket joint, where the talar head is the ball and the anterior calcaneal and proximal navicular surfaces form a socket (Prentice, 2003).
**Soft Tissue**

**Lateral Ligaments.** Soft tissue plays a large role in protecting the ankle when it is in plantar flexion, as this is the position most lacking bony support because of the narrow posterior portion of the talus. There are three primary ligaments on the lateral aspect of the ankle that aids in its support.

The first is the anterior talofibular ligament (ATF). It runs from the anterior portion of the lateral malleolus medially and anteriorly toward the neck of the talus (Anderson et al., 1962; Brostrom, 1964; Callaghan, 1997; Percy et al., 1969). The ligament is usually between 6-8 mm wide and around 2 cm long (Brostrom, 1964). The ATF is tense when the ankle is in either a plantar flexed or dorsiflexed position (Brostrom, 1964). This is the most easily injured of the ligaments (Wolfe, Uhl, Mattacola, & Mccluskey, 2001).

The second ligament is the posterior talofibular ligament (PTF). The ligament runs from the inferior, posterior portion of the lateral malleolar fossa medially and slightly posteriorly to the upper surface of the posterior tubercle of the talus (Anderson et al., 1962; Brostrom, 1964; Callaghan, 1997; Percy et al., 1969). It is known as the strongest of the three fibular collateral ligaments (Brostrom, 1964; Wolfe et al., 2001). The PTF is taut when the ankle is in full dorsiflexion (Percy et al., 1969).

The middle portion of the lateral ligaments is the Calcaneofibular ligament (CF). It starts at the tip of the lateral malleolus distally and slightly posteriorly and runs towards the middle of the lateral surface of the calcaneus, just superior and posterior to the peroneal tubercle (Anderson et al., 1962; Percy et al., 1969). When the foot is in a plantar flexion position the CF lies almost at right angles to the fibula (Brostrom, 1964).
The tension increases only when there is a large amount of inversion movement from the calcaneus (Brostrom, 1964).

**Medial Ligaments.** Medially, the deltoid ligament is the supporter of the ankle (Wolfe et al., 2001). It is a group of four specific ligaments that are arranged in a fan-like fashion. The deltoid ligament begins at the medial malleolus and fans out to attach to the calcaneus, talus, and navicular bone (Brostrom, 1964). The posterior tibial muscle tendon sheath covers the mid and posterior portions of the deltoid ligament (Brostrom, 1964).

**Muscles Working in Ankle Function.** Dynamic protection of the joint comes from contraction of the musculotendinous units which generate joint stiffness. The muscles that cross the ankle complex are often described based on their actions (Prentice, 2003). The muscles in the anterior compartment of the leg (peroneus tertius, extensor digitorum brevis, extensor digitorum longus, and anterior tibialis) can contribute to the dynamic stability of the lateral ankle complex by acting eccentrically during forced inversion (Martini et al., 2003). The muscles in the anterior compartment slow the plantar flexion component of supination and therefore reduce the risk of injury to the lateral ligaments (Hertel, 2002). The peroneus brevis and longus muscles are integral to the control of inversion and protect against lateral ankle sprains. The ankle plantar flexion muscles exert at least modest levels of activation at all times (Weaver, Price, Czerniecki, & Sangeorzan, 2001).

*How bony and soft tissue structures play a role in stability.* The greatest amount of bony stability of the ankle occurs in a position of dorsiflexion and eversion (Anderson, 1996; Wolfe et al., 2001). Commonly, pronation refers to a combination of
the motions dorsiflexion, eversion and forefoot abduction while supination refers to a combination of plantar flexion, inversion and forefoot adduction (Hamill & Knutzen, 2009). For the purpose of this study, however, inversion and eversion will be primary focus. The wider portion of the talus, the anterior portion, engages in the ankle mortise when the foot is in a dorsiflexed position. This creates a tighter fit with less laxity and therefore puts less reliance on the soft tissues for support. The position in which a majority of ankle sprains occur is plantar flexion and inversion (Anderson, 1996). In a plantar flexed position, the narrow, posterior portion of the talus is engaged in the ankle mortise (Wolfe et al., 2001). When the posterior portion of the talus is engaged in the ankle mortise, a greater ROM is found with inversion and eversion movements, due to the space created in the mortise (Anderson, 1996). Subsequently, there is little bony support and the ankle relies on soft tissue to be the primary structures of stability. Soft tissues, such as muscles and ligaments, are not as strong as the bone and therefore make the structures of the ankle more susceptible to injury.

The lateral malleolus extends further distally than the medial malleolus. This length difference creates less restriction on the medial side and allows for inversion at the calcaneus with respect to the talus (Wolfe et al., 2001). The position of the malleolus as well as the talus’ fit within the mortise make an inversion ankle sprain much more common than an eversion ankle sprain. When an eversion ankle sprain does occur, however, the overall damage that occurs is much greater (Anderson, 1996). When the ankle is forced into eversion a large amount of stress is placed on the lateral malleolus which may result in a fracture of the fibula.
Various degrees of ankle sprains

Ankle sprains most commonly involve the lateral ligaments (Milgrom et al., 1991). The widespread guidelines for classification of ankle sprain severity involve three grades. Sprains to single ligaments are typically graded “mild”, “moderate”, or “severe” or “I”, “II”, or “III”. A grade I, mild sprain, describes a stretch to a ligament that causes point tenderness and pain, but no laxity. A grade II, moderate sprain occurs if there is a partial tear to a ligament. This can be found with the help of stress tests, such as the Anterior Drawer test at the ankle (Hoppenfeld, 1976; Prentice, 2003). In this test, a certain amount of movement can be seen in the ATF but an end point is felt. A grade III, severe sprain, is a complete tear of a ligament and on occasion is associated with an avulsion fracture (Anderson, 1996). The Anterior Drawer test would have no pain and no end point, meaning a complete tear of the ATF (Prentice, 2003).

Repercussions of Ankle Sprains

Verhagen, van der Beek, Twisk, Bouter, Bahr and van Mechelen (2004) stated, “there is no such thing as a simple ankle sprain.” After an ankle has been sprained once, multiple sprains follow thereafter. While the exact reason for this chronic injury is yet to be determined, several studies have been executed to establish possible causes. Yeung, Chan, So and Yuan (1994) distributed a survey to 380 athletes with a history of ankle sprains. They found that athletes with multiple ankle sprains will complain of chronic crepitus, instability, stiffness and weakness in their injured ankle more than athletes with a single sprain (Yeung, Chan, So, & Yuan, 1994). Possible causes for ankle injury recurrence are stretching of the fibers or of the collagen of the ankle ligaments,
whereby the fibers are partially or completely disrupted (Diamond, 1989; Quigley, 1959)

**Physiological Repercussions.** Tissue damage and several physiological interactions occur during an ankle sprain (Starkey, 1976). Initially the metabolic rate will increase, elevating the tissues’ temperature in an attempt to aid injured cells. Once the metabolism increases, capillaries in the injured area dilate causing hydrostatic pressure of the interstitium to increase, which will, along with any interruption of blood flow, increase passage of serous fluid into the injury site causing edema. Lastly, the initial injury excites nerve endings causing pain to occur. An excessive amount of swelling and pressure, caused by an increase in blood and serous fluid in the area, causes damage to the pain receptors, maintaining the pain impulse. The response will result in an unwanted hematoma and large amounts of edema if left untreated causing an increase in recovery time and a delayed return to play for an athlete (Starkey, 1976).

**Proprioceptive Repercussions.** Proprioception is commonly thought of as the ability to verify a joint’s position in space (Prentice, 2003). It can also be thought of as awareness of the positions of joints, bones and muscles (Martini et al., 2003). According to Lephart and Fu (1995) “proprioception is mediated by afferent input from articular, muscular and cutaneous structures” (Lephart & Fu, 1995).

Nakasa, Fukuhara, Adachi, and Ochi (2008) found a deficit of joint position sense when comparing a healthy ankle versus an unstable ankle. Functional instability was defined as a chronic ankle inversion sprain and a giving way sensation. The difference between the index angle (reference angle) and replication angle was measured in 12 subjects while 17 healthy volunteers served as control group. Subjects were seated
with the knee flexed at 70°. Their foot was placed on a manual goniometer footplate and was randomly passively rotated internally at one of six positions while the subjects were blindfolded. The ankle was held in the position for 5 seconds, returned to 0° degrees and the subject was asked to replicate the previous test angle actively. The difference between the initial and replication angles was recorded as replication error. Replication errors were recorded for the unstable group as well as the stable ankle group. The unstable group had stable ankle error of 2.3° ± 0.9° while the unstable ankle error was 3.4° ± 1.0°. The replication error of the left ankle was 2.1° ± 0.6° and that of the right ankle was 2.3° ± 0.8° in the control group. The side-to-side difference of replication errors was 0.2° ± 0.7° in the control group and 1.0° ± 0.7° in the unstable group. A statistical difference was seen between the two groups (Nakasa, Fukuhara, Adachi, & Ochi, 2008). The conclusion of the authors was that an unstable ankle has the deficit of joint position sense in comparison with healthy subjects. Mechanoreceptors present in the structures of the lateral aspect of the ankle including the retinaculum, lateral ligaments, and capsule are damaged in an inversion ankle sprain. This could be the potential reason for a diminished position sense.

Gross (1987), however, found that ankle sprain injuries do not significantly affect an individual’s ability to judge ankle position. Subjects between the ages of 18 and 35 years old and had suffered from chronic ankle sprains. Three groups were divided by three different criteria. Group 1 had sustained recurrent unilateral ankle sprains involving lateral ligaments. Group 2 was the non-sprained contralateral ankles of the Group 1 subjects. Group 3 was the control group and had never sustained any injury to either ankle. Subjects were tested with six active and passive trials for each ankle. Two
electromyographic biofeedback units with surface electrodes were used during the passive trials to assist the subjects to maintain a relaxed state. Testing was performed by the Cybex II isokinetic dynamometer. The subject was blindfolded for testing. The ankle was put into a test position passively and held for 15 seconds. The ankle was then moved first to one extreme range of motion, and then to the opposite extreme. As the experimenter moved the ankle back toward the test position, the subject was instructed to say “stop” when they felt that the test position had been replicated. The trial was repeated twice at each of the three test positions. For each trial, the absolute difference in degrees of ROM between the test position and the position chosen by the subject was recorded. For each trial, the absolute difference in degrees of ROM was recorded, but the values were not reported in the manuscript. The sum of absolute difference measures for the six passive trials yielded a total error passive sum. A total error passive measure and a total error active measure were calculated for each subject. The results of the study suggest that ankle sprain injuries do not significantly affect an individual’s ability to judge ankle position. Passive judgments, however, were significantly better than active judgments among subjects with uninjured ankles. Joint receptors that play dominant roles in joint angle detection and muscle receptors become damaged during the stretching process of an ankle sprain. However, the authors suggested further research be done in order to shed further light on the extent of joint injury on position sense.

Docherty, Arnold, Zinder, Granata, and Gansneder (2004) suggest that proprioception and stiffness both contribute to joint stability. Healthy, male, college students were used in the study. All subjects were active and asymptomatic at the time
of the study. Subjects were tested on three separate conditions. During the first session, subjects underwent maximal voluntary isometric contraction testing as well as joint reposition sense testing. A custom-designed electric goniometer was blocked, allowing for only eversion and inversion motion to be performed. The second session required the subjects to perform a force-matching protocol, and on the third day, ankle stiffness was measured. For stiffness measurement, each subject stood on a custom-made eversion-inversion cradle device. A small, weighted ball was dropped on the corner of the device to perturb the cradle. Subjects were instructed not to interfere or assist with the inversion and eversion motion caused by perturbation. Transient motion oscillations were recorded with a potentiometer that had been aligned with the axis of rotation of the cradle. The decay and frequency of the rotational oscillations were calculated and from this information, stiffness of the ligaments was calculated in Newton meters per radian (Nm/rad). Significant correlations were found between force sense and stiffness ($r = 0.47 – 0.65$). Force matching was tested with unilateral and contralateral reproduction at 10% and 30% of the maximal voluntary isometric contraction (MVIC). The subjects used the digital readout from the load cell to establish the target force, and once obtained, they were asked to maintain the isometric contraction for five seconds and then relax. The authors suggest stiffness may be altered following an injury. They suggest two possible causes for the relationship: One explanation could be because of a decreased ability to appropriately sense force, which sends information to the central nervous system to increase muscle stiffness in a passive situation responds to an unexpected loss of stability. Another theory is that the
two function independently and change concurrently as a result of injury to the system (Docherty, Arnold, Zinder, Granata, & Gansneder, 2004).

People with chronic ankle sprains have impaired proprioceptive abilities and are more prone to repetitive ankle sprains, as reported by Hertel (2002). The study searched MEDLINE for articles published between the years 1985 and 2001 as well as CINAHL, from 1982 to 2001 using the key words ankle instability and ankle sprain. The review also concluded that slow nerve-conduction velocity and impaired cutaneous sensation were reported as indicators of common peroneal nerve palsy after acute lateral ankle sprain (Hertel, 2002).

Nakasa et al. (2008) add from their study (described previously) that the cause of chronic ankle instability is functional instability, caused by a deficit of sensorimotor control, as well as impairment in mechanical stability. This information can be used to potentially assess individuals at risk for ankle sprains. A study presented by Fu and Hui-Chan (2005) examined 36 male basketball players, 17 of which were healthy and 18 who had suffered bilateral ankle sprains within the last two years. After the examiner placed the joint either passively or actively, the subject was asked to reproduce a position from memory in order to examine joint repositioning error. When compared with the healthy group, the ankle sprained group had increases in joint repositioning errors (healthy players: right ankle = 1° ± 0.4°, left ankle = 0.8° ± 0.2°; injured players: right ankle = 1.4° ± 0.7°, left ankle = 1.1° ± 0.5°) at five-degrees of plantar flexion, which were deemed significant after a repeated-measures analysis of variance (ANOVA) (p < .05). This study found that close to 40% of the injured athletes that participated complain of postural instability, which may make them susceptible to further injuries
(Fu & Hui-Chan, 2005). Overall, it was concluded that there is an increase in passive ankle joint repositioning errors in male university basketball players, which may predispose them to further injuries.

Proprioception contributes to joint stability (Docherty et al., 2004). Functional instability arises from sensorimotor control deficits (Freeman, 1965). With a loss of proprioception, and subsequently functional stability, people are at greater risks for re-injury (Fu & Hui-Chan, 2005; Hertel, 2002). Mechanoreceptors that are present in the structures of the lateral aspect of the ankle, including the ligaments and capsule, become damaged by the mechanism of an inversion ankle sprain might result in functional instability (Nakasa et al., 2008).

**Effects of Ankle Sprains on Strength.** Weakness of the muscles which evert or pronate the ankle has been demonstrated following an eversion ankle sprain (Bosien, Staples, & Russell, 1955). The peroneus brevis and longus muscles are the primary movers during an eversion action.

A study done by Bosien, Staples, and Russell (1955) found that people with ankle sprains a large percentage had peroneal muscle weakness. The population used in this study were college aged and had been treated for an ankle sprain in their college career in the classes of 1953 and 1954. The student’s charts were examined and author’s requested a follow-up examination that occurred between two months and 45 months post-injury. A manual examination of the ankles showed the relative weakness of the peroneal muscles in 29 of the cases. Of the 35 injuries with residual changes (swelling, point-tenderness), 23 had peroneal weakness, which was a statistically significant
finding in the study. This theory suggests that the weakness may be due to
overstretching or disuse of the muscles themselves (Bosien et al., 1955).

**Sports Risk**

Different sports have various levels of risk for injury because of the movements
involved in the sport as well as the precautions to reduce risk that are in place. Some
sports coaches urge athletes to wear protective braces or taping to help reduce their
risk, however there is still some debate on the effectiveness of these prophylactics.
Footwear can affect the rate of risk for an athlete. Football players, for example, wear
more supportive footwear than a basketball player. However, the uneven terrain and
cleated shoe create a hazard to the ankle. Anderson, LeCocq and Clayton (1962) suggest
that when the foot is fixed (i.e.; stuck in the ground because of the cleat), external
rotation of the leg provides an additional fulcrum to lever the talus out of the ankle joint
mortise around the fixed point of the internal malleolus. This theory could account for
an increase rate of risk because of footwear.

The rate of occurrence of ankle injuries was 6 per 100 participants per season
with one ankle injury for every 17 participants in a study done by Garrick and Requa
(1978). Four girls’ high school athletic programs were studied for two years. A total of
870 participant-seasons in nine sports resulted in 192 injuries, where nearly two-thirds
of injuries were accounted for by strains and sprains. Of the injuries, 65.7% of them
involved the lower extremity, with the ankle being the most often injured (16.7%) in
their sample of athletes (Garrick & Requa, 1978). The vast majority of these ankle
injuries (85%) were sprains.
In a study done by Baumhauer, Alosa, Renstrom, Trevino and Beynnon (1995), 145 men and women college-aged athletes participating in intercollegiate field hockey, lacrosse, and soccer had relatively few subjects (n=15 subjects) who incurred an inversion ankle sprain during the season (grade I = 12, grade II = 3). Four of these athletes had a prior history of grade I inversion ankle sprains involving the same ankle. From the remaining 130 uninjured athletes, 45 had a past history of a grade I inversion ankle sprain (Baumhauer, Alosa, Renström, Trevino, & Beynnon, 1995).

A study by Lanese, Strauss, Leizman, and Rotondi (1990) examined risk of injury in collegiate athletes. This study matched eight men's and women's varsity sports; basketball, fencing, gymnastics, swimming, tennis, indoor track, outdoor track, and volleyball. Of the 232 men in the study, 66 received 154 injuries. While of the 150 women monitored, 61 received 91 injuries. Strains and sprains were the most common injury with men encountering roughly 32% of injuries due to strains, and women receiving 32% of injuries in the form of a sprain. The most frequent site of injury was at the foot and ankle, which accounted for nearly 23% of injuries in men and 25% of injuries in women (Lanese, Strauss, Leizman, & Rotondi, 1990).

Yeung, Chan, So, and Yuan (1994) examined 380 athletes with previous ankle sprains ranging from 13 – 47 years old and varying in their competitive level that included Hong Kong National Team athletes, competitive athletes, recreational athletes, and a fourth group of athletes who took part in regular sports activities or training (e.g., policemen). Of the 380 athletes, 183 of them reported having bilateral ankle sprains, while 197 athletes reported unilateral sprains. Of the 197 athletes with unilateral ankle sprains, the dominant ankle was involved in 139 of the athletes, while the remaining 58
ankles injured involved the non-dominant ankle. The method of identification of the dominant ankle was not described by the authors, simply that the dominant ankle was used. A total of 563 sprained ankles were recorded with injury solely to the dominant leg’s ankle, which was 2.4 times higher than injury solely to the non-dominant side. Of these 563 ankles, 149 had only been sprained once, while 414 had been sprained at least twice. The recurrence rate of ankle sprains for athletes in this study group was as high as 73.5%. Lastly, 124 ankle sprains were reported to have occurred five or more times (Yeung et al., 1994).

In areas other than sports, ankle injuries are still common. During the course of a basic training, 69 of 390 military recruits (18%) sustained lateral ankle sprains. Three of the recruits had two ankle sprains during the period of basic training. The grades of the sprains varied between 1 (n=55), and grades 2 or 3 (n=14) (Milgrom et al., 1991).

Specific sports have research dedicated to their risks and/or rate of injury. This type of analysis is seen most frequently in activities where ankle sprains are common. Basketball and volleyball are two sports that are greatly at risk for injury and multiple ankle sprains are seen within a season. Other sports examined for risk of injury include softball, baseball, soccer, gymnastics, ice hockey, field hockey, wrestling and lacrosse.

**Basketball.** Ankle sprains are one of the most frequent sports injuries, particularly in basketball. Ankle sprains were also the most common injury in basketball in Garrick and Requa’s (1978) study of injury risk. Ankle sprains constituted 38% of all injuries in men’s basketball and 45% in women’s basketball. Due to the high frequency of ankle injuries within a single sport, there is much research dedicated to the topic (Garrick & Requa, 1978).
McKay, Goldie, Payne, and Oakes (2001) observed a total of 10,393 basketball participants that were elite (22.1%) as well as recreational (77.9%). Ankle injuries occurred at a rate of 3.85 per 1000 participants. Almost half (45%) of ankle injuries occurred during landing. Other mechanisms were sharp twist/turn (30%), collision (10%), fall (5%), tripping (2.5%), and sudden stopping (2.5%). The authors state that a history of ankle injuries was the strongest predictor for the occurrence of ankle injuries. Athletes who had previously injured their ankle were almost five times more likely to injure an ankle than someone who was not previously injured. Seventy-three percent of the basketball players reported a previous injury (McKay, Goldie, Payne, & Oakes, 2001). Overall, the risk for suffering an ankle injury was significantly greater for female than male basketball players (Garrick & Requa, 1978; Hosea, Carey, & Harrer, 2000).

Hosea, Carey, and Harrer focused on 95 high schools, colleges and university with male and female basketball teams for two years. Eighty-one of the institutions studied were high school programs, while the remaining fourteen were university or college. During the two years, 1,384 injuries to the knee and ankle were recorded, with 76% of injuries involving the ankle. Seventy-two percent of the injuries were grade I ankle sprains in male and female athletes. Females who participated in basketball at the collegiate level had a relative risk of 1.33: 1 for overall ankle injuries than compared to males, which was a trend toward significance with p = 0.059. Possible reasons for this apparent difference in sex are intrinsic and extrinsic factors. Extrinsic factors include equipment, level of playing time and level of competition. These factors can lead to an increased, or decreased, exposure to potential risks. Intrinsic factors, such as, age, strength, joint
stability, limb alignment and generalized joint laxity (Hosea et al., 2000) also need to be considered when trying to explain differences in injury rates.

A descriptive epidemiology of collegiate basketball injuries study was performed in 2007. Agel et al. (2007) examined women’s basketball injuries from 1988 through 2004. The information came from the National Collegiate Athletic Association (NCAA) injury surveillance data. They found that the lower extremity accounted for 60.8% of all injuries in games and 65.6% of injuries that occurred during practice. Overall, the ankle was the highest injured body part, with 873 total injuries occurring and 24.6% of all game injuries. The ankle also had the highest frequency of injured body part during practices, incurring 1573 injuries, 23.6% of all practice related injuries (Agel et al., 2007).

**Volleyball.** Many volleyball teams require players, especially front row players, to wear ankle braces for every practice and game. These front row athletes are at higher risk for spraining their ankles because of high amounts of jumping as well as the risk of landing on an opponent’s foot under the net, causing it to “roll.” This mechanism becomes logical when the tactics of net play are described: In order to gain advantage over the attacker, a blocker will jump after the attacker is in the air (Bahr, Karlsen, Lian, & Ovrebø, 1994). Because the blocker leaves the ground after the attacker, s/he also lands after them, increasing the risk of landing on the foot of the attacker or a nearby teammate.

A retrospective cohort study in the Norwegian Volleyball Federation leagues was performed in April of 1992 by Bahr, Karlsen, Lian & Ovrebø (1994). A questionnaire was sent to coaches of the two highest men’s and women’s divisions, consisting of 15
teams each. All but three teams (one women’s and two men’s) responded to the questionnaire and were therefore included in the study. The questionnaire revealed that the most common place for an ankle injury was in the “net zone” (in close proximity to the net) with 86% of injuries occurring here. The most common mechanism of injuries at the net zone was landing on an opponents’ foot (52%), followed by landing on a teammates’ foot, (24%) or by landing on the floor (13%)(Bahr et al., 1994).

Agel et al. (2007) reviewed 16 years of NCAA injury data regarding women’s volleyball. The lower extremity accounted for 58.7% of injuries during games, and 55.9% of injuries during practices. The ankle had the highest frequency of injury in both games and practices, occurring 696 times (44.1%) and 955 times (29.4%), respectively. The second highest injured body part was the knee, with 222 (14.1%) of injuries occurring during games, and 401 (12.3%) during practices (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007).

**Ice Hockey.** Agel, Dick, et al. (2007) utilized the NCAA injury surveillance system to analyze injury that occurred from 2000 to 2004 in men’s and women’s ice hockey. They found that in women’s ice hockey, the lower extremity accounted for 31.8% of injuries during games and 31.1% of injuries during practice. In men’s ice hockey, however, the lower extremity accounted for 34.3% of injuries during games, and 35.9% during practices. Ankles were not listed as injuries that occurred during practices for women’s ice hockey because they did not account for at least 2% of all injuries. During games, however, ankles sprains, along with pelvis and hip muscle-tendon strains, occurred 11 times, accounting for 4.2% of injuries that occur in games (Agel, Dick,
Nelson, Marshall, & Dompier, 2007). For men’s ice hockey, ankle incidences occurred 187 times, accounting for 4.0% of injuries in games. In practice, an ankle sprain occurred 109 times, or 10.1% of injuries that occurred during a practice, which was the third highest injury, with hip injuries occurring 257 times and knee 198 times (Agel, Dompier, Dick, & Marshall, 2007).

**Soccer.** Collegiate soccer also underwent an injury analysis. Women’s soccer had 70% of all game and practice injuries were lower extremity related. Ankle ligament sprains (18.3%), knee internal derangements (15.9%), concussions (8.6%) and leg contusions (8.3%) accounted for a substantial portion of injuries that occurred during a game. Common practice injuries were: upper leg muscle-tendon strains (21.3%), ankle ligament sprains (15.3%), knee internal derangements (7.7%), and pelvis and hip muscle strains (7.6%)(Dick, Putukian, Agel, Evans, & Marshall, 2007). Men’s soccer showed the ankle as the most frequently injured body part in both games (17%) and practices (17.4%). The ankle was also one of the most common game and practice injuries resulting in ten days of activity loss in men’s soccer. The knee was the most frequent in games (29.5%) and practices (23.5%), while the ankle was second (15%, 16.5%, games and practices, respectively)(Agel, Evans, Dick, Putukian, & Marshall, 2007).

**Baseball and Softball.** Marshall et al. (2007) reviewed 16 years of NCAA injury surveillance data regarding women’s softball. The lower extremity accounted for 43.3% of injuries in games and 40.8% of injuries in practices. In games, ankle ligament sprains and knee internal derangements combine to account for 19% of all injuries. Ligament sprains occurred 260 times, which was 10.3% of injuries during a game.
During practice, ligament sprains occurred 266 times, which accounted for 9.5% of injuries (Marshall, Hamstra-Wright, Dick, Grove, & Agel, 2007). Dick et al. (2007) also reviewed 16 years of NCAA injury surveillance data for men’s baseball across all three NCAA divisions. The lower extremity accounted for 35.2% of injuries in games, and 31.7% in practice. The ankle was the second highest injured body part during games and practices, occurring 331 times (7.4%) and 332 times (8.5%), respectively (Dick, Sauers et al., 2007).

**Field Hockey.** Women’s field hockey was reviewed from 1988 to 2003 within the three divisions of NCAA. In the fifteen years reviewed, the lower extremity accounted for 43.2% of injuries in games and 60.2% of injuries in practices. The ankle had the highest frequency of injuries at 118 during games, which was 13.7% of overall injuries. Ankles were the second most frequently injured body part during practices, with 376 injuries accounting for 26.9% of total injuries (Dick, Hootman et al., 2007).

**Lacrosse.** Women’s lacrosse was examined within the NCAA between 1988 and 2004. The lower extremity accounted for over half of injuries in both games (61.0%) and practices (64.3%). Specifically, the ankle was the most frequently injured body part in both games and practices occurring 241 (22.6%) and 361 (15.5%) times respectively (Dick, Lincoln et al., 2007). Men’s lacrosse was also examined between 1988 and 2004. The lower extremity accounted for 48.1% of injuries during games, and 58.7% of injuries during practices. Ankles had the highest frequency of injury in games and practices occurring 218 times (11.3%) and 480 times (16.4%) respectively (Dick, Romani, Agel, Case, & Marshall, 2007).
**Wrestling.** For this study, men’s wrestling was examined with the NCAA injury surveillance data from 1988 to 2004. The lower extremity accounted for 40.3% of injuries during matches, and 31.3% of injuries during practices. Ankles had the second highest frequency in matches with 232 incidences (7.5%), second to knee injuries with 710 incidences (22.9%). In practices, ankle sprains occurred 483 times, accounting for 7.3% of injuries, while skin infection had the highest frequency and percentage (1142, 17.2%)(Agel, Ransone, Dick, Oppliger, & Marshall, 2007).

**Gymnastics.** Marshall et al. (2007) reviewed 16 years of NCAA injury data regarding women’s gymnastics. In the 1988 – 1989 academic year, 112 schools with 1550 participants were represented in the study. In 2003-2004, the numbers dropped to 86 schools with 1380 participants. The lower extremity accounted for 69.3% of injuries in competitions and 52.8% of injuries during practices. An ankle ligament sprain occurred 81 times, accounting for 16.4% of injuries during competitions, and was the highest body part injured in practices, occurring 342 times (15.2% of injuries), with knees internal derangement occurring the second largest amount of times (195 or 8.7%)(Marshall, Covassin, Dick, Nassar, & Agel, 2007).

**Football.** The lower extremity accounted for 54.7% of injuries during fall games, 50.8% of injuries during fall practices, and 55.7% of injuries during spring practices. During fall games, 4799 ankle injuries occurred, accounting for 15.6% of injuries. Fall practices produced 5011 ankle ligament sprains, which was 11.8% of injuries. During spring practices, ankle ligament sprains occurred 1519 times, or 13.9% of all injuries (Dick, Ferrara et al., 2007).
**Summary.** Sprains and strains account for the majority of injuries in athletics (Baumhauer et al., 1995; Garrick & Requa, 1989; Lanese et al., 1990; Milgrom et al., 1991). After an athlete has suffered a sprain they were more likely to suffer another (Finestone et al., 2008; Yeung et al., 1994) and the injury to become chronic. Causation of ankle sprains will vary with the movements required from the activity.

**Analyzing ankle range of motion**

There are several ways to analyze movement of the foot. A universal goniometer is a standard, plastic and manual instrument and will measure motion of the subtalar and talocrural joint. Electrical goniometers will, in addition to talocrural and subtalar motion, and requires for the subject’s foot to be secured to a footplate and often the thigh being restricted as well as to limit the amount of internal and external rotation from occurring at the hip. Radiography is also used to examine the amount of anterior talar displacement and talar tilting (Glick, Gordon, & Nishimoto, 1976; Larsen, 1984). The technique used for measuring ankle ROM will vary based on the author’s preference and what area is being examined (talocrural and subtalar versus talar tilt). Due to the room for error with manual goniometry, several studies have sought to validate the use of this specific method.

**Measurement techniques of ankle movement.** The universal goniometer is frequently used to measure the passive range of motion (PROM) of the ankle and subtalar joint (Elveru et al., 1988). Elveru, Rothstein and Lamb (1988) sought to determine the degree of intra-tester and inter-tester reliability for measurements obtained with a goniometer for ankle and subtalar joint PROM. Forty-three subjects with neurological or orthopedic disorders were used in this study. Both feet of seven
subjects with orthopedic disorders were measured so that reliability was examined making 50 feet total examined. Fourteen volunteer physical therapists (PT) employed by a hospital made the goniometric measurements. Before the study, the PT’s had limited or no experience in measuring subtalar joint PROM with a goniometer, meaning they had no more experience of measuring than once every two weeks. Nine plastic goniometers were used that had 5-inch moveable arms, with the scale marked in 1-degree increments. Subjects were measured from different positions, including inversion, eversion and subtalar joint neutral. Measurements of the subtalar joint and ankle PROM range from moderately to highly reliable (subtalar joint intraclass correlation coefficient = 0.74 to 0.90) when taken by the same therapist over a short period of time. Elveru, Rothstein and Lamb (1988) suggest that, when possible, one therapist should take all repeated measurements.

Menadue, Raymond, Kilbreath, Refshauge, and Adams (2006) evaluated the goniometer technique of measuring ROM. The subjects were seated during the ROM measurements. When in a seated position, the measurements must be made from the dorsal aspect of the foot and ankle, which therefore involves both ankle and forefoot motion. A goniometer was placed with one arm on the tibia and the second arm over the second metatarsal. The axis of the goniometer sits over the midpoint of the malleolus on the anterior aspect of the ankle. The inversion and eversion range of motion was averaged for each observer across 3 trails in sixty ankles. The average ROM for inversion and eversion on the first day was 31.5° ± 8.8° and 11.1° ± 7.4°, respectively. Day two yielded different measurements for inversion and eversion of 32.9° ± 8.4° and 9.9° ± 7.6°, respectively. Intra-observer reliability between sessions
ranged from 0.91 to 0.96, and 0.82 to 0.93 for inversion and eversion measurements, respectively. Inter-observer reliability for inversion and eversion was 0.73 and 0.62, respectively. On the second day, the mean inversion and eversion measurements were 32.9° ± 8.4° and 9.9° ± 7.6°, respectively. Overall, their research suggests that for an individual clinician the measurement of eversion and inversion is highly reproducible (Menadue et al., 2006). Elveru et al. (1988) and Menadue et al. (2006) came to the same conclusion that one therapist taking the measurements is reproducible and accurate within a short period of time.

**Range of Motion in the Ankle.** Boone and Azen (1979) created a study to determine the amplitudes of active motions of the joints of the extremities of male subjects using a standard goniometer. One hundred and nine male volunteers ranging from the ages of eighteen months to 54 years volunteered for the study. All subjects were functionally right-handed and were excluded if they had a past history of musculoskeletal or neural lesions. Arcs of active motion were measured using an ordinary goniometer in the basic planes. One tester measured all subjects who were supine for the measurements. Inversion and eversion were measured from the anterior portion of the foot/ankle in all the subjects and data was presented in three different groups: all subjects (n = 109), subjects 19 years of age or younger (n = 53), and subjects older than 19 years of age (n = 56). Plantar flexion in the overall group was 56.2° ± 6.1°. It was found to be significantly different (p < 0.01) between subjects younger than 19 years of age or younger (58.2° ± 6.1°) and subjects older than 19 years of age (54.3° ± 5.9°). Dorsiflexion in the overall group was 12.6° ± 4.4°, with no difference seen between the younger group (13.0° ± 4.7°) and the older group (12.2° ± 4.1°). Inversion
was 36.8° ± 4.5° in the overall group, 37.5° ± 4.78° in subjects 19 years or younger, and 36.2° ± 4.28° in a group older than 19 years of age. Eversion was 20.7° ± 5.0°, 22.3° ± 4.6°, 19.2° ± 4.9° in the overall group, subjects 19 years or younger, and older than 19 years of age, respectively. These numbers were significantly different (p < 0.01) and in each case the ROM was less in the older group (Boone & Azen, 1979).

**Comparing the stabilizing effects of bracing and taping**

Several advantages exist to wearing a brace instead of having an ankle taped. Aside from the cost difference of paying for tape every time there is an event or buying one brace per season, there is also a convenience factor. Applying a brace requires less work than having someone tape an ankle. Studies also look into the lasting effects of taping and bracing. Braces can be adjusted mid-practice very easily while tape cannot. There is also inquiry on the rate of injury in braced ankles, ROM, mechanical stability and proprioception superiority of an ankle brace to ankle taping.

Bot, Verhagen, and van mechelen (2003) analyzed the effect of ankle bracing and taping on functional performance in a literature review from 1988 to 2003. They performed an online search of MEDLINE, CINAHL and SPORTDiscus with the keywords: performance, running, jump, agility, speed, brace, orthotic devices, tape, taping and ankle. After analyzing eighteen separate studies, the authors noted that all of the studies only looked at the short-term effects of external ankle supports. They argued that, from a biomechanical point of view, ankle musculature and ligament function may be affected with prolonged use of an ankle support. While using an external support for a prolonged time, a decrease in muscle strength or altered muscle function could affect athletic support. However, the authors also suggest that the support prevents stress to a
healthy ligament while it also supports an injured ligament, making prolonged use beneficial. Only one study was found in the online search that addressed the effect of ankle bracing on sports performance after long-term use, which showed no effect on running speed, agility or vertical jump after a three-month basketball season. Since ankle bracing is a common daily practice in sports, future studies should compare the effects of short-term and prolonged use of external ankle supports (Bot, Verhagen, & van Mechelen, 2003).

Bahr et al. (1994) analyzed multiple men’s and women’s volleyball teams where 10% of athletes were injured while wearing braces. Many of these athletes had suffered previous injuries, with no mention as to how many they have suffered in their careers (Bahr et al., 1994).

Sharpe, Knapik, Joseph, and Jones (1997) found that the frequency of ankle sprain recurrence during soccer practices and games were significantly lower in the braced group than the other three groups (taped = 0%, combination = 25%, no treatment = 35%) (Sharpe, Knapik, & Jones, 1997). McKay, Goldie, Payne, and Oakes (2001) found that the use of ankle tape and ankle braces was not significantly related to the occurrence of ankle injuries in basketball. However, it should be noted that the subjects were primarily recreational players and made little use of ankle tape or braces, and therefore only strong relationships would be detected (McKay et al., 2001). A comprehensive review by Kadakia and Haddad (2003) suggests that the biomechanical evidence strongly supports the mechanical superiority of semi-rigid orthoses over tape in restricting ankle eversion and inversion after brief and prolonged periods of exercise (Kadakia & Haddad, 2003).
Range of motion in bracing. Studies show that a Swede-O support brace, as well as the Air-Stirrup support brace, restrict inversion ROM when compared to an unsupported ankle (Greene & Wright, 1990; McCaw & Cerullo, 1999; Paris, Kokkaliaris, & Vardaxis, 1995). Greene and Wight (1990) showed that the Air-Stirrup supported the ankle for longer than the Swede-O brace, with 35% of the initial restriction lost by the Swede-O brace, and 12% lost by the Air-Stirrup brace (Greene & Wright, 1990) during a collegiate softball practice. However, despite a restricted ROM, athletes who were wearing semi-rigid ankle support systems had no interference with jumping, speed, or overall running abilities (Bot & van Mechelen, 1999; Bot et al., 2003; MacKean et al., 1995; Verbrugge, 1996).

Effectiveness of a brace on mechanical stability. Sefton, Hicks-Little, Koceja, and Cordova (2007) found that external ankle support, which in this study was a brace, does provide sufficient mechanical stability. Sefton and colleagues’ study looked at a supportive brace’s effect on reflex response in the peroneus brevis and longus. A custom platform was made to create sudden inversion movement. There were two separate flat surfaces and the platform was manually tilted at 30 degrees of inversion through the use of a magnetic switch that dropped the right side. The results suggest that the external support may actually reduce the need for an increased reflex response because of the mechanical stability (Sefton, Hicks-Little, Koceja, & Cordova, 2007).

Twenty-four subjects with no previous history of lower extremity injury six months before the study served as volunteers for Cordova et al.’s (2007) study evaluating the effects of ankle bracing on rear-foot angular displacement and angular velocity during a sudden inversion movement. A motion analysis system was used to
capture, model and calculate 2-D rear-foot motion while the subject’s ankle/foot complex was inverted to 35 degrees on a platform device. The semi-rigid brace groups showed significantly reduced rear-foot angular displacement and angular velocity when compared with the lace-up and control groups (Cordova, Dorrough, Kious, Ingersoll, & Merrick, 2007).

**Bracing’s effect on proprioception.** Hubbard and Kaminski (2002) performed a test involving 16 subjects (8 men, 8 women) that analyzed whether subjects wearing prophylactic ankle bracing and taping would improve kinesthesia. The movements examined were inversion and eversion while the three conditions were ankle tape, Swede-O Ankle Lok or Aircast Air-Stirrup. When compared with the unbraced condition, bracing with either the Ankle Lok or Air-Stirrup decreased the ability to detect passive motion in a device specifically built to measure passive ankle movements while maintaining a constant speed in uninjured ankles. Measurements were taken and reported as the ROM that occurred before subjects detected passive motion (Ankle Lok: eversion $= 4.24° \pm 4.22°$, inversion $= 4.03° \pm 3.72°$; Air-Stirrup: eversion $= 4.10° \pm 3.26°$, inversion $= 3.77° \pm 3.69°$; unbraced: eversion $= 2.89° \pm 2.56°$, inversion $= 3.39° \pm 2.99°$; taped: eversion $= 3.78° \pm 2.81°$, inversion $= 3.34° \pm 2.79°$). While there is a difference between the detected passive range of motion in the three conditions, there are no significant relationships noted among any of the variables (Hubbard & Kaminski, 2002).

Contrary to the findings of Hubbard and Kaminski (2002), Konradsen and Magnusson (2000) found that external ankle support may improve position sense in subjects with chronic ankle instability. Their study placed subjects in a seated position and placed the foot into a footplate that was aligned with the base of the metatarsal
heads. A torsion goniometer registered subtalar inversion in the frontal plane when the footplate rotated. A computer provided an index inversion angle of 10°, 15° or 20° chosen at random and repeated a total of ten times. After one second, the foot was passively brought back to neutral and subjects were asked to actively match the index angle, which was recorded by the computer. Subjects were blindfolded during the study. The results were broken into a healthy control group, as well as functionally unstable subjects who were either taped or not taped for the study. Subjects were required to have sustained seven inversion ankle sprains per year in an unprovoked situation to guarantee a substantial functional problem. By calculating the absolute error of angle replication, the authors ensure that a total magnitude of error was expressed, while a real error was used to reveal a systematic tendency to over or under estimate inversion angles. The replication error for the affected ankle in the functionally unstable group had an absolute value of 2.5° ± 0.4°. The absolute error was significantly greater for the affected ankle in the functionally unstable group versus healthy subjects (1.7° ± 0.2°, p < 0.01). Unstable subjects also had a significant difference in absolute error between then unaffected and affected limb (2.0° ± 0.3°, p < 0.05). No significant difference in real error between stable and unstable groups or between unaffected and effected sides was found. Results from the study found that a greater error of inversion position assessment was found in subjects with chronic functional instability. The application of an external support in subjects who were accustomed to wearing external support resulted in a trend towards decreased position assessment error (Konradsen & Magnusson, 2000).
**Summary.** Overall, research suggests ankle bracing is superior than taping for restricting ankle eversion and inversion ROM following exercise (Kadakia & Haddad, 2003). The ankle brace, despite being rigid, will not interfere with speed, jumping or running abilities (Bot et al., 2003; MacKean et al., 1995; Verbrugge, 1996) and has been shown that external support will have either no effect (Hubbard & Kaminski, 2002) or a positive (Konradsen, 2002) effect on proprioception.

**Ankle Taping**

Ankle taping is a highly studied aspect of athletic training because of its common use as well as high cost and apparent ineffectiveness compared to the bracing alternative. Tape durability, its affects on proprioception, technique, and material have been the subject of research to validate this common practice.

**Taping effect on ROM and tape durability.** Taping was shown to have the highest initial passive stability when compared to stirrup and lace-up braces (Eils, Imberge, Völker, & Rosenbaum, 2007). Its effectiveness, however, is more dependent on the tape’s tensile strength than its adhesive properties (Laughman et al., 1980). Correctly applied to a joint, the tape acts as an additional, external ligament, which aids in restricting excess joint motion. Like a ligament, the tape is dependent on its adherence at the insertion and origin, which, for the ankle is in areas of minimal soft tissue and motion, and this favors maximum adherence (Laughman et al., 1980).

While the increased rigid support of the athlete’s ankle is a large benefit of taping, a major factor working against it is the mobile nature of the skin itself as it moves over the subcutaneous tissue that covers bone and ligaments that the taping is intended to reinforce (Ferguson, 1973). Therefore, as moisture accumulates
underneath the tape, skin adherence is lessened still further (Ferguson, 1973). Taping restriction is the greatest between the first 5 and 20 minutes of exercise, but begins to become weaker and less restrictive of movement thereafter (Bot et al., 2003; Eils et al., 2007; Glick et al., 1976; Greene & Hillman, 1990; MacKean et al., 1995).

Fumich, Ellison, Guerin, and Grace (1981) utilized a custom ankle device that measures ROM to determine the ROM before taping (untaped, UT), immediately after taping (taped, T), and with tape following a 2.5-3 hour college football practice (taped post-exercise, TPE). Sixteen male football players with no history of an ankle sprain were used during the course of this study. Mean values were found in degrees and determined for all ankle motions in each of the three (UT, T, TPE) conditions. They found values for the following motions: plantar flexion (U = 45.5°; T = 31.5°; TPE = 38.3°), plantar flexion with inversion (U = 26.6°; T = 15°; TPE = 20.8°), plantar flexion with eversion (U = 12.5°; T = 8.8°; TPE = 11.3°), dorsiflexion (U = 24.4°; T = 18.6°; TPE = 23.4°) inversion (U = 30.6°; T = 19°; TPE = 24.25°), and eversion (U = 24.18°; T = 19°; TPE = 20.8°). The statistical comparisons revealed that taping reduces the motions of plantar flexion with inversion and the individual motions of eversion, inversion, and plantar flexion before exercise. The taped post-exercise ROM was more restricted than the untaped conditions, which suggests that there is still mechanical support after an excessive exercise, despite a breakdown of the tape previously described (Fumich, Ellison, Guerin, & Grace, 1981).

Larsen (1984) conducted a study with 20 subjects who had chronic ankle instability that had been previously active in sports but had eventually ceased participation because of ankle instability. Anterior displacement and frontal plane talar
tilting was determined through radiographical examination before and after the taping condition, as well as after a 20 minute run. Non-elastic adhesive tape was used, followed by a slightly elastic 3-inch tensoplast. The area was prepared by shaving and directly applying tape to the skin. Of eight subjects with untaped ankles, all had a talar tilt of at least 7 degrees. In general, ankles with the highest displacement indices saw the best results from taping. There was a reduction in displacement between the untaped and taped ankles averaging an improvement of 42%. After a 20 minute run, the average talar tilt was 7.3 degrees, which, while a reduction of 19% in the initial taping was seen, was nevertheless significant (p < 0.02). Details of the statistical significance were not described within the article, making its results difficult to interpret. The author suggests that taping gave the best support to subjects with the highest degree of ankle instability. The author attributed the general loosening of the tape to perspiration and unevenness of skin during muscle activity, but found the tape to have a beneficial effect of reducing instability during exercise (Larsen, 1984).

Delahunt et al. (2009) examined the effects of ankle joint taping and exercise on ankle joint sagittal and rear-foot frontal plane movement in subjects with chronically unstable ankles. Eleven subjects with chronic ankle instability volunteered for the study. Each subject performed three single-leg drop landings onto a force plate in three conditions: no tape, tape, and post-exercise tape. Data was used to identify ankle joint sagittal and rear-foot frontal plane positions 50 ms before contact and at initial contact. The exercise protocol included ten, 60 cm forward hops, ten medial and lateral 60 cm hops, a series of ten repetitions of ladder drills as well as slalom and cutting drills ten times. On average, the exercises took an average of 25 minutes to complete. Overall, the
study found no significant effect on rear-foot frontal plane (inversion/eversion) movement before contact or at initial contact. There was a significant effect of the angle of ankle joint plantar flexion, 50 ms before and at initial contact with no tape being significantly greater than tape as well as post-exercise tape. The results suggest that taping acted to reduce the amount of plantar flexion at both times and the reductions remained even after exercise. Overall, the study shows that ankle joint taping can restrict sagittal plane movement at the ankle joint during landing activities in subjects with chronic ankle instability (Delahunt, O'Driscol, & Moran, 2009).

Fifteen male rugby players with no history of lower-leg injury within the previous six months limiting activity for more than two days participated in Pederson et al.’s (1997) study of ankle taping. They sought to compare the effects of spatting, taping and spatting, taping and not spatting on the amount and rate of inversion of the ankle before and after exercise. Spatting is a taping technique that involves applying tape over both the sock and shoe of an athlete. This technique is common among sports where cleats are worn, as some athletes believe it helps to keep their shoes on tighter. Subjects were measured for ankle inversion ROM and rate of inversion under four conditions: untapped, taped, taped and spatted, and spatted. They were then randomly assigned a number and counterbalanced the order of the treatments to control for possible sequence and order effects. Subjects were videotaped on an inversion platform before and after 30-minutes of rugby drills conducted by the rugby coach. The platform used produced a sudden inversion of the ankle to 35 degrees. A shuttered video camera, set at 1/500 of a second, approximately 5 meters behind the subject and 60 cm off the ground, was set to record the motion in the frontal plane at 60 frames/sec. One-
centimeter reflective tape markers were placed on subject's right gastrocnemius, Achilles tendon, and top and bottom of heel of the shoe. Subjects were positioned on the platform and instructed to put all of their weight on the right foot and balance with the toes of the left foot to avoid shifting his weight. The authors then calculated rear-foot angles from raw x- and y- coordinates of the four landmarks. There was a significant condition by exercise interaction for the rate of inversion. Before exercise, all pairwise comparisons of the rates of inversion were significantly different, except the taped condition, which was not different from spattering. The amount of inversion for the taped condition changed from $21.5^\circ \pm 5.2^\circ$ before exercise, to $27.0^\circ \pm 5.4^\circ$ and the rate of inversion also increased from before exercise to after exercise ($268.7 \pm 59.0^\circ$/sec to $349.2 \pm 63.0^\circ$/sec, respectively), while pre-taped measurements were not presented in the study. The combined preventions of spattering and taping was the most effective in reducing inversion rate as well as range of motion before and after exercise (Pederson, Ricard, Merrill, Schulties, & Allsen, 1997).

**Different taping techniques’ effect on ROM and durability.** Various investigators have examined the use of the Gibney basketweave (Alt et al., 1999; Firer, 1990; Laughman et al., 1980; Lindley & Kernozek, 1995; MacKean et al., 1995; McCaw & Cerullo, 1999; McCluskey et al., 1976; Purcell et al., 2009; Ricard et al., 2000; Robbins et al., 1995; Verbrugge, 1996) method of taping with heel-locks (Alt et al., 1999; Firer, 1990; Laughman et al., 1980; Lindley & Kernozek, 1995; McCaw & Cerullo, 1999; McCluskey et al., 1976; Purcell et al., 2009; Refshauge, Kilbreath, & Raymond, 2000; Refshauge, Raymond, Kilbreath, Pengel, & Heijnen, 2009; Ricard et al., 2000; Robbins et al., 1995; Verbrugge, 1996) and figure-of-eights (Alt et al., 1999; Firer, 1990; Laughman
et al., 1980; McCaw & Cerullo, 1999; Pope, Renstrom, Donnemeyer, & Morgenstern, 1987; Purcell et al., 2009; Ricard et al., 2000) when comparing different methods of support because it reduces medial and lateral deviation of the calcaneus yet allows for a sufficient amount of plantar and dorsiflexion.

Rarick, Bigley, Karst, and Malina (1962) used a device created specifically for the experiment, allowing for inversion and plantar flexion to be measured after passive movement. Subjects were braced with different levels of an ankle taping (basket weave, basket weave and stirrup, basket weave and heel lock, or basket weave with stirrup and heel lock). An exercise protocol was performed that involved ten minutes of running, jumping, quick starts and stops, as well as pivoting. Immediately after exercise, ROM readings were taken. The study showed that before exercise all types of taping gave greater support than without taping. After 10 minutes of exercise, however, the taping effect was substantially less than the same taping before exercise (Rarick, Bigley, Karst, & Malina, 1962). The study made no comment as to restriction of taping compared to the barefoot condition.

Ricard, Sherwood, Schulties & Knight (2000) tested thirty college-aged male and female students. Subjects were either not taped, taped without prewrap (directly to skin) or taped with prewrap. With the help of an electronic goniometer, subjects were asked to place most of their weight on the right leg while standing on an inversion platform with a trap that caused the platform to drop, mimicking an inversion ankle sprain. An exercise protocol then occurred which included a 10-minute treadmill run, shuttle runs, bilateral toe raises, and running figure of eights. After exercise, the subject took place on the platform again and trials were performed with the platform dropping.
While no difference was seen between the two taping conditions, both taping conditions were significantly different from the no tape condition. Total inversion was approximately 10 degrees less during the two tape conditions than during the no-tape condition and inversion increased one to two degrees during exercise in each of the conditions. These results led the authors to conclude that applying tape over prewrap is as effective as applying tape directly to the skin in reducing the amount of ankle inversion. Despite the observation that tape loosens after exercise, they conclude that ankle taping does provide residual inversion restriction (Ricard et al., 2000).

Pope, Renstrom, Donnermeyer, and Morgenstern (1987) applied tape to a mechanical simulation of the human ankle that was constructed of wood and the joints articulated by the means of steel hinges screwed into the joints. Four different types of ankle tapings were applied and analyzed. A mechanical testing machine applied angular deflection onto the ankle model at a controlled loading rate. The results showed that only the taping condition involving the figure of eight taping had adequate strength to withstand the applied loads and is, therefore, the recommended taping (Pope et al., 1987).

**Different tapes utilized and their effects on ROM and durability.** Abián-Vicén, Alegre, Fernández-Rodríguez, & Aguado (2009) used 27 active women for a test comparing three taping conditions: without taping, inelastic taping (IT), and elastic taping (ET). Although it is unclear whether this tape is heavy elastic or light elastic, it is the only one found to compare elastic tape to white tape. The women were asked to go through 30 minutes of intense exercise or jumping and landing drills and ankle ROMs (plantar flexion, dorsiflexion, inversion and eversion) were measured before and after
the ankle taping as well as after exercise. Ankle inversion and plantar flexion were significantly restricted with both types of taping compared to untaped values (IT = 40.74%, ET = 41.77%; IT = 14.54%, ET = 11.15%; percentage of restriction in inversion and plantar flexion, respectively). Both types of taping reduced in the degree of restriction after exercise (IT = 26.74%, ET = 20.84%; IT = 14.54%, ET = 11.15%, percentage of restriction in inversion and plantar flexion, respectively). These unusually identical numbers for the pre- and post-exercise measurements of inversion and eversion when in a plantar flexed position were reported by the authors and may reflect a typographical error. Although the results demonstrated a reduced ability to restrict inversion, Abián-Vicén and colleagues (2009) recommend the use of elastic taping to limit plantar flexion and inversion in a prophylactic ankle taping as it still provides 20% better restriction in inversion ROM than an untaped condition (Abián-Vicén, Alegre, Fernández-Rodríguez, & Aguado, 2009).

Purcell, Schuckman, Docherty, Schrader, and Poppy (2009) compared white cloth tape with self-adherent tape. Range of motion was measured in inversion-to-eversion range as well as plantar flexion to dorsiflexion range. The ROM was measured at baseline, pretest and again at posttest, after 30 minutes of exercise. Measurements with no tape were taken for inversion to eversion range of motion (baseline = 31.49° ± 8.83°, pretest = 32.23° ± 9.53°, posttest = 31.03° ± 8.92°) as well as dorsiflexion to plantar flexion ROM (baseline = 70.14° ± 12.54°, pretest = 68.07° ± 11.21°, posttest = 67.44° ± 12.77°). The study showed that white cloth tape lost some of its support in the inversion to eversion range after exercise (baseline = 32.01° ± 8.79°, pretest = 27.77° ± 9.87°, posttest = 31.82° ± 10.80°). The self-adherent tape, however, maintained more of
its original restriction (baseline, 30.00° ± 8.16°, pretest = 22.66° ± 7.83°, posttest = 25.76° ± 9.68°). Both tapes maintained approximately 65% of their original restrictive properties in the dorsiflexion to plantar flexion range (white tape, baseline = 68.37° ± 12.51°, pretest = 56.04° ± 13.77°, posttest = 60.73° ± 13.62°; self-adherent tape, baseline = 67.84° ± 12.77°, pretest = 51.05° ± 12.50°, posttest = 57.74° ± 12.52°). In conclusion, the self-adherent tape and white cloth tape condition provided dorsiflexion to plantar flexion ROM restriction before and after exercise. After 30 minutes of exercise, however, only the self-adherent tape sustained the restriction, which will ultimately assist in decreasing the risk of injury (Purcell et al., 2009).

**The effect of taping on proprioception.** After examining 20 healthy males who were free of current or chronic ankle injuries, Simoneau, Degner, Kramper, and Kittleson (1997) concluded that taping and bracing provide an increase in cutaneous stimuli in addition to the external support to the joint it surrounds. Subjects stood on a custom made ankle joint movement and position perception apparatus that had been designed to objectively measure various aspects of ankle proprioception. The feet were placed on its own moveable platform with an electrically driven electromagnetic actuator used to move each platform individually at angular velocities varying from 0.1 to 4.0 degrees/second. An inclinometer was mounted directly onto each foot platform to measure the angular position of each ankle. To test joint position perception, the tester passively placed the subject’s ankle in a predetermined position for five seconds. The subject was passively returned to a neutral position and after three seconds, asked to provide the necessary instructions to the tester in order to return to the previous position. Subjects were in four different conditions for the test: weight bearing with
tape, weight bearing without tape, non-weight bearing with tape, and non-weight bearing without tape. While weight bearing, the ankle joint position error in perception varied between being taped and not taped as well as whether the ankle was in plantar flexion or dorsiflexion (no tape/plantar flexion = 1.64 ± 0.65°; tape/plantar flexion = 1.36 ± 0.62°; no tape/dorsiflexion = 0.98° ± 0.52°; tape/dorsiflexion = 1.08° ± 0.59°).

The authors found that on healthy subjects, athletic tape does not provide any advantages for the detection of joint movement in either weight bearing or non-weight bearing situations. However, from the research the authors suggest that the amount of increased stimulation of cutaneous proprioceptors, provided through either indirect or direct contact with the skin, that could possibly enhance joint position awareness and possibly help prevent injuries (Simoneau, Degner, Kramper, & Kittleson, 1997).

Robbins, Waked, and Rappel (1995) showed an increase in foot position awareness when an ankle was taped in healthy university subjects who were wearing athletic footwear. Subjects were asked to participate in two testing session, exercise and a no-exercise control. The exercise condition included basketball and running for a 30-minute period. The no-exercise portion placed the subjects in a non-weight bearing position for 30 minutes. After each condition, subjects were blindfolded and asked to stand on a block and perceive the direction and amplitude of the surface slope. When looking at surface slope of 10 degrees and greater, barefoot subjects underestimated surface slope before and after exercise (net error -5.7°, -6.78°, respectively). When taped, error before exercise was neutral, but changed to a moderate underestimation after exercise (net error -2.52°). When compared to the barefoot control condition, foot position awareness was 107.5% worse in untaped subjects with athletic footwear, and
58.1% worse in ankle taped subjects wearing athletic footwear. Possible causes for this connection are that the traction of tape on the skin of the leg and foot is used to help judge foot position. This conclusion was made based on the fact that the supporting function (restricting ROM) of an ankle taping declined, yet the position awareness was still increased post-exercise (Robbins et al., 1995).

Leanderson, Ekstam, and Salomonsson (1996) also found a positive effect of taping on postural sway during perturbation before a practice session in elite Swedish male soccer players with unilateral functional instability after a sprain. An ankle disc standing on four bars on top of a force plate served as the perturbation device. The bars were removed by an experimenter standing behind the subject, so as not to forewarn subjects about the upcoming tilt. However, the difference in postural sway was no different between a taped or untaped ankle after exercise. This suggests that ankle taping is more important for postural stability during the first part of an athletic event. The authors propose that the results of the study could be explained by the mechanical support of an ankle taping and its diminishing restriction after time (Leanderson, Ekstam, & Salomonsson, 1996).

Tape loses its effectiveness when moisture is added to it. When an ankle is taped and an athlete begins to participate in activities, moisture from sweat begins to accumulate underneath the tape. From there, the tape becomes less stiff and is not as tight against the skin. Taping an ankle with the aid of figure-of-eight has been shown as an advantageous step in increasing the strength of the ankle against motion. The research suggests that materials of tape other than the standard non-elastic white tape can be used effectively for restricting ankle ROM when used for taping. The largest
difference seen between ankle taping and bracing, excluding length of effectiveness, is the improvement that taping has on proprioception before and after exercise. However, tapings continue to done either because of a lack of a brace, it is an acute injury, or simply personal preference by the athlete.

**Summary**

Sprains are commonly experienced in sports and are likely to occur at the ankle due to quick, sharp movements that athletics demand from the joint particularly in sports where obstacles or uneven terrain are involved. Ankle sprains cause a decrease in ankle strength, joint proprioception, and stability, which could possibly lead to more ankle sprains and greater damage to the structures involved. To support and prevent this common injury, ankle taping and braces are utilized on a routine basis. The most widely studied types of ankle sprain prevention are the brace and non-elastic white cloth tape. Research suggests ankle tapings diminish in restriction after a short period of time. Therefore, techniques, methods and materials are under constant scrutiny to help improve this common practice. Beneficial effects of ankle taping have been documented, including restricting ROM, as well as providing cutaneous stimulation to improve proprioception. This justifies the further use of these preventative measures, and warrants further investigation into additional taping methods to restrict ROM. Heavy elastic tape has not been examined as much as non-elastic white tape. There are only a handful of studies that compare its ROM properties to non-elastic white tape yet the taping material is commonly used due to an assumed improved restriction. This study was performed to justify the use of the expensive, commonly used heavy elastic tape.
Chapter III

Methods and Procedures

Introduction

The purpose of this study was to compare the effects of ankle taping with heavy elastic tape and non-elastic white tape before and after 15 minutes of multi-directional exercise. Data was gathered by an experienced ATC using a manual goniometer.

Description of Study Population

The population for this study consisted of 26 volunteers who were recruited from Western Washington University in Bellingham, WA, following approval of the study from the University Human Subjects’ Committee. Subjects had to be able to perform a five-minute jog and ten minutes of agility drills to be included in the study. Subjects were required to have been free of an ankle injury within the last month. If they could not finish the exercises, subjects were removed from the study.

Design of Study

Analysis of ankle ROM was performed using a two-way repeated measures ANOVA with a cross-over design. All subjects had one ankle taped with white tape and the other ankle taped with heavy elastic.

Data Collection Procedures

Instrumentation. A manual goniometer has been used to examine the range of motion (ROM) measurements in previous studies (Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999). This method for evaluating ROM was examined by Menadue, Raymond, Kilbreath, Refshauge, and Adams (2006). Their research suggests that, for an
individual clinician, the measurement of eversion and inversion is highly reproducible within a session (Menadue et al., 2006).

Cramer brand heel and lace pads were placed on both ankles over the Achilles as well as the anterior ankle joint. The heel and lace pads were 3”x3”x1/16” and had a small amount of skin lube in the middle of the squares. These pads help to reduce the incidence of tape cuts that can occur from running. In both conditions, Cramer brand Tuf-Skin colorless formula spray adhesive (Cramer Tuff-Skin, Cramer Products Inc, Gardner, Kansas) was used to prepare the skin. Mueller brand Pre-Taping Underwrap was part of preparation and also used in both conditions. Johnson & Johnson brand Coach athletic tape, which is 1.5” in width and 15 yards in length, was used as the white tape condition. Tensoplast brand, elastic athletic tape was used for the heavy elastic tape condition with specific measurements of 2” x 5 yards.

Measurement Techniques and Procedures. Each subject completed an injury history and personal information sheet including the following information: age, self reported weight and height, leg dominance that was defined as which foot the subject would jump from, level of activity and previous injuries.

Pre-test protocol. Subjects were measured for ROM in four directions: plantar flexion, dorsiflexion, inversion and eversion, by the same technician using a manual goniometer while barefoot. The subjects were prone during the inversion and eversion ROM measurements. For each direction, the subject was instructed to actively move the joint to the maximal ROM. A coin toss determined if the right ankle would be taped with elastic or non-elastic tape, while the left ankle was taped using the second material.
**Skin preparation.** With the subject sitting and the foot held actively in a dorsiflexed position of about 90 degrees the ankle taping began. The foot and ankle were cleaned thoroughly with non-sterile gauze pads and alcohol. Heel and lace antifriction pads with a small amount of skin lubricant were placed over the Achilles tendon and anterior ankle joint (Appendix B, Figure 5). Subjects were sprayed with an adhesive spray over the lower leg and the foot. Prewrap was then applied from the base of the calf to the midfoot in a circular pattern (Appendix B, Figure 6).

**Modified Gibney basket weave.** Three anchors were applied, starting at the top of the prewrap, overlapping onto the skin by half the width of the white tape and working down the leg (Appendix B, Figure 8). Three stirrups were applied medial to lateral, with circular strips to anchor after each stirrup (Appendix B, Figure 9). Several strips were then placed covering the lower leg until the calcaneus was covered (Appendix B, Figure 10). A heel lock gives additional support to the ankle (Appendix B, Figure 11). Starting high on the instep, the tape was brought down at a slight angle, hooking the heel, taken under the arch, then came up the opposite side of the foot. This was repeated, starting on the opposite side of the ankle to create a full heel lock. A heel lock was performed medially twice and laterally twice. Two figure-of-eight strips were placed on each ankle as well (Appendix B, Figure 12, Figure 13). The tape was placed in a medial-to-lateral direction around the midfoot and continued under the foot, coming up near the base of the fifth metatarsal, crossing in front of the ankle in order to wrap around the lower leg, and be brought back down to the starting position. Three anchors were then placed at the base of the calf, where the taping began and one placed lightly around the base of the foot.
**Taping conditions.** The ankle taping procedure was the same in both conditions until the heel locks and figure of eights were to be done. Heel locks and figure-of-eights are designed to limit inversion and eversion motions in the ankle. Therefore, for the purpose of this study, both heel locks and both figure-of-eights were done with white cloth tape for one ankle and heavy elastic tape with the opposite ankle. All anchors, stirrups, and protection pieces of tape (covering the calcaneus to reduce tape cuts) were done using the white cloth tape.

**Goniometry protocol.** Goniometric range of motion measurements were carried out according to the procedures outlined by Norkin and White’s book (2003). Subjects were placed in a seated position, with the knees flexed to 90° for dorsiflexion and plantar flexion measurements. The lateral malleolus served as the fulcrum point for these measurements. The proximal arm of the goniometer was in line with the lateral midline of the fibula, using the head of the fibula for the reference. The distal arm was parallel to the lateral aspect of the fifth metatarsal. For rear-foot inversion and eversion measurements, the subject was instructed to lay prone, with the hip in zero degrees of flexion, extension, abduction, adduction, and rotation. The knee was also in zero degrees of flexion and extension. The fulcrum for inversion/eversion measurements was over the posterior aspect of the ankle, midway between the malleoli. The proximal arm was also on the posterior leg, in the midline of the lower leg and the distal arm on the midline of the calcaneus (Norkin & White, 2003). After the ankle taping finished, ROM (degrees) was measured for each of the conditions. The left ankle was taped and again the four directions were measured. The investigator made markings on subject’s legs for both measurements, line of the fibula and midline of the lower leg, to serve as a
point of reference for measurements, in a barefoot condition, as well as before and after exercise.

**Exercise protocol.** At the end of their comprehensive review, Kadakia and Haddad (2003) suggest that the duration of wear for a given taping procedure must be controlled for, as length of time may affect the proprioceptive feedback of the subject and consequently alter results. Therefore, the exercise time was been set at 15 minutes for each subject. This number was chosen based on findings from previous studies (Glick et al., 1976; MacKean et al., 1995; Rarick et al., 1962). After baseline and pretest ROM were measured, subjects were put through an exercise routine. The exercise routine consisted of five stations, involving: forward and backward running, zig-zags, lateral shuffles, jumping over cones, and running a figure-of-eight pattern. The first station was set up with two cones being 10 meters apart. Subjects ran forward to a cone than backwards to the second cone. The second station had subjects shuffle in a zig-zag pattern with cones placed four meters apart in width as well as distance forward. Two cones placed 10 meters apart were used for the third station of lateral shuffles. The fourth station had a series of four cones arranged in a line for subjects to jump over. The fifth and last station had subjects running figure-of-eight patterns around two cones that were spaced four meters apart. Each station was done for thirty seconds and rotated through until the ten minutes had passed. Subjects were instructed to exercise at what they felt was a moderate level. Directly after the participants finished the exercises, ankle ROM was measured according to the aforementioned protocol. Exercises were directed and monitored by the same experimenter for all subjects. The subjects were instructed to move as normally as possible and to attempt equal
movements with both ankles. The experimenter monitored subjects’ movements to assure that they were equal in both directions.

**Data Collection and Processing.** Three measurements were taken at the beginning of the study before subjects were taped, after taping but before exercise and again after exercise in four motions: dorsiflexion, plantar flexion, inversion and eversion. Measurements were made to the nearest degree from the manual goniometer. The three measurements were averaged and those values used in statistical analysis.

**Data Analysis**

The statistical analysis software package used was from PASW Statistics, Incorporated (version 17). For each of the conditions, dorsiflexion, plantar flexion, eversion and inversion ranges of motion were entered into a spreadsheet. A two-way repeated measures analysis of variance was used to assess the differences across the ankle restraint conditions and the difference in the ROM before and after exercise (Time by Condition). Mauchly’s test of sphericity was examined for each range of motion for scores at each testing time. If the assumption of sphericity was violated (p < .05), the degrees of freedom were corrected using Greenhouse-Geisser estimates. The results of all statistical tests were evaluated at the 0.05 level of significance. If a Time by Condition interaction effect was detected, the main effects of Time and Condition were still examined. If the Time main effect was significant (but the Time by Condition interaction effect was not), then pairwise comparisons were conducted to identify which Time points were different from each other. The factor Condition had only two levels, and so pairwise comparisons were not necessary if a Condition main effect was
significant. The effect size \((r)\) was calculated. The \(r\)-value illustrates a small, medium or large effect size (small, \(r = .10\); medium, \(r = .30\); large, \(r = .50\)) (Field, 2005).
Chapter IV

Results and Discussion

Introduction

The range of motion effects in the ankle taped with white tape versus an ankle taped with heavy elastic were examined in this study. The experimental design utilized a multiple participant two-way repeated measures ANOVA assessing change in range of motion in four ranges of motion: plantar flexion (PF), dorsiflexion (DF), inversion (IN) and eversion (EV). The different ranges of motion were the dependent variables, whereas tape (heavy elastic versus white tape) and time (two measurements before and one after the exercise protocol) served as independent variables. Following a description of subject characteristics, results that pertain to the analysis are presented and discussed.

Subject characteristics

Twenty-seven subjects (8 men, 19 women) volunteered for the study. One subject could not complete the exercise protocol because of a previous injury and her information was removed from the records. A total of 26 subjects (men = 8, women = 18) completed the study. The average age of the subjects was 21.96 years old (20 - 25 years). The average height was 1.67 meters (1.4 – 1.88 m), and average mass 68.11 kg (51.81 - 97.72 kg). Of the twenty-six subjects, four regularly wear ankle braces or had their ankle taped previously, while 13 had experienced an ankle injury. None of the subjects had encountered an ankle injury within the last month. Overall, 14 subjects had their right ankle taped with white tape and left ankle with heavy elastic tape. Twelve subjects had their right ankle taped heavy elastic tape and left ankle with white tape. Of
these, 13 subjects had their dominant ankle taped with heavy elastic, while the
remaining 13 subjects had a dominant ankle taped with white tape. See Appendix C for
additional individual subject data.

Results

Effects are reported significant at $p < .05$. A paired t-test was performed when
either a main or interaction effect was significant. The r-value presented illustrates a
small, medium or large effect size (small, $r = .10$; medium, $r = .30$; large, $r = .50$)(Field,
2005).

Plantar flexion.

Mauchly’s test of sphericity indicated the assumption of sphericity was not
violated for the main effect of Time in the plantar flexion (PF) ROM ($p = .42$). There was
a significant effect of Time ($F(2,26) = 141.74$, power =1.00, $p < 0.001$, $r = 0.99$). On
average, PF ROM decreased significantly between Barefoot and Pre-Exercise (Mean
change ($M\Delta$) = 25.48, standard deviation (SD) = 9.49, $t(52) = 19.35$, $p < .001$) and the
effect size was large ($r = 0.94$). The positive value for mean change illustrates a
decrease in ROM. Overall, between Pre-Exercise and Post-Exercise, subjects
experienced an increase in ROM ($M\Delta = -10.71$, SD = 8.89, $t(52) = -8.68$, $p < .001$) with a
large effect size ($r = 0.77$). The negative value for mean change between these two time
periods illustrates an increase in ROM. Between Barefoot and Post-Exercise an overall
decrease in PF ROM was seen ($M\Delta = 14.77$, SD = 8.41°, $t(52) = 12.66$, $p < .001$) with a
large effect size ($r = 0.87$). Raw Time and Condition information can be seen in Table 1.
The main effect of Condition was not significant ($F(1, 26) = 1.216$, power = 0.19, $p =
0.28$, $r = 0.74$).
Mauchly's test of sphericity indicated that the assumption of sphericity was not violated for the Time by Condition interaction effect in the PF ROM ($p = 0.57$). An ANOVA found the interaction effects of Time by Condition to be non-significant ($F(2,26) = 0.05$, power = 0.06, $p = 0.95$, $r = 0.15$). An interaction plot of the changes of Condition over Time can be seen in Figure 1.

Table 1

*Descriptive Data for Plantar Flexion Values*

<table>
<thead>
<tr>
<th>Type and Time</th>
<th>Mean ($^\circ$)</th>
<th>Minimum ($^\circ$)</th>
<th>Maximum ($^\circ$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White PF Barefoot</td>
<td>56.19</td>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>White PF Pre-Exercise</td>
<td>30.50</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>White PF Post-Exercise</td>
<td>41.15</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>Heavy PF Barefoot</td>
<td>57.19</td>
<td>30</td>
<td>71</td>
</tr>
<tr>
<td>Heavy PF Pre-Exercise</td>
<td>31.92</td>
<td>5</td>
<td>52</td>
</tr>
<tr>
<td>Heavy PF Post-Exercise</td>
<td>42.69</td>
<td>15</td>
<td>64</td>
</tr>
</tbody>
</table>

*Figure 1.* The white tape (blue) acts similarly to heavy elastic tape (red). Error bars presented on the graph represent the standard deviation of the ranges of motion in all subjects. The ROM (degrees) varies with each Time. The chart depicts that Post-Exercise, the ROM does not return to the normal values found when subjects were barefoot.
These differences indicate that plantar flexion ROM decreased with the application of tape for both conditions (from Barefoot to Pre-Exercise). The plantar flexion ROM increased again following exercise (Post-Exercise), but still remained more restrictive than the barefoot conditions. After exercise plantar flexion ROM increased again. However, the values at which ROM increased to after exercise were still more restrictive than ROM values in a barefoot condition. The Barefoot conditions found in the plantar flexion ROM (56.19° and 57.19°, white tape and heavy tape, respectively) is within the range established by Boone and Azen (1979) (56.2° ± 6.1°). While comparing PF ROM across other studies (Table 6), the current study follows the trend of losing ROM immediately after application of tape, followed by a subsequent increase in ROM after exercise. Following exercise, white tape still provided restriction for PF ROM, so that only 73.2% of Barefoot ROM was allowed. Heavy elastic tape allowed for 74.7% of the original movement.

Table 6

Comparing Plantar Flexion ROM Across Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Barefoot</th>
<th>Pre-Exercise (White)</th>
<th>Pre-Exercise (Elastic)</th>
<th>Post-Exercise (White)</th>
<th>Post-Exercise (Elastic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Study</td>
<td>White – 56.19°</td>
<td>30.5°</td>
<td>31.92°</td>
<td>41.15°</td>
<td>42.69°</td>
</tr>
<tr>
<td>Fumich (1981)</td>
<td>Heavy – 57.19°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abian-Vicen et al. (2009)</td>
<td>45.5°</td>
<td>31.5°</td>
<td></td>
<td>38.3°</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.6° ± 7.8°</td>
<td>55.9° ± 7.0°</td>
<td>58.2° ± 7.4°</td>
<td>60.6° ± 7.0°</td>
<td>61.9° ± 6.7°</td>
</tr>
</tbody>
</table>
Dorsiflexion.

Mauchly’s test of sphericity was violated for the Time effect ($p = .007$). Therefore, the Greenhouse-Geisser correction was applied and the Time effect was significant ($F(1.49, 26) = 24.96$, power = 1.00, $p < .001$, $r = 0.96$). On average, subjects experienced a significant decrease in dorsiflexion (DF) ROM between Barefoot and Pre-Exercise ($MA = 6.90$, $SD = 5.96$, $t(52) = 8.56$, $p < .001$) and with a large effect size ($r = 0.77$). Between Pre-Exercise and Post-Exercise, a significant increase in DF ROM was seen ($MA = -2.48$, $SD = 4.81^\circ$, $t(52) = -3.72$, $p < .001$). However, the difference signified a medium effect size ($r = 0.46$). When examining Barefoot and Post-Exercise, subjects did experience an overall decrease in ROM ($MA = 4.42$, $SD = 6.79^\circ$, $t(52) = 4.70$, $p < .001$) and represented a large effect size ($r = 0.55$). The mean results of dorsiflexion can be seen in Table 2. A main effect of Condition was found to be non-significant ($F(1, 26) = .01$, power = 0.05, $p = 0.92$, $r = 0.09$).

Mauchly’s test confirmed that the assumption of sphericity was not violated for the DF ROM variable for the Time by Condition ($p = 0.35$). The results of the two-way ANOVA indicated no significant Time by Condition interaction effect ($F(2,26) = 0.34$, power = 0.10, $p = 0.72$, $r = 0.38$). A graph comparing Condition at each Time point is shown in Figure 2.
Table 2

Descriptive Data for Dorsiflexion Values

<table>
<thead>
<tr>
<th>Type and Time</th>
<th>Mean (°)</th>
<th>Minimum (°)</th>
<th>Maximum (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White DF Barefoot</td>
<td>13.50</td>
<td>2</td>
<td>36</td>
</tr>
<tr>
<td>White DF Pre-Exercise</td>
<td>7.08</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>White DF Post-Exercise</td>
<td>9.46</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Heavy DF Barefoot</td>
<td>14.15</td>
<td>3</td>
<td>36</td>
</tr>
<tr>
<td>Heavy DF Pre-Exercise</td>
<td>6.77</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Heavy DF Post-Exercise</td>
<td>9.35</td>
<td>0</td>
<td>22</td>
</tr>
</tbody>
</table>

**Figure 2.** The error bars represent the standard deviation of the dorsiflexion ROM. While the total ROM is smaller during dorsiflexion, the graph provides similar results as the PF ROM. An initial decrease from Barefoot to Pre-Exercise is seen, followed by a subsequent increase in Post-Exercise.

Results from the paired t-test illustrate that the dorsiflexion ROM decreased equally after the application of both types of tape (Barefoot to Pre-Exercise). The DF ROM increased after exercise (Post-Exercise), but still remained more restricted than the barefoot condition (Barefoot), and both tapes performed equally. The barefoot ROM for white tape and heavy elastic tape (13.5° and 14.15°, respectively) is within the range presented by Boone and Arzen (1979) (12.6° ± 4.4°). The DF ROM varies among
different studies (Table 7). Despite the difference in raw measurements, a similar trend occurs between Times. Interestingly, Post-Exercise for white and elastic conditions are close to each other within studies (current and Abian-Vicen et al., 2009), but very different when comparing the studies to each other. This difference could be because of the way in which ROM was measured. The current study used active ROM, while Abian-Vicen used passive ROM. White tape allowed for 70.1% of the original DF ROM from the Barefoot baseline after exercise, while heavy elastic only allowed 66.1% of the original ROM.

Table 7

Comparing Dorsiflexion ROM Across Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Barefoot</th>
<th>Pre-Exercise (White)</th>
<th>Pre-Exercise (Elastic)</th>
<th>Post-Exercise (White)</th>
<th>Post-Exercise (Elastic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Study</td>
<td>White: 13.5°</td>
<td>7.08°</td>
<td>6.77°</td>
<td>9.46°</td>
<td>9.35°</td>
</tr>
<tr>
<td>Fumich (1981)</td>
<td>Elastic: 14.15°</td>
<td>24.4°</td>
<td>18.6°</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Abian-Vicen et al. (2009)</td>
<td>18.4° ± 7.0°</td>
<td>15.9° ± 6.4°</td>
<td>16.4° ± 7.2°</td>
<td>17.3° ± 6.8°</td>
<td>17.1° ± 7.7°</td>
</tr>
</tbody>
</table>

Inversion.

A main effect of Time was found in the two-way ANOVA analysis (F(1.67, 26) = 73.23, power = 1.00, p < 0.01, r = 0.97). Subjects experienced a significant difference in inversion ROM between Barefoot and Pre-Exercise (MΔ = 10.60, SD = 5.90, t(52) = 12.95, p < .001) and the effect size was large (r = 0.88). Between Pre-Exercise and Post-Exercise there was an increase in ROM (MΔ = -4.54, SD = 3.93, t(52) = -8.33, p < .001) and this represented a large effect size (r = 0.76). When examining the ROM while
barefoot to ROM post exercise, an overall significant decrease in inversion ROM was established (MΔ = 6.06, SD = 5.21, t(52) = 8.38, p < .001) and was a large effect size (r = 0.76). Raw values for Condition in specific Times can be seen in Table 3. The main effect of Condition was not significant (F(1, 26) = 0.38, power = 0.09, p = 0.54, r = 0.52).

Table 3

Descriptive Data for Inversion Values

<table>
<thead>
<tr>
<th>Type and Time</th>
<th>Mean (°)</th>
<th>Minimum (°)</th>
<th>Maximum (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White IN Barefoot</td>
<td>15.35</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>White IN Pre-Exercise</td>
<td>5.58</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>White IN Post-Exercise</td>
<td>10.81</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Heavy IN Barefoot</td>
<td>16.62</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>Heavy IN Pre-Exercise</td>
<td>5.19</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Heavy IN Post-Exercise</td>
<td>9.04</td>
<td>1</td>
<td>16</td>
</tr>
</tbody>
</table>

Mauchly’s test indicated that the assumption of sphericity was violated for inversion ROM for a Time by Condition effect (p = 0.02). The degrees of freedom were therefore altered with the Greenhouse-Geisser correction for the Time by Condition effect and was significant. Inversion ROM was the only Time by Condition interaction effect found to be significant within the study (F(1.58, 26) = 5.97, power = 0.79, p = 0.01, r = 0.89). Because of the significant p-value seen in the ANOVA, a paired t-test was performed to examine the Conditions in each Time for inversion ROM. The t-test revealed a significance of restriction in only one time period: Post-Exercise (MΔ = 1.77, SD = 2.96°, t(26) = 3.05, p < .001) and this was a large effect size (r = 0.52). The interaction plot of Time by Condition can be seen in Figure 3. Specific values for the Time by Condition paired t-test can be seen in Table 5.
Figure 3. The difference in ROM during Post-Exercise suggests that the relationship between white tape and heavy elastic tape during inversion ROM is statistically significant. Over time, the inversion ROM decreases after the application of tape (Pre-Exercise) and increases Post-Exercise, but still remaining a greater restriction than Barefoot.

Table 5

Paired T-Test for Inversion ROM, White Tape versus Heavy Tape

<table>
<thead>
<tr>
<th>Type and Time</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig.</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>White IN – Heavy IN Barefoot</td>
<td>-1.27</td>
<td>5.02</td>
<td>-1.29</td>
<td>25</td>
<td>0.21</td>
<td>-</td>
</tr>
<tr>
<td>White IN – Heavy IN Pre-Exercise</td>
<td>0.39</td>
<td>2.00</td>
<td>0.98</td>
<td>25</td>
<td>0.34</td>
<td>-</td>
</tr>
<tr>
<td>White IN – Heavy IN Post-Exercise</td>
<td>1.77</td>
<td>2.96</td>
<td>3.05</td>
<td>25</td>
<td>0.01</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Overall, the results of the paired t-test showed that Post-Exercise, the heavy elastic tape resisted more inversion motion than the white tape. Between Barefoot and Pre-Exercise, the tapes performed similarly by both restricting ROM in the inversion ROM. From Barefoot to Post-Exercise, both tapes restricted the inversion ROM with a large effect size with the heavy elastic tape restricting inversion ROM significantly more than the white tape. The mean ROM for inversion is different in the current study than other research (Table 8). This difference could be partially due to the technique used
for measurement, in that it was an active ROM of the rear foot motion, as opposed to
passive ROM of forefoot motion. Despite a difference in raw measurements, a similar
result of decreased ROM between Barefoot and Pre-Exercise is seen, as well as an
increase between Pre-Exercise and Post-Exercise. After exercise, white tape allowed for
70.4% of the original inversion ROM from the Barefoot baseline. Heavy elastic tape,
however, only allowed for 54.4% of the original motion to occur.

Table 8
Comparing Inversion ROM Across Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Barefoot</th>
<th>Pre-Exercise (White)</th>
<th>Pre-Exercise (Elastic)</th>
<th>Post-Exercise (White)</th>
<th>Post-Exercise (Elastic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fumich (1981)</td>
<td>30.6°</td>
<td>19°</td>
<td>-</td>
<td>24.25°</td>
<td>-</td>
</tr>
<tr>
<td>Abian-Vicen et al. (2009)</td>
<td>36.7° ± 7.8°</td>
<td>21.3° ± 3.8°</td>
<td>21° ± 5.1°</td>
<td>27° ± 4.6°</td>
<td>25.3° ± 5.4°</td>
</tr>
</tbody>
</table>

**Eversion.**

According to Mauchley’s test, sphericity was not violated for Time or Time by
Condition (p = .104 and p = .074, respectively) for the dependent variable eversion
ROM. There was a significant effect of Time (F(2, 26) = 63.32, power = 1.00, p < .001, r =
.91). A significant decrease in eversion ROM was seen between Barefoot and Pre-
Exercise (MA = 5.25, SD = 3.22, t(52) = 11.77, p < .001) and this was a large effect size (r
= 0.85). An increased ROM was seen between Pre-Exercise and Post-Exercise (MA = -
2.98, SD = 2.58, t(52) = -8.34, p < .001) and was also a large effect size (r = 0.76). From
Barefoot to the end of the study, Post-Exercise, subjects had a general decrease in ROM
(MA = 2.27, SD = 3.57, t(52) = 4.58, p < .001) and this represented a large sized effect (r = 0.54). Specific mean, minimum and maximum values for eversion ROM can be seen in Table 4. The main effect of Condition was significant (F(1, 26) = 4.72, p = 0.04, power = 0.55, r = 0.91). There was a mean difference when comparing white tape and heavy elastic (MA = .83, SD = 3.08, p < .001). This information suggests that white tape had consistently greater range of motion compared to heavy elastic at each time point, including barefoot. Therefore, it can be interpreted that the effect seen is because of a difference in ankle ROM between ankles taped with white tape and ankles taped with heavy elastic, rather than the condition causing the effect. Sphericity was not violated for the interaction effect of Time by Condition during the eversion motion (p = 0.07). The ANOVA for Time by Condition for eversion ROM found the effect not significant (F(2,26) = 0.35, power = 0.10, p = 0.70, r = 0.39). A graph of Condition at each Time can be seen in Figure 4.

Table 4

Descriptive Data for Eversion Values

<table>
<thead>
<tr>
<th>Type and Time</th>
<th>Mean (°)</th>
<th>Minimum (°)</th>
<th>Maximum (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White EV Barefoot</td>
<td>9.77</td>
<td>8.39</td>
<td>11.15</td>
</tr>
<tr>
<td>White EV Pre-Exercise</td>
<td>4.23</td>
<td>3.20</td>
<td>5.26</td>
</tr>
<tr>
<td>White EV Post-Exercise</td>
<td>7.19</td>
<td>5.9</td>
<td>8.49</td>
</tr>
<tr>
<td>Heavy EV Barefoot</td>
<td>8.54</td>
<td>7.58</td>
<td>9.5</td>
</tr>
<tr>
<td>Heavy EV Pre-Exercise</td>
<td>3.58</td>
<td>2.71</td>
<td>4.45</td>
</tr>
<tr>
<td>Heavy EV Post-Exercise</td>
<td>6.58</td>
<td>5.61</td>
<td>7.54</td>
</tr>
</tbody>
</table>
Figure 4. White tape and heavy elastic tape react similarly during eversion ROM. However, despite the difference in degrees of movement, an interaction effect between Time and Condition was not found.

These results suggest that applying tape to the ankle limits eversion ROM. The eversion ROM increased following exercise (Post-Exercise) but was still more restricted than when subjects were Barefoot. When comparing barefoot to after exercise, the values were significantly different, confirming that taping an ankle - regardless of the type of tape - does hold some restrictive properties after fifteen minutes of exercise. As the main effect of Condition was significant, it can be inferred that at each Time, the Conditions acted differently from each other, however, they maintained a similar difference at each Time. Because of the discrepancy in Barefoot across conditions, the results suggest that the subjects’ eversion ROM differed between feet, and the two tapes performed similarly in restricting ROM Pre-Exercise and Post-Exercise.

While measurement techniques could be the reason for a difference in mean of ROM (Table 9) across all three studies, Pre-Exercise ROM decreases from Barefoot.
However, when comparing the current study to a study by Abian-Vicen et al. (2009), the ROM increase Post-Exercise was not nearly as drastic in the white tape condition. As previously discussed, however, this discrepancy in ROM could have been a typographical error, as the numbers presented were the same as for inversion ROM in the previous study. Following 15 minutes of multidirectional exercise, white tape allowed for 73.6% of the original eversion ROM to return of the original Barefoot ROM. Heavy elastic tape allowed for 77% of the baseline Barefoot ROM to return after exercise.

Table 9

Comparing Eversion ROM Across Studies

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Summary

The two tapes performed similarly, restricting ROM after fifteen minutes of exercise. Overall, the application of tape has initial restricting effects. The short-term restriction of the tape (as depicted by Post-Exercise values) was greater than the ROM without tape (Barefoot); however, the results were not significant when comparing heavy elastic to white tape between Barefoot and Post-Exercise for PF, DF and EV ROM. Inversion ROM was an exception, in which case heavy elastic tape restricted ROM more
than white tape Post-Exercise. Eversion ROM acted in a different manner than PF and DF. While there was no interaction effect of Time by Condition, there was an effect of Time and Condition separately. Time acted in a predictable manner, where both tapes restricted more motion Post-Exercise than a Barefoot condition. Heavy elastic tape was more restrictive at each Time compared to the white tape, including the barefoot condition, which suggests a systematic difference in the EV ROM for the subjects’ feet.
Chapter V
Summary and Conclusions

Summary

Athletic trainers are constantly searching for taping methods that are practical, applicable, and cost efficient in order to help athletes return to play safely and quickly. While the standard has been tape with white cloth, new taping materials have been released that athletic trainers find effective in their practice, but are without the research to support their higher costs. Several studies have shown that white tape degrades in its restrictive qualities as early as five minutes into exercise (Bot et al., 2003; Eils et al., 2007; Glick et al., 1976; Greene & Hillman, 1990; MacKean et al., 1995).

Subjects of this study consisted of eight men and eighteen women from Western Washington University. Participants were recruited from classes in the college. Subjects met with the researcher once for an average time of forty-five minutes. The subjects were measured for ROM in both ankles, and then had one ankle taped with white tape, and the other with heavy elastic tape. After taping, subjects were again measured for their ROM in both ankles. The exercise protocol consisted of a five-minute warm-up, followed by ten minutes of five stations, including: forward and backward jogging, lateral shuffle, zig-zags, hops, and jogging figure-of-eights. A similar protocol can be seen in the study by Purcell et al. (2009). After exercising, subjects were measured for ROM in both ankles. All measurements were performed by the same experienced ATC, and all ankle tapings were performed by another experienced ATC.
**Conclusions**

Based on the findings of this study, there was a significant difference between white tape and heavy elastic tape during the inversion movement Post-Exercise. Heavy elastic tape restricted the inversion ROM a greater amount than white tape after fifteen minutes of multi-directional exercise. Heavy elastic tape also restricted a greater amount of eversion motion than white tape at all times, though since this was the case also during the barefoot condition, this may simply reflect a difference between feet in eversion ROM.

The restriction of inversion ROM seen with the application of heavy elastic suggests the validity of using this tape versus a normal white tape. Wolfe et al. (2001) advise that an inversion ankle sprain is far more likely to occur because of the length discrepancy of the medial and lateral malleoli. By having a much shorter medial malleolus, the ankle is lacking the bony structure to limit inversion motion, thereby relying on the lateral ligaments and muscular support for protection (Wolfe et al., 2001). As previously described in the literature review, Nakasa et al. (2008) illustrates the importance of limiting inversion ROM. When evaluating ROM in subjects with previous ankle injury, they suggested that mechanoreceptors present in the structures of the lateral aspect of the ankle (retinaculum, lateral ligaments, and capsule) are damaged in an inversion ankle sprain and lead to a diminished position sense during inversion ROM. This contributes to greater susceptibility to excessive ROM due to disrupted ligamentous support. By aiding the damaged ligaments with the heavy elastic tape, it is possible to reduce the risk of a recurring injury (Nakasa et al., 2008).
The results of this study pertain to a particular duration of time of exercise. The research suggests that with a longer exercise protocol, a more significant difference between the tapes could be seen (Bot et al., 2003; Eils et al., 2007; Glick et al., 1976; Greene & Hillman, 1990; MacKean et al., 1995; Rarick et al., 1962). The current study demonstrated that white tape still provided restriction following exercise, whereas other studies have shown the taped ankle to return to closer to Barefoot ROM values following exercise. By expanding the length of the study the results may change by allowing both tapes to lose their stiffness and become less effective. However, the results confirm that white tape restricts ROM in four directions a significant amount before and after fifteen minutes of multi-directional exercise. The results also demonstrate that heavy elastic tape is as effective as white tape in the same exercise protocol, with the exception of an improvement in restricting inversion ROM after fifteen minutes of exercise.

It may be possible that the present study resulted in the tape maintaining its integrity longer and restricting ROM better than previous studies may because of the population of the subjects. Many of the current subjects had never experienced an ankle taping. While they were watched during exercise and showed no visible change in gate, their inexperience could have resulted in not being able to perform the same as people who had their ankle taped prior to the study. It is also noted that many of the subjects were runners and of smaller mass. Additional weight provided by the subjects may affect the breakdown rate of the tapes. It would be interesting to see if the same results were found in a subject population with a larger mass.
Although studies have shown a range of moderate to highly reliable intraclass correlation coefficients when taken by the same therapist over a short period of time (Elveru et al., 1988; Menadue et al., 2006) human error can occur. While a manual goniometer is common in an athletic training room, results may have slightly varied if an electrogoniometer was utilized instead of a traditional measuring method.

The results of this study support the use of heavy elastic tape instead of white cloth tape for athletes requiring greater restriction of inversion ROM, but the long-term effects (e.g. of a 2-3 hour practice session) remain unknown. This study has set the foundation for future research to be performed with heavy elastic tape and further explore its lasting effects.

**Recommendations**

The following recommendations are suggested for further investigations:

1. A longer exercise protocol may show a greater difference in the lasting effects of the different tapes.

2. Using an electric goniometer may provide more accurate results than the manual goniometer used in the current study.

3. Using subjects who have prior experience with ankle tapings may provide more applicable result.
References


Appendix A

Informed Consent
INFORMED CONSENT FORM

Title of Investigation: The effect of ankle taping utilizing two different types of tape on range of motion.

Investigator: Laura Grambo, ATC, AT/L, phone: (360) 430 - 8014  
Department of Physical Education, Health and Recreation  
516 High St., Carver 102  
Western Washington University  
Bellingham, WA 98225-9067

This is to certify that I, ____________________________________________________________, agree to participate as a volunteer in a scientific investigation as an authorized part of the education and research program of Western Washington University conducted by Laura Grambo.

Purpose of the Study:

The study in which I will be participating is designed to investigate the effectiveness of heavy elastic tape compared to non-elastic, cloth tape on ankle range of motion after ten minutes of multi-directional exercises. This study will lay the foundation for future research which can compare the effects of an ankle taping with heavy elastic tape to an ankle brace. I understand this study is directed towards improving the understanding of a common tool in the athletic training profession.
**Procedures to be followed:**

I understand that males and females will be invited to participate in this study involving ankle taping and range of motion. I understand that in order to participate in this study:

- I can not have experienced an ankle injury within the last month,
- I must meet a pre-determined range of motion in the ankle,
- I must be able to perform ten minutes of agility drills and tasks.

**Discomforts and Risks:**

I understand that, as with any exercises, there are risks of injury due to accidents during the exercise activities. There is also a minimal risk that trauma to the bone, such as fractures, or to the muscle or joint could result from an abnormal response to the exercise activities. I understand that if an exercise task is painful, I can stop at any time. If I feel I cannot, or should not, perform any of these tasks, I should not participate in this study. I understand that if I feel lightheaded or dizzy I may stop immediately, and resume later; or I may withdraw from participation altogether.

I also understand that some people can be allergic to athletic tape and spray adhesives, experiencing a rash reaction on their skin. There is also a small possibility that a tape cut, skin fold, or blister could result from the tape application. If I experience any discomfort due to the tape or spray adhesive, I understand that I should inform the investigator, who will cut off the current tape and re-apply it in an attempt to relieve discomfort and allow me to restart the study, if I so desire.

**Benefits to Me:**

I understand that there are no direct benefits to me as a result of participating in this study.

**Potential Benefits to Society:**

By participating in this study I will be contributing to research that aims to advance the understanding of the effectiveness of athletic tape in the field of athletic training.
**Statement of Confidentiality:**

I understand that my identity will remain confidential at all times during this study. Only the investigator will have access to my identity and to the information that can be associated with my identity. In the event of this research becoming published, no personally identifying information will be disclosed.

The procedures of this study and a description of any risks and discomfort have been discussed in detail with me. The study and my part in the research have been defined and fully explained to me and I understand the explanation. I understand that a copy of the signed consent form will be provided to me.

**Right to Ask Questions:**

I will be given an opportunity to ask whatever questions I may have and all such questions will be answered to my satisfaction. I understand that I am not required to answer specific questions that I am uncomfortable with in the initial interview.

I understand that for additional information about my rights as a research participant, I may contact Dr. Ken W. Clark, WWU Human Protections Administrator, at:

Dr. Ken W. Clark, Director  
Research and Sponsored Programs  
Old Main Building 530  
Western Washington University  
Bellingham, WA 98225-9038  
(360) 650-4403
Compensation:

I understand that I will not receive compensation by participating in this study.

Event of injury:

I understand that in the event of an injury resulting from this study, emergency medical care will be summoned. If adverse effects do occur in relation to this study, I understand that I shall contact Dr. Ken W. Clark at the office listed above. I also understand that I am not waiving any rights that I may have against Western Washington University for injury resulting from negligence of investigators or the University.

Voluntary Participation:

I understand that I may withdraw from this study at any time by notifying the investigator, as my participation is voluntary. I also understand that if I do not fit any of the predetermined subject categories, the investigator may deny or terminate my participation.

This certifies that I am over 18 years of age and consent to my participation as a volunteer in this study. I have read and understand the content of this consent form and will receive a signed copy.

Volunteer ___________________________ Date __________

I, the undersigned, have fully explained the investigation to the above subject.

Investigator ___________________________ Date __________
Audiotaping, Videotaping, and Photography

By initialing on the lines below, I am indicating that I give the research team permission to (please initial any that apply*):

______ Photograph, audiotape and/or videotape my participation in this study.

______ Use photographs, audiotape or videotape recordings of me when they present this research in educational and professional venues, even if I am personally identifiable.

______ Use photographs, audiotape or videotape recordings of me when they present this research in educational and professional venues, only as long as I am not personally identifiable.

* Note: permission to record the sessions is not required for participation in this study, but will improve my ability to present the findings at educational and professional venues.
Appendix B

Ankle Taping Photos
Ankle Taping Photos

*Figure 5.* Heel and lace pads are applied on the ankle before Tuff-Skin is sprayed. These pads help to decrease the risk of tape cuts.

*Figure 6.* Prewrap is laid down. This material is used for comfort for the person being taped. It is important to keep the ankle in extreme dorsiflexion from this point on.
Figure 7. Three anchors are placed at the top of the prewrap. The most proximal anchor lays half directly on the skin, and half on the prewrap.

Figure 8. Stirrups are placed medial to lateral. This helps to pull the ankle into eversion, which is a more stable position.
Figure 9. Horse shoes are placed around the stirrup to help hold them tightly against the skin. A horse shoe is placed after each stirrup.

Figure 10. After the third stirrup is placed, cover strips are placed around the exposed Achilles’ heel. Cover strips help to reduce tape cuts that can occur from heel locks.
Figure 11. Heel locks were performed on each side. The heel lock began above the lateral malleolus, traveled downward, behind the Achilles, wrapping the calcaneus and coming up on the forefoot on the lateral side. This is a half heel lock. The same steps are followed, beginning above the medial malleolus.

Figure 12. Two figure-of-eights were the last step before cover strips. The technique started on the medial, dorsal aspect of the foot. The tape travels down near the navicular bone, under the arch, up near the base of the fifth and across the forefoot to wrap around the calf.
Figure 13. This is a lateral view of a figure of eight. This is performed twice and is the last step before the cover strips.
Appendix C

Raw Data
## Raw Data

### Subject Characteristics

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