2005

Joint Kinematics and Kinetics During Drop Landings Under Braced and Taped Conditions in Persons with Functional Ankle Instability

Hayley McKelle Ulm

BARRY UNIVERSITY

SCHOOL OF HUMAN PERFORMANCE AND LEISURE SCIENCES

JOINT KINEMATICS AND KINETICS DURING DROP LANDINGS UNDER BRACED AND TAPED CONDITIONS IN PERSONS WITH FUNCTIONAL ANKLE INSTABILITY

By

Hayley McKelle Ulm

A Thesis submitted to the
Department of Sport and Exercise Sciences
in partial fulfillment of the
requirements for the Degree of
Master of Science in
Movement Science
with a specialization in
Biomechanics

Miami Shores, Florida
2005

JOINT KINEMATICS AND KINETICS DURING DROP LANDINGS UNDER BRACED AND TAPED CONDITIONS IN PERSONS WITH FUNCTIONAL ANKLE INSTABILITY

A Thesis

Submitted to the Faculty of the Department of Sport and Exercise Sciences in Partial Fulfillment of the Requirements for the Degree of Master of Science in Movement Science

Barry University

By

Hayley McKelle Ulm

Barry University

December, 2005

Signature page

ACKNOWLEDGEMENTS

I would like to thank the people who have inspired and encouraged me along this adventurous journey at Barry University.

Dad, Mom, Kolt and the rest of the Ulm clan, my family, thank you for all the love and support you have given to me. Thank you for never giving up on me and supporting me in all my dreams. Mom and Dad, thank you for the money that magically appeared in my bank account. Dad, I promise I will buy you a big farm with a tractor (when I win the lottery). Mom, I promise to buy you postcards.

Dr Butcher-Mokha, Dr. Ludwig, and Dr. Cramer, my committee, thank you for helping me along the way. Thank you for all the knowledge you all have passed down to me. I have listened to everything you have taught me and feel prepared to go out into the work force with confidence.

Jessica, Michelle, Grethel and Marie, my best friends, thank you for all the support you have given me the past two years. Thank you for always believing in me even when I felt nothing could go right and for never letting me quit in my times of struggle. I will definitely miss our times at Starbucks and Jamba Juice.

To the rest of the group, Jason, Chris, Edward, Joe, Joel, Lars, and Johnny, thank you for all your jokes and always making me laugh. I will miss ALL the hurricane parties we had.

Akiko, my partner in crime, thank you for pushing me through the last couple of months. Thank you for always bringing a smile to my face. May all your dreams come true.

Monica, my roommate, thank you for being the best roommate I ever had. I may be asking you for a job one day.

To Pastor Mark and Miami Shores Baptist Church, my home church away from home, thank you for everything you have done for me. Thank you to the many “parents” I had looking out for me and keeping me out of trouble.

ABSTRACT

The most common injury among athletes is the lateral ankle sprain. In order to protect and prevent ankle injuries, ankle braces and/or tape are commonly used by sports medicine professionals. **Purpose:** To determine the effects of ankle stabilizers on ankle and knee joint ROM and ankle and knee joint kinetics between participants with healthy ankles and those with FAI. **Methods:** A total of fourteen participants were used (7 control, 7 with FAI volunteered for this study). Participants were asked to perform a single-leg drop landing off a platform .60m high onto force plate .11m away from the platform under three conditions: ankle taped, ankle braced and with no stabilizer. The participants were required to stick the landing for a total of five seconds. If the participant could not land on the center of the force plate or hold the landing for five seconds or fell, the landing was retried immediately. A repeated measures 2 x 3 MANOVA (groups x stabilizers) was used to analyze the results**.** **Results:** Three of the eleven dependant variables were significant; ankle medial joint forces ($F(1,36) = 6.095$, $p < .05$); knee medial joint forces ($F(1,36) = 4.844$, $p < .05$); ankle abduction moments ($F(1,36) = .4.754$, $p < .05$). There were no other significance differences to report among the other dependant variables between the groups. Ankle dorsiflexion ROM ($F(1, 36) = .057$, $p >.05$); ankle abduction/adduction ROM ($F(1,36) = .001$, $p >.05$); knee flexion/extension ROM ($F(1,36) = 3.088$, $p > .05$); peak vertical GRF ($F(1,36) = 2.614$, $p > .05$); ankle anterior joint forces ($F(1,36) = 1.283$, $p>.05$); knee anterior/posterior joint forces ($F(1,36) = .830$, $p > .05$); ankle flexion/extension ($F(1,36) = .307$ $p > .05$); knee flexion/extension moment ($F(1,36) = .000$, $p >.05$).
Conclusions: Stabilizers had no effect on ankle and knee ROM, or peak vertical GRF between FAI and FAS groups. FAI had greater medial ankle joint forces, medial knee joint

forces and less abduction ankle moments than those with FAS regardless of stabilizer condition.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

CHAPTER ONE

Introduction

The most common injury among athletes is the lateral ankle sprain (Fink & Mizel, 2001; Lynch & Renstrom, 1999; Thonnard, Bragard, Willens, & Plaghki, 1996). In the ankle there are three main ligaments on the lateral side of the ankle: the anterior talofibular ligament (ATF), the calcaneofibular ligament (CF) and the posterior talofibular ligament (PTF). Because the ATF runs parallel to the axis of the leg when the foot is in plantar flexion, it is sprained the most (Lynch, 2002). About 85% of ankle sprains involve the inversion movement (Hubbard & Kaminski, 2002). The CF and the PTF are also sprained in more severe ankle injuries (Lynch, 2002).

Most ankle sprains are not only painful, but also can decrease range of motion (Madras & Barr, 2003). Depending on the severity of the damage done to the ligament, there are different grades given to ankle sprains (Madras & Barr, 2003). Balance, proprioception, inflammation, coordination and nerve damage are some of the side effects that might occur because of ankle sprains (Madras & Barr, 2003). Ankle sprains can easily become a chronic problem. Once an ankle has been sprained, it is very challenging to regain the balance that he/she once had (Madras & Barr, 2003).

Many people do not recognize the dangers of ankle instability. Hertel (2002) estimated that 55% of athletes who have sprained an ankle do not seek professional medical attention. Lynch (2002) estimated that 7% to 10% of ankle injuries require emergency room visits.

Causes of ankle sprains can be categorized as intrinsic and extrinsic (Beynnon, Murphy & Alosa, 2002). Intrinsic factors include previous sprains, gender, height and weight, limb dominance, anatomic foot type and foot size, generalized joint laxity, anatomic alignment, ankle-joint laxity, and range of motion (ROM) of the ankle, muscular strength, muscle reaction time, and postural sway. Ankle bracing and taping, shoe type, and the time and intensity of the activity and the position of the athlete injured are the extrinsic factors that could affect ankle instability

Ankle taping is widely accepted as an effective ankle stabilizer. It helps restrict joint range of motion (ROM). According to McCaw and Cerullo (1998), ankle braces reduced ankle ROM. The results of their study suggest that some ankle stabilizers used to prevent ankle sprains impinge on the normal kinematics of the ankle joint during drop landings. However, one study showed that ankle taping starts to loosen 18% to 40% of its support after ten minutes of exercise (Thonnard et al, 1996). Also, ankle tape is expensive when used throughout the season.

Over the past few years, ankle braces have become popular among athletes. The ankle brace was designed to mechanically restrict any plantar flexion and inversion movements of the ankle (Palmieri et al, 2002). The most commonly used ankle braces are made of soft cloth and can be laced up. This allows the athlete to tie the brace as tight as he/she feels comfortable. If the brace loosens up during activity, it is easy to tighten again. However, McKay, Goldie, Oakes (2001) found that ankle tape is the best method to reduce the risk of ankle injuries.

Since ankle sprains are the most common injury in sports, it is imperative that athletes are educated on the prevention of ankle injuries. Ankle injuries can become chronic if not treated appropriately. Researchers have thought that ankle instability is caused by reduced proprioception, muscular strength, and muscular power (Mattacola &

Dwyer, 2002). Past research has indicated that the use of ankle supports significantly reduces ankle injuries and chronic ankle instability.

Statement of the Problem

Some researchers state that ankle stabilizers, such as a brace or tape, restrict ankle range of motion (ROM) and therefore create more stress on the knees and hip (Hopper, McNair, & Elliot, 1999). Others state that ankle stabilizers help reduce ankle injuries by reducing ankle ROM (Hartsell & Spaulding, 1997). Many researchers say that ankle stabilizers should only be used by those athletes who have been diagnosed as having functional ankle instability (FAI).

Purpose of the Study

The purpose of this study is to determine the effects of ankle stabilizers on ankle and knee joint ROM, ground reaction forces (GRF), and joint forces and moments in participants with functional ankle stability (FAS) and participants with FAI.

Research Hypotheses

- Ankle braces will reduce ankle dorsiflexion ROM more than tape.
- Ankle braces will reduce knee flexion ROM more than tape.
- Ankle braces will produce greater GRF more than tape.
- Ankle braces will reduce ankle medial and anterior forces at the knee and ankle.

Null Hypotheses

- There will be no significant differences in dorsiflexion ROM between the brace, tape, or no stabilizer conditions.

- There will be no significant differences in dorsiflexion ROM between FAI or FAS.
- There will be no significant differences in knee flexion ROM between the brace, tape, or no stabilizer conditions.
- There will be no significant differences in knee flexion ROM between FAI or FAS.
- There will be no significant differences in peak GRF between the brace, tape, or no stabilizer conditions.
- There will be no significant differences in joint kinetics between the brace, tape, or no stabilizer conditions.
- There will be no significant differences in joint kinetics between those with FAS and those with FAI.
- There will be no significant interaction between the stabilizer conditions and the groups in joint kinetics, joint kinematics and GRF.

Significance of the Study

Athletic trainers and physical therapists are seeking methods of reducing the incidence of ankle sprains. Athletic trainers and physical therapists must make a decision on what they believe will reduce the occurrence of ankle sprains. The data collected during this study will be designed to assist athletic trainers and physical therapists make informed choices regarding the use of two common methods of external stabilization.

Operational Definitions

- Anterior talofibular ligament (ATF) - Restrains anterior displacement of the talus. The weakest of the three lateral ankle ligaments (Prentice, 2003).

- Athletic trainer – An athletic trainer is a professional individual who is trained to the deal with an athlete throughout the entire rehabilitation period, from the time the athlete sustains an injury, till the time the injury heals and the athlete is allowed to return to practice and compete. An athletic trainer is responsible for the all phases of health care in the athletic environment, including prevention of injury, providing initial care and first aid, assessment of injury and designing an effective rehabilitation program that will return the athlete to activity in a timely manner (Prentice, 2003).
- Calcaneofibular ligament (CF) - Restrains inversion of the calcaneus.
- Deltoid ligaments - Prevents abduction and eversion of ankle and subtalar joint and prevents eversion, pronation, and anterior displacement of talus (Prentice, 2003).
- Eversion ankle sprains - Only represents 5 to 10% of all ankle sprains. Pain is severe over the foot and lower leg. Eversion ankle injuries could potentially produce a tear in the deltoid ligaments on the medial side of the ankle (Prentice, 2003).
- Functional Ankle Instability (FAI) – Characterized by a tendency for the foot to repeatedly sprain or give way (Freeman, Dean & Henham, 1965) as a result of inability to maintain stability of the ankle joint during dynamic activity (Caulfield, Crammond, O'Sullivan, Reynolds, & Ward, 2004). Researchers have used the FAI Questionnaire to test for FAI (Hubbard & Kaminski, 2002).

- Functional Ankle Stability (FAS) – The group with no previous history of lower extremity injuries and reported having no problems with the instability or the ankle giving way.
- Grade 1 inversion ankle sprain - The most common ankle sprain. The ankle is inverted, plantar flexed and adducted. The ATF is stretched with mild pain, point tenderness, and swelling over the ligament (Prentice, 2003).
- Grade 2 inversion ankle sprain - Causes the most ankle disability. The ankle is inverted, plantar flexed, and adducted. The athlete will complain that the ankle will make a pop or snapping sound on the lateral side. There is also moderate pain with point tenderness, edema, and disability (Prentice, 2003).
- Grade 3 inversion ankle sprain - Very uncommon among athletes. The ankle will often subluxate and spontaneously reduce. A grade 3 inversion ankle sprain is caused by a considerable inversion force combined with plantar flexion and adduction. There is considerable pain in the around the lateral malleolus (Prentice, 2003).
- Ground Reaction Forces (GRF) – The forces of gravity that act downward through the centers of mass of each segment and are equal to the magnitude of the mass times acceleration due to gravity (normally 9.8 m/s^2)(Winter, 2005).
- Mechanical instability – Refers to joint motion beyond normal physiological limits (Tropp, Odenrick, & Gillquist, 1985).
- Moment (Muscle Moment) – The net effect (torque) of muscle activity at a joint Winter (2005)

- Physical therapists – An individual who duty is to supervise rehabilitation programs for injured athletes. In many sport medicine clinics, athletic trainers and physical therapist work together to help athletes during rehabilitation. (Prentice, 2003)
- Posterior talofibular ligament (PTF) - Restrains posterior displacement of the talus (Prentice, 2003).
- Stability – The condition of remaining unchanged in the presence of forces that would normal alter a state or condition. (Taber's Cyclopedic Medical Dictionary, 1993).
- Torque – "The same as *moment of force*, especially when the moment of force is about the longitudinal axis of a body" (Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2004).

Assumptions

The following are the assumptions of this study: (a) participants gave their best effort; (b) participants reported ankle stability conditions correctly.

Limitations

The following were limitations in this study: (a) the participants may be predisposed to one stabilizer or another because of past history.

Delimitations

The following delimitations for this study were: (a) the participants with FAI have a negative anterior drawer test and talar tilt test, (b) the participants with FAS have not had an lower extremity injury in the past year, and (c) all the participants in this study have not used an ankle stabilizer, tape or brace, in the past year, (d) participants who were currently using an ankle stabilizer were excluded from this study, and (e) the participants' ankle was taped by the same athletic trainer using the same techniques as described in Prentice (2003), (f) the participants were physically active, performing vigorous activity three times a week 30 minutes a day.

CHAPTER TWO

Review of Literature

The joint in the body that bears the most stress during physical activity is the ankle (Smith, 2003). This stress leads to ankle injuries and instability. In order to protect and prevent inversion ankle sprains, ankle braces and tape are commonly used (Alves, Alday, Ketcham, & Lentell, 1992; Jerosch, Thorwesten, Bork & Bischof, 1996; Karlsson, Sward, & Andreasson, 1993; Shapiro, Kabo, Mitchell, Loren, & Tsenter, 1994; Wilkerson, 1991). The purpose of this study is to determine differences in ankle stabilizers as measured by ankle and knee range of motion (ROM) and ground reaction forces (GRF). Also The goal is to determine differences in ankle stabilization as measured in joint ROM, GRF, and joint forces and moments between participants with functional ankle stability (FAS) and functional ankle instability (FAI). This review of literature will address the following topics: (a) ankle anatomy, (b) ankle instability, (c) ankle braces, (d) ankle tape, (e) stabilizer effects on knee ROM, (f) ground reaction forces, (g) joint motion during drop landings.

Ankle Anatomy

The ankle is a complex structure made of many bones, ligaments, muscles and tendons that provide stability and flexibility (Magee, 1997). The two main functions of the lower leg, foot and ankle are to provide support and propulsion. The bones of the ankle include the tibia, fibula, talus, and the calcaneous (Prentice, 2003).

The tibia is the longest bone in the body (Prentice, 2003). It is located on the medial side of the lower leg and is the primary weight-bearing bone of the leg. The tibia joins with the talus below and the femur above (Taber's Cyclopedic Medical Dictionary, 1993).

The fibula is known as one of the longest yet thinnest bones in the body (Taber's Cyclopedic Medical Dictionary, 1993). It is located on the lateral side of the tibia, just below the knee joint (Prentice, 2003). The primary function of the fibula is to provide attachments for muscles. The fibula attaches proximally to the tibia and distally to the tibia and talus (Taber's Cyclopedic Medical Dictionary, 1993).

The talus articulates with the tibia, fibula, calcaneus, and navicular bone (Taber's Cyclopedic Medical Dictionary, 1993). It is the primary weight bearing bone of this articulation (Prentice, 2003). The talus rests on the calcaneus and articulates with both the lateral and medial malleoli.

The calcaneous, or heel bone, is the main attachment for the Achilles tendon and other structures located on the plantar surface of the foot (Prentice, 2003). The cuboid bone and the talus both articulate with the calcaneous (Taber's Cyclopedic Medical Dictionary, 1993). It is the largest tarsal bone in the foot and supports the talus and shapes the heel (Prentice, 2003). The primary function of the calcaneous is to transmit the body weight on the ground.

The three ligaments located on the lateral side of the ankle are the anterior tibofibular ligament (ATFL), calcaneofibular (CFL), and posterior talofibular ligament (PTFL) (Lynch & Renstrom, 1999). They are not as strong as the deltoid ligaments on the medial side of the ankle (Hoppenfeld, 1976). According to Safran et al (1999), these ligaments are designed to provide proprioceptive information about the body's movement and position and help improve ankle stability and guide motion. The ankle joint is securely positioned between the tibia and fibula (Lynch & Renstrom, 1999).

The ATFL is the most common ligament in the ankle to tear during inversion sprains (Lynch & Renstrom, 1999). According to Hoppenfeld (1976), this is because it is the first of the three ligaments to undergo stress when the ankle is inverted and plantar-flexed. According to Brostrom (1964), the ATFL is approximately 6 to 10mm wide, 20mm long and 2mm thick. Its primary function is to restrain anterior displacement of the talus (Prentice, 2003). The ATFL runs anterior to the lateral malleolus and to the lateral portion of the talar neck (Hoppenfeld, 1976).

The CFL's primary function is to restrain inversion of the calcaneus (Prentice, 2003). According to Lynch and Renstrom (1999), the CFL is the most commonly injured ligament during moderate to severe ankle sprains that could also produce tears to the ATFL. It is only torn after the ATFL is torn (Hoppenfeld, 1976). The CFL is 20-25mm long and has a diameter of 6-8mm wide. The CFL stretches plantarward, inserts into the lateral wall of the calcaneus, and attaches to the small tubercle of the calcaneus (Hoppenfeld, 1976).

The PTFL is the strongest of the three ligaments (Hoppenfeld, 1976). Its primary function is to prevent the fibula from slipping forward onto the talus. It also prevents posterior displacement of the talus (Lynch & Renstrom, 1999). The PTFL is only injured during the most severe ankle injuries such as ankle dislocations. It has a diameter of 6mm and is placed under the most strain when the ankle is in dorsiflexion. The PTFL originates along the posterior edge of the lateral malleolus and attaches to the small lateral tubercle on the posterior side of the ankle (Hoppenfeld, 1976).

The deltoid ligament is located on the medial aspect of the ankle (Hoppenfeld, 1976). It has a triangular shape and attaches superiorly to the borders of the medial malleolus and inferiorly to medial surface of the talus, the sustentaculum tali of the calcaneus, and the posterior margin of the navicular bone (Prentice, 2003). The deltoid has many functions including prevention of abduction and eversion of the ankle subtalar joints and prevention of eversion, pronation, and anterior displacement of the talus.

Movement of the foot is controlled by numerous muscles (Prentice, 2003). Dorsiflexion is controlled by the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and the peroneus tertius muscles. The plantar flexor muscles are the gasrocnemius, soleus, plantaris, peroneus longus, peroneus brevis, tibialis posterior, flexor hallucis longus, and the flexor digitorum longus. Inversion and adduction movements are produced by the tibialis posterior, flexor digitorum longus, and flexor hallucis longus. Supination movements are produced by the muscles that pass in front of the medial malleolus which are the tibialis anterior and the extensor hallucis longus. The peroneus longus and the peroneus brevis cause the lateral movements of the foot and also produce the eversion and abduction movements. Pronation is caused by the peroneus tertius and the extensor digitorum longus.

Ankle Instability

Ankle instability can be measured by using two clinical stability tests (Lynch, 2002). The tests are called the anterior draw test and the talar tilt test. The anterior draw test is designed to test the ATFL, which is the most frequently injured ligament during ankle sprains (Magee, 1997). The patient is instructed to lie down on his or her back while the examiner stabilizes the tibia and fibula. The patient’s foot is to be in a relaxed position while the examiner holds the foot in 20 degrees of plantar flexion and draws the talus forward. A positive sign is indicated by a clunking sound made as the ATFL reaches its end point (Prentice, 2003). A positive sign will indicate laxity in the joint. This generally indicates a tear in the ATFL.

The other clinical stability test is called the talar tilt test (Magee, 1997). According to Prentice (2003), the talar tilt is used to determine the severity of inversion and eversion ankle injuries. During this test, the patient is instructed to lie either on his or her back or in a side-lying position. The examiner must first place the patient's foot in the anatomic position. The examiner will then tilt the talus from side to side into adduction and abduction. The deltoid ligament is the ligament tested during the abduction movement. During the adduction movement, the examiner stresses the CFL and some of the ATFL. A positive sign will indicate joint laxity.

Researchers have used the FAI Questionnaire to test for FAI (Hubbard & Kaminski, 2002). Hubbard and Kaminski used this questionnaire to acquire general information about the participants in their study. After the participants filled out the questionnaire, an orthopedic surgeon performed the anterior draw and talar tilt tests in order to rule out mechanical instability.

Smith and Reischl (1986) and Yeung, Chan, So and Yuan (1994) asserted that ankle sprains are likely to be re-injured 80% of the time. The recurrences of ankle injuries can be caused by mechanical and functional instability (Hertel, 2002). Lynch (1999) defined mechanical instability as abnormal laxity of the ligaments of the ankle. Hertel (2002) defined mechanical instability as structural changes to the ankle joint. Lynch (1999) defined functional instability as having normal ligament restraint but abnormal function. Lynch described functional instability as being more subjective to the athlete's complaint of the ankle "giving way." Functional instability is joint motion beyond physiological limits (Tropp, Odenrick, & Gillquist, 1985). Some symptoms associated with FAI are decreased postural control (Freeman, 1965; Freeman, Dean, & Hanham, 1965; Gauffin, Tropp, & Odenrick, 1988; Goldie, Evans, & Bach, 1994; Jerosch & Bischof, 1996; Leanderson, Wykman, & Ericksson, 1993; Tropp, Odenrick, & Gillquist, 1985; Perrin, Bene, Perrin & Durupt, 1997), joint-position sense (Konradsen, 2002; Konradsen & Magnusson, 2000; Konradsen, Olesen, & Hansen, 1998; Willems, Wivrouw, Verstuyft, Vaes, & De Clercq, 2002), kinesthesia (Forkin, Koczur, Battle, & Newton, 1996; Garn & Newton, 1988; Konradsen, 2002; Lentell, Bass, Lopez, McGuire, Sarrels & Snyder, 1995; Refshauge, Kilbreath, & Raymond, 2000) and ROM (Leanderson, Wykman, & Ericksson, 1993; Hertel, 2000). Athletes may feel the ankle "giving way" when playing on uneven ground and may not be able to participate in sports that involve cutting or jumping (Hockenbury & Sammarco, 2001). Even people with chronic ankle instability may have full ROM and no presence of instability but may exhibit symptoms of muscle imbalances, inadequate proprioceptive feedback, and lack of neuromuscular control (Prentice, 2003). Hockenbury and Sammarco (2001) also reported that athletes with FAI may not feel confident in using braces or ankle tape. Other factors of ankle instability are strength deficits or nerve damage (Hertel, 2002). Staples in 1975 reported four possible causes of FAI: mechanical instability, peroneal weakness, tibofibular sprain, and proprioceptive deficits.

Caulfield, Crammond, O'Sullivan, Reynolds, and Ward (2004) compared patterns of ankle muscle activation during jump landings between people with known functional instability and those in a control group. Twelve participants with functional instability and ten control participants were used in this study. All the participants were involved in sporting activity. Functional instability was determined using the following criteria:

- The participants had a past history of a minimum of 2 inversion ankle injuries to one ankle and required a time of protected weight bearing and/or immobilization.
- The participants had no history of a lower extremity fracture.
- The involved ankle was chronically weaker, more painful, and less functional than the other at the time of testing.
- The current complaints of the participants were secondary to past history of inversion ankle sprains.

Control participants used in Caulfield et al. (2004) had no prior history of ankle sprains or fractures. Also, they felt no instability or their ankle "giving way" during participation in any activity. Researchers found that the peroneus longus electromyography activity (EMG) of the FAI group was reduced when compared to the control group. No significant differences were found in EMG activity of the soleus or the tibialis anterior.

Brown, Ross, Mynark, and Guskiewicz (2004) compared joint position sense (JPS), time to stabilization (TTS), and EMG in recreational athletes with and without FAI. Participants were excluded if they had a history of an acute lower extremity injury, a lower extremity injury in the past three months, or had a surgical procedure on the lower extremity. Participants were placed in the functional ankle stability (FAS) group if they had no history of lateral ankle sprains or lower extremity injuries in the past three months and no feeling of the ankle giving way. Participants were placed in the FAI group if they had a recent ankle sprain (at least in the past two years), a feeling of the ankle giving way during activity, and a score of 20 or less on the Ankle Joint Functional Assessment Tool (AJFAT) (Rossi, Lephart, Sterner, & Kuligowski, 1999). The results showed no differences between the JPS or medial-lateral TTS measures between the two groups. They did find a longer anterior-posterior TTS in the unstable ankle group. The stable group had higher muscle activity in the soleus after landing. In conclusion, researchers found that participants with FAI demonstrated deficits in landing stability and soleus muscle activity when compared to participants in the stabile group. Researchers found that participants in the stability group had increased muscle activity to prepare for the landing, giving them a better defense mechanism (Konradsen, Voigt, & Hojsgaard, 1997)

Ankle Braces

Researchers and clinicians state that the focal points of ankle instability should be prevention and intervention (Murphy, Connolly, & Beynnon, 2002). Some athletes have used ankle braces or tape in order to reduce the risk of inversion ankle sprains (Alves, Alday, Ketcham, & Lentell, 1992; Jerosch, Thorwesten, Bork & Bischof, 1996; Karlsson, Sward, & Andreasson, 1993; Shapiro, Kabo, Mitchell, Loren, & Tsenter, 1994; Wilkerson, 1991).

Ankle braces have advantages and disadvantages. It has been shown through research that ankle braces and tape reduce motion of the ankle and could increase forces placed on the lower limb (Hopper, McNair, & Elliot, 1999). Several researchers have concluded that ankle stabilizers restrict ankle inversion and eversion ROM (Bruns, Scherlitz, & Luessenhop, 1996; Martin & Harter, 1993; Wiley & Nigg, 1996; Wilkerson, 1991). Joint motion and muscle activity are important in absorbing the impact forces of the landing phase of a jump (McNitt-Gray, 1991; Melville-Jones & Watt, 1971). Devita and Skelly (1990) found that the muscles responsible for reducing the body's kinetic energy were the ankle plantar flexors and knee extensors. Braces were not used in the Devita and Skelly study and the question remains whether or not braces will restrict the motion of the muscles needed to reduce the kinetic energy. Hartsell and Spaulding (1997) concluded that ankle braces reduce ROM thus reducing ankle injuries. One research team found that braces also increase the afferent feedback from cutaneous receptors thus improving ankle joint awareness (Feuerbach, Grabiner, & Koh, 1994).

Several researchers have tested ankle braces by evaluating athletic performance outcomes (Feuerbach & Grabiner, 1993; Greene & Hillman, 1990; Greene & Wight, 1990; Shapiro, Jones & Knapik, 1994; Wiley & Nigg, 1996). Some researchers have looked at the effects of ankle braces on speed, vertical jump ability and agility (the ability to change directions quickly) (Juvenal, 1972; Mayhew, 1972; Robinson, Frederick & Cooper, 1986; Greene & Wright, 1990; Maidment, 1990; Burks, Bean, Marcus, & Barker, 1991; Paris, 1992; Beriau, Cox, & Manning, 1994; Bocchinfuso, Sitler, & Kimura, 1994; Gross, Everts, Roberson, Roskin & Young, 1994; MacKean, Bell, & Burnham, 1995; Macpherson, Sitler, Kimura, & Horodyski, 1995; Pienkowski, McMorrow, Shapiro, Caborn & Stayton, 1995; Verbrugge, 1996; Wiley & Nigg, 1996; Gross, Clemence, Cox, et al., 1997; Hume & Gerrard, 1998; Hals, Sitler, & Mattacola, 2000; Yaggie & Kinzey, 2001) (see Table 1). Hopper, McNair and Elliot (1999) studied 15 netball players to investigate the effects of bracing and taping on vertical GRF, muscle activity, and rear foot motion when performing a landing similar to landings in the sport of netball. They found that an ankle brace can lead to changes in muscular activity but not changes of any importance in influencing the position of the foot during landing or at the peak of vertical GRF. Thus, ankle braces would not increase the potential of an ankle injury or be damaging to the athlete's performance. Other researchers, such as Mackean, Bell, and Burnham (1995) and Burks, Bean, Marcus, and Barker (1991) found significant impairments in athletic performance in athletes wearing different types of ankle braces. Mackean Bell and Burnham (1995) found that vertical jump was significantly lower with ankle tape when compared to no tape. They also found that jump shot accuracy was better when the participants wore tape compared to the Swede-O- Universal. Burks, Bean, Marcus and Barker (1991) found that ankle tape reduce performance in the vertical jump, shuttle run and sprint when compared to no support. They also found that the Swede-O brace decreased performance in the vertical jump, broad jump and sprint when compared to the use of no stabilizer. Pienkowski, McMorrow, Shapiro, Caborn and Stayton (1995) and Verbrugge (1996) also found no significant differences in speed and agility between athletes in braced and non-braced groups.

Researchers have also studied the effects of ankle braces on balance and proprioception (Steussi, Tigermann, Gerber, Taemy & Stacoff, 1987; Surve, Schwellnus, Noakes, & Lombard, 1994) and discrete movement skills (Alves, Alday, Ketcham, & Lentell, 1992; Greene, & Wight, 1990; Macpherson, Sitler, Kimura, & Horodyski, 1995). It has been found that ankle braces improve balance (Steussi, Tigermann, Gerber, Raemy & Stacoff, 1987) and proprioception (Hartsell, 2000). Arnold and Docherty (2004) stated that balance improvement only occurs in those athletes with previously injured ankles who use ankle braces.

Table 1

Characteristics of the studies used in the meta-analysis (Cordova, Scott, Ingersoll, & LeBlanc, 2004)

Author	Subj.	Age (yr)	Height (cm)	Mass (kg)	Test	Brace	Pathology	Activity
Beriau et al	85	15.9 ± 1.2	-	-	A	R, L	H	C
Bocchinfuso et al	8 M, 7 F	14.3	169	64	J, S, A	R	NL	C
Greene and Wight	12F	18-22	-	-	S	R, L	NL	C
Gross et al.	8 M, 8 F	M 24.6 ± 5.1	M 174.2 ± 8.9	M 67.9 ± 4.5	J, S, A	R	I	NL
		F 20.1± 1.6	F 169.9 ± 6.9	F 62.4 ± 10.4				
Gross et al.	14 M, 9 F	M 22.6 ± 4	M 179.7 ± 6.7	M 76.2 ± 11.6	J, S, A	R	H	NL
		F 23.1 ± 5.2	F 160.7 ± 4.7	F 59.4 ± 8.2				
Hals et al.	8 M, 17 F	16.2 ± 6.0	168.91 ± 33.02	61.10 ± 29.5	J, A	R	I	NL
Jerosch et al.	25 M, 16 F	20-26	NL	NL	A	T, R	I, H	R, C
Juvenal	30 M	-	-	-	J	T	H	R
McKean et al.	11 F	17-25	-	-	J, S	T, R, L	H	C
Macpherson et al.	25 M	16.0 ± 1.0	178.82 ± 7.06	80.7 ± 12.7	J, S, A	R	H	C
Maidment	13 M	-	-	-	A	T, R, L	H	C
Mayhew	66 M	-	-	-	J, S, A	T	NL	R
Paris	18 M	17.6 ± 1.7	176.3 ± 11.2	70.6 ± 4.5	J, S	T, L	H	C
Saffran et al.	14 M	21.6 ± 13	165.6 ± 6.4	58.5 ± 5.5	S, A	R, L	NL	NL
Verbrugge	24 M	20.3	-	-	J, S, A	T, R	H	C
Wiley & Nigg	8 M, 4 F	24.2 ± 3.8	-	-	J, A	R	I	NL
Yaggie & Kinzey	30	24.03 ± 0.76	172.95 ± 2.16	75.08 ± 2.69	J, A	R, L	H	R

F, female; M, male. Mean ± SD. A, agility; J, vertical jump; S, sprint. L, lace-up; R, semirigid; T, tape.
I, injured ankle; H, healthy ankle; NL, information not provide; R, active subjects; C, athletes

Research has also shown that ankle braces loosen over time during exercise (Verhagen, van der Beek & van Mechelen, 2001). However, in a separate study, Gross, Lapp, and Davis (1991) showed that after ten minutes of exercise, both the Swede-O and Sport Stirrup ankle stabilizers showed no significant loosening.

Researchers have different opinions on whether ankle braces reduce injury but some do recommend that athletes with chronic ankle instability use ankle braces, some of them for at least six months after an ankle injury (Thacker, Stroup, Branche, et al., 1999). Callaghan (1997) stated that a majority of athletes use ankle braces because they are more cost effective. Hopper, McNair and Elliot (1999) concluded that the choice of wearing a brace or tape should be made by the athletes themselves.

Ankle Tape

The most common stabilizer used by athletic trainers and therapists is ankle taping (Olmsted-Kramer, 2004). Along with ankle braces, ankle taping is also thought to prevent ankle injuries by restraining excessive ROM (Cordova, Ingersoll, & Palmieri, 2002; Wilkerson, 2002). Several researchers found that ankle taping significantly reduces ankle eversion and inversion ROM, but the taping loosened after a sporting activity or exercise (Greene & Hillman, 1990; Gross, Lapp, & Davis, 1991; Myburgh, Vaughan, & Isaacs, 1984; Rovere, Clarke, Yates, et al., 1988). Glick, Gordon, and Nishimoto (1976) Greene and Hillman (1990), Hume and Gerrard (1998), and Myburgh, Vaughan, and Isaacs (1984) have found that bracing is much more effective than tape because tape loosens up after 20 minutes of activity. Gross, Bradshaw, Ventry, et al. (1987) and Gross, Lapp, and Davis (1991) also found that ankle tape loosened up after ten minutes of activity. However, they found that after ten minutes, the taped ankle still reduced ankle inversion ROM when compared to the untaped ankle by 19% and 24% respectively.

Several taping techniques exist for the ankle. Prentice (2003) suggested three different ways to tape an ankle. Materials needed to tape an ankle include pre-wrap, tape adherent, and a roll of white athletic tape. Pre-wrap and foam provide the ankle significantly better support than does taping an ankle to the skin (Prentice, 2003).

Athletes who play sports involving at-risk activity, for example soccer and basketball, will benefit the most from ankle taping (Prentice, 2003). According to Lindley (1995), ankle braces can be as effective as ankle taping. The method used to tape an ankle is found in Appendix B.

Stabilizer Effects on Knee Range of Motion (ROM)

Sprains to the anterior cruciate ligament (ACL) are the most common knee injury seen in athletes (Noyes, Basset, Grood, & Butler, 1980). The ACL's primary function is to prevent the femur from moving posteriorly during weight bearing and stabilizes the tibia against excessive internal rotation (Prentice, 2003). Noyes, Mooar, Matthews, and Butler (1983) reported that the knee is at greater risk of injury during movements involving rotation, such as turning and twisting. A study conducted by Santos, McIntire, Foecking and Liu (2004) used ten healthy participants. Their goal was to determine if ankle braces increase the angular motion of the knee joint, thus increasing the risk of a knee injury. Their participants were asked to rotate their trunk while standing on one leg and to try to catch a ball by turning sideways and then to turn sideways to touch a target with their shoulder. The participants in this study completed the tasks with and without the use of an ankle brace worn on their supporting leg. The researchers found that the ankle braces did decrease trunk rotation while catching the ball and increased knee axial rotation while touching the target. They concluded that ankle braces significantly increase knee axial rotation, which may increase the risk of knee injuries. Other studies have reported that knee injuries also can be increased by the use of rigid boots, such as skiing boots (Rossi, Lubowitz, & Guttmann, 2003; Tuggy and Ong, 2000).

While ankle bracing may decrease ankle injuries, they many increase stress on the knee, thus increasing the risk for knee injury. Activities that include motions such as turning and twisting place stress on the trunk and knees. Coaches, athletic trainers and athletes need to look at the possibilities of braces increasing the risk of knee injuries and evaluate whether or not using a brace is appropriate.

Ground Reaction Forces (GRF)

Many sports include jumping and landing techniques (Hopper, McNair, & Elliot, 1999). Athletic activities such as running, jumping and landing can lead to overuse injuries in the lower extremity (James, Bates, & Osternig, 1978; Nigg & Bobbert, 1990; Tauton, McKenzie, & Clement, 1988; Williams, 1993). An athlete must be able to land correctly in order to avoid injury and improve his or her performance. Steele and Milburn (1989) noted that VGRF are 6.8 times the body weight (BW). Additionally, researchers found that GRF can reach 3 to 14 times a BW when rebounding a basketball, landing from a block in volleyball, and performing back somersaults in gymnastics (Dufek & Bates, 1990; Mizrahi & Susak, 1982; Oggero, Pagnacco, Morr, et al, 1997; Ozguven & Berme, 1988; Panzer, Wood, Bates, et al, 1997; Simpson & Kanter, 1997; Stacoff, Kaelin & Stuessi, 1988; Valiant & Cavanagh, 1985).

In order to absorb the impact of landing, joint motion and muscle activity are important (McNitt-Gray, 1991; Melville-Jones & Watt, 1971). McCaw and Cerullo (1999) found that ankle stabilizers impinge on the normal kinematics of the ankle joint during drop landings. They hypothesized that there would be greater eccentric activity in the dorsiflexors of the ankle when an athlete lands without a stabilizer. Winter (2005) found that shock absorption occurs when there is eccentric activity in the muscles. This would suggest that there could be greater shock absorption in the knee and hip without a stabilizer.

In one study, Caulfield and Garrett (2004) compared GRF during jump landings between participants with functional instability (FI) and those participants with healthy ankles. Fourteen participants with unilateral FI and ten control participants were asked to perform single leg jumps from a height of 40 cm while barefoot onto a force plate. Researchers found that the GRFs post-impact were similar in the two groups, but the timing of the peak forces was different. The difference was seen in the initial 150 ms post-impact ranging from 5% body mass (BM) to 20% BM in the medial/lateral forces at 30-40 ms and in the sagittal plane forces at 44-50 ms post-impact. In the VGRFs, differences were up to 100% BM in the immediate post-impact period. There was a difference in VGRFs in two periods and they were found to be statistically significant ($p < 0.05$). The two periods were 24-36 ms and 85-150 ms post-impact. There was some overlap between the two groups. Not all the FI participants differed from their counterparts with healthy ankles. Caulfield and Garrett suggest that those who exhibit FI have disordered force patterns and are more likely to suffer repeated ankle injuries because of the increase in stress on the ankle joint during jump landings. Results are seen in Table 2. Again, ankle braces and tape have been designed to reduce ankle injuries but may place undue stress on the knees and hips. Using a stabilizer may restrict the normal kinematics of the ankle, hip and knee, thus increasing the risk of injury. Shock absorption is important during the landing phase of a jump. Since stabilizers restrict ROM, this might decrease the muscular activity needed to absorb shock in the ankles, knees, and hips.

Table 2

Magnitude of peak GRF post impact (Caulfield and Garrett, 2004)

Direction of force	FI group (n = 14)	Control group (n = 10)
Lateral	35.3 (13.7)	35.3 (9.5)
Medial	17.5 (10.2)	14.4 (6.2)
Anterior	37.2 (29.5)	44.5 (27.7)
Posterior	74.3 (14.8)	78.8 (18.2)
Vertical	501.9 (131.0)	476.9 (117.4)

Values are mean (SD). Differences between the groups are non-significant ($P > 0.05$).

Joint Motion during Drop Landings

The final section will be devoted to joint motion during landings covering joint motion of the hip, knee, and ankle. Many athletic events such as gymnastics, basketball, soccer, football, volleyball, and parachuting involve landing (Self & Paine, 2000).

In a study conducted by Self and Paine (2000), male recreational athletes were to perform four different techniques of the drop landing; the bent knee landing (BN), the stiff knee, natural plantar flexion landing (SN), the stiff knee, in which the plantar flexor absorb the during impact landing (SP), and the stiff knee, which absorbs impact on the heels landing (SH). The purpose of this study was to determine minimum VGRFs and maximum tibial accelerations by calculating Achilles tendon stiffness and to determine the kinematics and kinetics of the ankle during the four different landing techniques. Researchers found that the SP drop landing technique had a lower VGRF than did the BN landing. This finding could indicate that the body does not maximize the energy-absorbing characteristics of the ankle plantar flexors. During the BN drop landing, the knees may be “set” to bend. Because of this, the gastrocnemius will not fully fire because it is a two-headed muscle and becomes slack when the knees are bent. When compared to other drop landings, participants in this study had a softer landing during the SP landing both in maximum acceleration and in peak forces. During this landing, participants were instructed to land with more ankle plantar flexion to absorb the energy through their toes. Results showed that the lowest Achilles tendon force values occurred during the stiff knee, landing with maximum ankle plantar flexion. This would indicate that participants did not use the full potential of the triceps surae muscles. Researchers also found that the tibia was nearly vertical during impact. The purpose of a study conducted by Devita and Skelly (1990) was to identify and compare GRF, joint positions, moments, and muscle powers in the lower extremity during the descent and contact phase of a fall. During the descent phase, hip flexion occurred in preparation for the landing in order to reduce the stress of impact on the spine. Later in the descent, hip extensors eccentrically worked to reduce hip flexion velocity. During the stiff landing, the hip extensor moment decreased hip flexion and caused the participant to have a more erect body during impact. Having a more erect body during landing caused the moment arms of the external forces, which accelerated joint flexion of the hip and knee, to be reduced. This led to a 23% increase in GRFs. Prior to contact, researchers noted a flexor moment at the knee. However, this could be a result of the extensor moment of the hip because of the muscle activity in the hamstring group. Knee flexion during the landing was necessary to ensure that the knee would flex during floor contact since a posterior force acted on the thigh, which produced a posterior force knee joint reaction force. An extensor torque was created around the leg center of mass which, if unchecked, would force the knee into extension and put the participant in an injury prone position. Devita and Skelly (1990) concluded that the principal moments during the landing phase were the extensor moments of the hip and the flexor moments at the knee. These moments helped participants prepare for soft or stiff landing impact.

During the floor contact phase, results indicated that the primary muscle groups that reduce the amount of kinetic energy were the ankle plantar flexors and knee extensors, followed by hip extensors (Devita & Skelly, 1990). The hip had the largest extensor moment values during contact phase. Ankle plantar flexion increased as the stiffness of the landing increased while the hip and knee extensors decreased. Devita and Skelly (1990) also found that the muscular system absorbs 19% more kinetic energy in soft landings than in stiff landings. Ankle plantar flexors absorbed 12% less energy in soft landings. The hip and knee extensors absorbed approximately 50% more energy in soft landing.

Zhang, Bates, and Dufek (2000) studied the changes of lower extremity joint energy absorption for the different landing heights and techniques. In this study, nine healthy, active male participants performed step-off landings from three different heights (0.32 m, .35m, and 1.03 m) using three different landing techniques, soft (SFL), normal (NML), and stiff landing (STL). Participants were free of lower extremity injuries at the time of testing. Changes in the lower extremity are related to the demands placed on the human body during landing. Results showed that there was increased activity in the hip, knee, and ankle. As the height of the jump increased, so did the amount of eccentric work in the ankle. The lower the height of the jump, the ankle and knee muscle groups absorbed more energy during the stiff landing, whereas the hip and knee extensors were more involved in soft landings. During STL, hip extensors were primarily involved during the lower heights and became more involved as the heights increased. The hip joint posture became more flexed because of the massive potential energy reduction for the muscle group. Zhang, Bates, and Dufek (2000) also found that peak hip moments and power took longer to occur than the peak ankle and knee extensor moments and power. Also, during the impact phase of landing, there was only one significant hip joint moment. Similarly two minimums were observed in the power curves of the ankle and knee. These power moments and curves occurred close to the first and second impact forces.

The purpose of McNitt-Gray, Hester, Mathiyakom, and Munkasy (2001) was to determine how diverse momentum conditions and anatomical orientation at contact influence loading and multi-joint control of the reaction force during drop landings. In this study six male collegiate gymnasts performed three different tasks (drop landings, front and back saltos) without taking a step or hop as commonly performed in gymnastic competition. McNitt-Gray, Hester, Mathiyakom and Munkasy (2001) found that during the drop jump, the knee had approximately .005 NJM Impulse (Nms/kg) on contact and .02 Nms/kg at the end of landing. The ankle had approximately .02 Nms/kg on contact and .01 Nms/kg at the end of landing. On contact during the front saltos landing, the ankle had a NJM of approximately .03 Nms/kg and .02 at the end of landing. The knee had approximately -.02 Nms/kg on contact and .01 Nms/kg at the end of landing. During the back saltos landing, the knee had .01 Nms/kg on contact and .005 at the end of landing. The ankle had a .04 Nms/kg on contact and .02 Nms/kg at the end of landing.

Salci, Kentel, Heycan, Akin, and Korkusuz (2004) compared kinematic and kinetic differences in the knee, hip and ankle between male and female volleyball players during landing. Sixteen national university first league volleyball players with no severe previous lower leg injury were used (eight males and eight females). Results show that females have a lower knee and hip flexion angle compared to males in knee flexion at a 40 cm spike and hip flexion at 40 cm block landings (see Table 3 and Table 5). Comparing the groups, the male players' peak knee extensor moment at 60 cm block landing was significantly different from the female players. In addition, it was concluded that females may not use their thigh muscles as effectively as males. In a similar study, Decker, Torry, Wyland, Sterett, and Steadman (2003) had their participants perform drop landings from a height of 60 cm. Researchers wanted to determine whether or not there were gender differences in the lower extremity joint motions and energy absorption landing strategies between age and skill matcher recreational athletes. Twelve male and nine female recreationally active participants performed drop landings from 60 cm. The participants had no history of orthopedic injury to the lower extremity joints. Researchers found that females land more erectly and used greater hip and ankle joint ROMs and maximum joint angular velocities compared to males (see Table 6). The knee was the primarily shock absorber in both genders but the hip extensors in males were the second largest use muscle contributor to shock absorption and ankle plantar-flexors were the second largest used muscle during shock absorption. Results are listed in Table 4 (peak internal joint moments (%BW*ht)) and Table 4 (peak internal joint powers (%BW*ht/s)).

The participants used in these studies all had healthy ankles. Some of these studies only observed differences between male and female participants. The question that remains is how different would kinematic and kinetic data be between those with functionally stable ankles and those with FAI?

Table 3

Peak Joint Moments (Nm)

Peak Joint Moments	Spike landing from 40 cm	Spike landing from 60 cm	Block landing from 40 cm	Block landing from 60 cm
Hip extension				
Male	-1.5 (1.3)	-2.5 (0.7)	-1.1 (2.0)	-1.1 (2.0)
Female	-2.1 (0.9)	-2.7 (0.8)	-2.6 (0.6)	-2.8 (0.6)
Knee Extension				
Male	-0.7 (2.1)	-0.1 (3.6)	.01 (3.2)	-0.1 (3.2) *
Female	0.0 (3.4)	-2.0 (3.7)	-1.5 (3.6)	-3.0 (2.2)
Ankle plantar flexion				
Male	-1.6 (0.7)	-1.3 (1.1)	-1.3 (0.8)	-0.9 (2.0)
Female	-2.3 (0.7)	-2.1 (0.9)	-2.0 (0.6)	-2.0 (0.7)

*P<0.05

Salci, Kentel, Heycan, Akin, and Korkusuz (2004)

Table 4

Peak internal joint moments (%BW*ht))

Peak Internal Joint Moments	Males	Females
Hip extensor	38.87	25.42
	(13.41)	(19.36)
First knee extensor	17.69	14.59
	(4.57)	(2.01)
Second knee extensor	13.24	15.31
	(3.42)	(3.30)
Ankle plantar flexor	11.31	10.71
	(3.08)	(2.39)

Decker, Torry, Wyland, Sterett, and Steadman (2003)

Table 5

Peak internal joint powers (%BW*ht/s)

Peak internal joint powers	Male	Female
Negative hip power	-252.25	-200.48
	(80.78)	(166.17)
First negative knee power	-144.42	-133.86
	(44.15)	(16.05)
Second negative knee power	-135.35	-183.15*
	(39.43)	(58.02)
Negative ankle power	-94.15	-151.43*
	(29.47)	(23.26)

Decker, Torry, Wyland, Sterett, and Steadman (2003)

Table 6

Means (SD) of kinematic variables during the landing phase

	Males	Females
Contact position (deg)		
Hip	-30.8	-24.0
	(7.8)	(10.6)
Knee	-30.0	-22.8*
	(7.7)	(8.0)
Ankle	-11.3	-21.3*
	(5.1)	(9.6)
Range of motion (deg)		
Hip	50.4	57.9
	(13.0)	(13.8)
Knee	63.4	75.8*
	(9.3)	(9.1)
Ankle	41.6	58.0*
	(6.9)	(7.9)
Peak angular velocity (deg/s)		
Hip	-443.6	-579.4*
	(75.1)	(78.2)
Knee	-601.7	-725.8*
	(51.9)	(103.3)
Ankle	-573.0	-1044.1*
	(154.3)	(230.6)

Decker, Torry, Wyland, Sterett, and Steadman (2003) $P < .05$; deg = degrees; deg/s = degrees per second*

Summary

Ankles are re-injured nearly 80% of the time (Smith & Reischl, 1986; Yeung, Chan, So and Yuan, 1994). These reoccurrences could be directly related to functional ankle instability (Hertel, 2002). Functional ankle instability (FAI) is defined as joint motion going beyond its physiological limits (Tropp, Odenrick, & Gillquist, 1985). The athlete with FAI may complain of the ankle "giving way" during activity (Lynch, 1999).

In order to give those individuals with FAI more support and protection, ankle braces and tape are used. Ankle braces and tape have been used by athletes to reduce the risk of inversion ankle sprains (Alves, Alday, Ketcham, & Lentell, 1992; Jerosch, Thorwesten, Bork & Bischof, 1996; Karlsson, Sward, & Andreasson, 1993; Shapiro, Kabo, Mitchell, Loren, & Tsenter, 1994; Wilkerson, 1991). Some of the positive aspects of using ankle braces include improvement of joint awareness (Feuerbach et al., 1994), balance (Steussi, Tigernamm, Gerber, Raemy, & Stacoff, 1987) and proprioception (Hartsell, 2000). However, some of the negative aspects of using an ankle stabilizer include the restriction of ankle inversion and eversion, thus restricting the normal kinematics of the ankle joint (McCaw et al., 1999). In order for the body to absorb the impact forces during landing, joint motion and muscle activity are important. Since ankle stabilizers are known to restrict joint motion and muscle activity, they may increase the risk of injury to the ankles, knees, and hips. Thus, the use of an ankle stabilizer may or may not be a useful aid to prevent inversion ankle sprains in those individuals with FAI.

The use of an ankle stabilizer will only be useful to some athletes. One team of researchers found that ankle braces decrease trunk rotation and increase knee axial rotation during motions that involve twisting and turning (Santos, McIntire, Foecking, & Liu, 2004). By increasing knee axial rotation, the risk of knee injuries increases. For those who have a prior history of knee injuries and are involved in activities that include twisting and turning motions, the use of an ankle stabilizer may not be beneficial by increasing the risk of injury by placing undue stress on the trunk and knee.

After all this research, there are many questions that remain as to what is the most effective method in reducing ankle sprains, the use of a tape, brace or nothing. Who would benefit the most from the use of an ankle stabilizer, the healthy population or the FAI population?

CHAPTER THREE

Methods

The purpose of this study is to determine how ankle taping and bracing affect landing biomechanics in persons with functional ankle instability (FAI). Specifically we measured peak ground reaction forces (GRF) knee and ankle range of motion (ROM), and knee and ankle joint moment and torques during drop landings under braced and taped conditions in persons with and without.

Participants

Fourteen participants (age 23.5 ± 4.36 yrs; 69.94 ± 12.37 kg; 171.89 ± 10.23 cm) who were recreationally active participants in vigorous activity three time per week for 30 minutes) were included in this study. Seven of the participants were without any previous ankle injuries and were placed in the functional ankle stability group (FAS) (mean age 22.57 ± 2.88; weight 72.29 ± 12.57; height 174.34 ± 10.07) and seven participants had functional ankle instability (FAI) (mean age 20.57 ± 5.56; weight 61.78 ± 12.68; height 145.87 ± 10.55) and had no ankle or knee injuries in the past year. Before the day of data collection, participants filled out the Functional Ankle Instability Questionnaire (Hubbard and Kaminski, 2002) (see Appendix A). Participants were placed in the FAI group if they answered “yes” to questions 3, 5, 6, 7, and 9 and “no” to questions 4, 8, and 10. If participants answered “no” to these questions and have had no lower extremity injuries in the past 6 months, they were placed in the FAS group. All participants were students at Barry University in Miami Shores, Florida.

Instrumentation

Ankle Brace

A Mueller Ankle Soccer Brace (Mueller Sports Medicine, INC, Prairie du Sac, WI) was used in this study. The Mueller Ankle Soccer Brace is designed with supportive steel strings in order to protect the ankle from inversion ankle sprains. It is not only used by national soccer teams but also in sports such as racquet ball, gymnastics, cheerleading, running and wrestling. It can fit either foot.

Ankle Tape

The ankle taped used in this study is 1 ½ inch Coach Johnson and Johnson Athletic tape (New Brunswick, NJ). Johnson and Johnson athletic tape is known for its tensile strength. It is breathable, lightweight and comfortable to the athlete.

How to tape an ankle

See Appendix B for standard instructions by Prentice (2003) on how to apply the Gibney ankle tape method used in this study.

Videography

The Vicon Peak Performance Motion Measurement System 8.2 (Vicon Peak Performance Technologies, Inc., Centennial, CO) was used. Ground reaction forces were collected with an AMTI force plate (Watertown, MA). Four JVC 60 Hz cameras (JVC Professional Products, Denver, CO) were used; two were placed diagonally to the left and right of the participant and two cameras were placed to back right and back left of the participants (see Appendix C). Four high speed Panasonic VCRs (Secaucus, NJ) were used to record video onto JVC Super VHS ET videocassettes (JVC Professional Products Company, Denver, CO). Participants performed a single-legged drop landing onto the center of the force plate. The participant was also required to stick the landing for at least five seconds.

Procedures

Participants were students at Barry University. Each participant participated in physical activity at least 30 minutes a day three times a week. Volunteers were asked to fill out the Functional Ankle Instability Questionnaire form (Hubbard and Kaminski, 2002)(Appendix A) in order to determine which students could be used in the study. One national board certified athletic trainer (ATC) was utilized to determine the ankle instability by performing the anterior draw test and the talar tilt test. The same ATC was used to evaluate ankle instability for every participant.

The participants were asked to wear sneakers, dark shorts and a dark t-shirt for data collection. When they arrived, they were asked to read and sign a consent form. Before the trial, participants were asked to warm up on a stationary bike for ten minutes. Anthropometric parameter measurements were taken before the day of data collection (see Appendix D). After the warm-up, reflective markers were placed on bilaterally on the lateral malleolus, the 2^{nd} metatarsal, calcaneus, lateral condyle, anterior superior iliac spine (ASIS), and the sacrum. The center of the thigh of both legs was also determined. A tibial wand was placed on the biggest circumference of the gastrocnemius and a femoral wand was placed on the middle of the thigh (see figure 1).

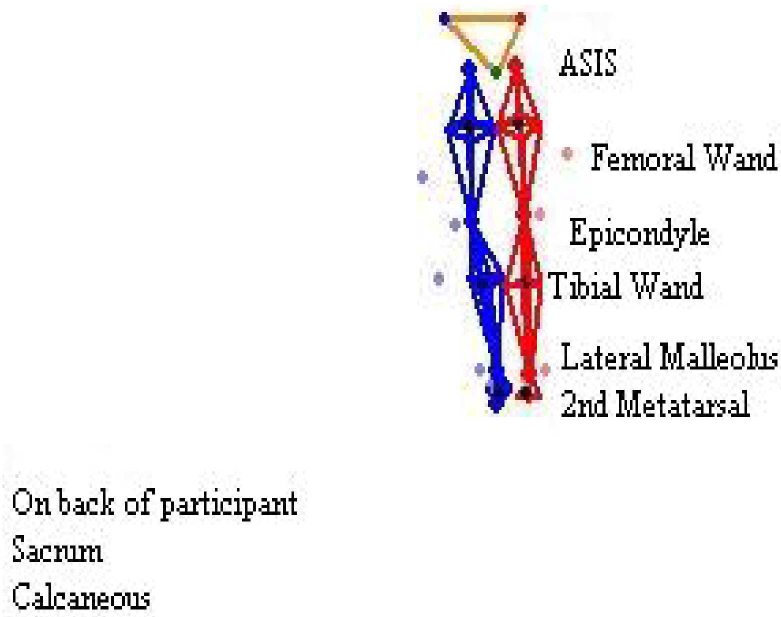


Figure 1. Placement of reflective markers

Each participant was tested one trial under the three different conditions. The conditions were randomized for each participant. Participants were given no more than five practices trials. When ready, the participant performed a single leg drop landing of a platform .60m high onto the center of the force plate. Single leg landings are the most common mechanism of injury in ankle sprains (Caulfield & Garrett, 2004). Participants stood with arms flexed to shoulder height and the heel of their involved foot resting against the front edge of the platform. The same technique was used in a research study performed by McCaw and Cerullo (1999) and was designed to minimize horizontal motion. Participants were asked to practice dropping off the box onto the force plate three different times under the three different conditions. The platform was placed .11m from the force plate. During the trial if the participants did not land on the center, they repeated the jump immediately. The participants were instructed to stick the landing for at least five seconds for a trial to be considered successful. If the participant was not able to keep his/her balance for five seconds, uses their other leg for stabilization, or has a double landing on the force plate, they were asked to repeat the trial. After each successful trial, a different stabilizer was given the participant. Each participant's involved ankle was taped by the ATC. The trainer used the standards set in Prentice's (2003) *Principles of Athletic Training* (Appendix B). Each participant was fitted with the right size brace according to their shoe size.

Design and Analysis

A repeated measures 2 x 3 MANOVA (groups x stabilizers) was used. The dependant variables for this study were ankle dorsiflexion range of motion (ROM), ankle abduction, knee flexion ROM, peak vertical ground reaction forces (GRF), ankle anterior joint forces, ankle medial joint forces, knee anterior joint forces, knee medial joint forces, ankle abduction moments, ankle flexion moments, and knee flexion moments. Alpha was set at $\leq .05$. All dependant variables were collected after toe contact with force plate.

CHAPTER FOUR

Results

Fourteen participants were used, seven with functional ankle instability (FAI) and seven with functional ankle stability (FAS). Participant demographic information is seen in Table 7. Participants were asked to drop off a platform .60m high three different times, one time wearing an ankle brace, one time with ankle taped and one time without the use of a brace or tape. A successful landing occurred when the participant landed on the center of the force plate and stuck the landing for at least five seconds. Reflective markers were placed bilaterally on the lateral malleolus, the 2^{nd} metatarsal, calcaneus, lateral condyle, anterior superior iliac spine (ASIS), and the sacrum. The center of the thigh of both legs will be determined. A tibial wand was placed on the biggest circumference of the gastrocnemius and a femoral wand was placed on the middle of the thigh.

A repeated measures 2 x 3 MANOVA (groups x stabilizers) was used to analyze the results. The dependant variables for this study were ankle dorsiflexion range of motion (ROM), ankle abduction, knee flexion, peak vertical ground reaction forces (GRF), ankle anterior joint forces, ankle medial joint forces, knee anterior joint forces, knee medial joint forces, ankle abduction moments, ankle flexion moments, and knee flexion moments. Alpha was set at $\leq .05$. Means and standard deviations for the kinematic dependant variables are found in Table 8. Means and standard deviations for the kinetic dependent variables are found in Table 9. Table 10 contains the means and standard deviations of peak ankle and knee joint moments.

Table 7

Participant Demographic Information

FAS

	Age	Weight	Height
mean	22.57	72.29	174.34
st. dev	2.87	12.57	10.07

FAI

	Age	Weight	Height
mean	20.57	61.78	145.87
st. dev	5.56	12.68	10.55

Table 8

Means and Standard Deviations for Kinematic Dependant Variables

Ankle dorsiflexion (deg.)	Brace	Tape	Without
FAS (n = 7)	30.12 (10.28)	29.27 (5.57)	31.17 (7.59)
FAI (n = 7)	29.78 (8.35)	28.26 (8.27)	30.82 (12.53)
Ankle abduction (deg.)			
FAS (n = 7)	25.56 (12.46)	23.65 (6.68)	34.60 (9.47)
FAI (n = 7)	30.36 (14.05)	24.86 (11.69)	28.96 (8.33)
Knee flexion (deg.)			
FAS (n = 7)	38.43 (6.80)	43.05 (5.95)	39.28 (7.68)
FAI (n = 7)	33.72 (8.65)	37.43 (9.69)	35.54 (11.82)

Table 9
Means and Standard Deviations for Kinetic Dependant Variables

Peak vertical GRF (N)

	Brace	Tape	Without
FAS (n = 7)	2590.95 ± 377.19	2635.64 ± 364.42	2655.07 ± 372.55
FAI (n = 7)	2488.73 ± 343.26	2485.52 ± 345.71	2325.21 ± 506.53

Ankle peak anterior joint forces (N)

FAS (n = 7)	-535.28 ± 128.79	-428.18 ± 234.91	-504.14 ± 168.97
FAI (n = 7)	-473.37 ± 109.41	-448.20 ± 137.22	-368.52 ± 201.86

negative numbers (-) denote posterior forces

Ankle peak medial joint forces (N)

FAS (n = 7)	44.59 ± 154.01	(-)19.72 ± 43.40	(-)12.63 ± 87.17
FAI (n = 7)	88.95 ± 147.60	134.06 ± 202.14	122.16 ± 177.35

negative numbers (-) denote lateral forces

Knee peak anterior joint forces (N)

FAS (n = 7)	531.00 ± 170.99	499.79 ± 171.96	580.45 ± 104.65
FAI (n = 7)	470.93 ± 234.63	487.26 ± 262.73	482.83 ± 224.79

Knee peak medial joint forces (N)

FAS (n = 7)	108.28 ± 364.96	(-)13.77 ± 47.62	(-)52.26 ± 52.34
FAI (n = 7)	243.06 ± 358.85	183.56 ± 318.50	163.04 ± 254.13

negative numbers (-) denote lateral forces

Table 10
Means and Standard Deviations of Peak Joint Moments

	Brace	Tape	Without
Ankle peak abduction moments (Nm)			
FAS (n = 7)	104.86 ± 68.12	120.29 ± 22.65	111.53 ± 91.21
FAI (n = 7)	43.61 ± 46.79	78.43 ± 66.36	91.56 ± 46.55
Ankle peak flexion moments (Nm)			
FAS (n = 7)	126.25 ± 86.87	128.70 ± 83.18	190.67 ± 116.10
FAI (n = 7)	129.68 ± 91.51	126.29 ± 103.13	138.61 ± 111.40
Knee peak flexion moments (Nm)			
FAS (n = 7)	36.55 ± 89.91	40.28 ± 54.47	56.10 ± 103.27
FAI (n = 7)	51.31 ± 86.14	29.64 ± 76.67	50.33 ± 61.15

Results of the Multivariate Tests

No significant interaction was found between groups and stabilizer condition as seen in Table 11. However there were significant differences between the groups regardless of stabilizer condition. No significant differences were found between stabilizers as a main effect.

Table 11
Results of Wilks' Lambda Multivariate Test

Effect	F	Hypothesis df	Error df	Sig.	Observed Power(a)
Group	2.39	11.00	26.00	0.03	0.85
Stabilizer	0.69	22.00	52.00	0.82	0.45
Group * Stabilizer	0.56	22.00	52.00	0.93	0.36

Ankle Medial Joint Forces

Because the main effect for Group was significant in the Two-Way MANOVA, a follow-up MANOVA was run which indicated that ankle medial/lateral joint forces were significantly different ($F(1,36) = 6.095$, $p < .05$) between groups. Participants with FAI tended to land with greater medial force (mean force of 115 N) than those with FAS (mean force 4.08) (see Table 9).

Knee Medial Joint Forces

A one-way MANOVA was calculated examining the differences in the dependent variables between those with FAI and those with FAS. Results indicated that knee medial/lateral joint forces were significantly different ($F(1,36) = 4.844$, $p < .05$). Participants with FAI again landed with greater medial force (mean force 197 N) than those with FAS (mean force 14 N) (see Table 10).

Ankle Abduction moments

A one-way MANOVA was calculated examining the differences in the dependent variables between those with FAI and those with FAS. Results indicated that ankle abduction moments were significantly different ($F(1,36) = .4.754$, $p < .05$). Those with FAS landed with greater abduction moment (mean 112 Nm) than those with FAI (mean 71 Nm).

Other Results

There were no other significance differences to report among the other dependant variables between the groups. Ankle dorsiflexion ROM ($F(1, 36) = .057$, $p > .05$); ankle abduction/adduction ROM ($F(1,36) = .001$, $p > .05$); knee flexion/extension ROM ($F(1,36) = 3.088$, $p > .05$); peak vertical GRF ($F(1,36) = 2.614$, $p > .05$); ankle anterior joint forces ($F(1,36) = 1.283$, $p > .05$); knee anterior/posterior joint forces ($F(1,36) = .830$, $p > .05$); ankle flexion/extension ($F(1,36) = .307$ $p > .05$); knee flexion/extension moment ($F(1,36) = .000$, $p > .05$).

CHAPTER FIVE

Discussion

The most common ankle injury among athletes is the lateral ankle sprain (Fink & Mizel, 2001; Lynch & Renstrom, 1999; Thonnard, Bragard, Willens, & Plaghki, 1996). According to Hubbard and Kaminski (2002), 85% of ankle sprains occur during inversion movements of the ankle. Ankle taping is an accepted as an effective stabilizer as it helps restrict joint range of motion (ROM). Ankle braces are also known to reduce ankle ROM (McCaw & Cerullo, 1998). However, research has suggested that ankle braces impinge on the normal kinematics of the ankle during drop landings.

The purpose of this study was to determine the differences in ankle stabilizers (brace, tape and no appliance) by measuring ankle and knee joint ROM, ground reaction forces (GRF), and ankle and knee joint forces and moments in those with functional ankle stability (FAS) and those with functional ankle instability (FAI).

A repeated measures 2 x 3 one-way MANOVA (groups x stabilizers) was used to analyze the results. The dependant variables for this study were ankle dorsiflexion range of motion (ROM), ankle abduction ROM, knee flexion ROM, peak vertical ground reaction forces (GRF), peak ankle anterior joint forces, peak ankle medial joint forces, peak knee anterior joint forces, peak knee medial joint forces, peak ankle abduction moments, peak ankle flexion moments, and peak knee flexion moments. Alpha was set at .05.

Summary of Null Hypotheses

- There will be no significant interaction between groups and stabilizers.
    - Accepted ($p > .05$).

- There will be no significant differences in dorsiflexion ROM between the brace, tape, or no stabilizer conditions.
    - Accepted ($p > .05$).
- There will be no significant differences in dorsiflexion ROM between FAI or FAS.
    - Accepted ($p > .05$).
- There will be no significant differences in knee flexion ROM between the brace, tape, or no stabilizer conditions.
    - Accepted ($p > .05$).
- There will be no significant differences in knee flexion ROM between FAI or FAS.
    - Accepted ($p > .05$).
- There will be no significant differences in peak GRF the brace, tape, or no stabilizer conditions.
    - Accepted ($p > .05$).
- There will be no significant differences in joint kinetics between the brace, tape, or no stabilizer conditions.
    - Accepted ($p > .05$).

- There will be no significant differences in joint kinetics between the FAS and FAI groups: rejected, $p < .05$.

Stabilizer by Group Interaction

There was no significant interaction between stabilizer condition and group membership on ankle and knee ROM, joint forces, or joint moments. Regardless of stabilizer condition, participants seemed to land with similar patterns and joint kinetics. This result is contrary to the findings of McCaw and Cerullo (1999). They found significant differences in stabilizer effect on ankle joint angle at touch down. In their study, five stabilizers were used, three braces and a taped ankle and no stabilizer. Hume and Gerrard (1998) also stated that ankle braces and tape provided stabilization by decreasing the inversion motion of the ankle, thus decreasing the strain placed on the ligaments. In another study, Eils, Cemming, Kollmeier, Thorwesten, Volker, and Rosenbaum (2002), measured passive ROM between ten different braces and found that all ten braces significantly reduced ROM. They did not measure passive ROM of a taped ankle or an ankle without stabilization. In our study, three stabilizers were used, one brace (Mueller Ankle Soccer Brace), a taped ankle and no stabilizer. There were no significant differences in ankle or knee ROM. It was found that those with FAS tended to have greater knee flexion. However, small differences can be seen in Table 7. Perhaps the brace used in the present study did not provide the level of support of those in previous studies.

Joint motion and muscle activity are important in absorbing the impact forces of the landing phase of a jump (McNitt-Gray, 1991; Melville-Jones & Watt, 1971). Winter (2005) found that shock absorption occurs when there is eccentric activity in the muscles.

Therefore, the greater muscular activity one has during a drop landing, the greater the shock absorption. In the present study, there was no significant difference between stabilizers and the groups, however, it was found that those with FAS tended to have higher peak vertical GRF, greater ankle posterior joint forces, greater knee anterior joint forces, and greater ankle flexion moments, than those with FAI regardless of the stabilizer being used. Even though there were no significant differences, the possibility of those who have greater knee flexion, peak vertical GRF, anterior forces and ankle flexion moments are less likely to have a risk of an ankle or knee injury needs further evaluated.

Landing Kinematics

Participants in both the FAS and FAI group used similar ROM at the knee and ankle during the landing task regardless of stabilizer condition. This is contrary to what McCaw and Cerullo (1999) found. Their results showed that ankle stabilizers impinge on the normal kinematics of the ankle joint during drop landings. The ankle stabilizers used in their study were the Aircast, Swedo-O and the Active Ankle. They hypothesized that there would be greater eccentric activity in the dorsiflexors of the ankle when an athlete lands without a stabilizer, and that stabilizers will change the normal kinematics of the ankle during a drop landing. Reduced energy would increase the demand on the hip and knee muscles to absorb the energy during a drop landing. Researchers in another study looked at the differences of four different landing techniques; the bent knee landing (BN), the stiff knee, natural plantar flexion landing (SN), the stiff knee, in which the plantar flexor absorb the during impact landing (SP), and the stiff knee, which absorbs impact on the heels landing (SH) (Self & Paine, 2001). They found differences in the four different techniques. Since we asked our participants to land as naturally as possible using one leg, we can expect to find difference in landing techniques regardless of the stabilizer being used. Our results showed that the FAI group landed with more medial ankle force, more knee medial force and with more abduction than the FAS group. Therefore we expected to find differences.

Decker, Torry, Wyland, Sterett and Steadman (2002) determined that there was a difference in ROM between males and females with no history of orthopedic injury to the lower extremity joints (see Table 6). Their procedures involved 12 males and 9 females performing drop landings from a platform 60cm high. Their results showed higher ROM at the knee and ankle than the present study. The difference between these studies is that our study required participants to land on one foot while Decker, Torry, Wyland, Sterett and Steadman (2002) allowed their participants to land on two feet, one foot landing on a force plate. Perhaps landing on two feet allowed their participants to land with more stability and control, which could influence their results.

Even though 9 of our 11 dependant variables were not significant, we did find differences in some of the dependant variables and the stabilized conditions and the groups (see Table 8).

Ankle Abduction ROM (degrees)

The brace and tape restricted Abduction ROM in the FAS group more than the stabilizers in the FAI group (FAS brace -9.04º, tape -10.95º; FAI brace 4.10º, tape 1.40 º). This is contrary to the purpose of using a brace or tape for the FAI population.

Peak vertical GRF (N)

The brace and tape restricted Peak Vertical GRF (N) in the FAI group more than the stabilizers in the FAS group (FAI brace 163.52N, tape 163.31N; FAS brace 64.12N, tape 19.43N). This would be beneficial to those with FAI.

Ankle Anterior Joint Forces (N)

The stabilizers restricted Ankle Anterior Joint Forces (N) in the FAI group more than the stabilizers in the FAS group (FAI brace 104.85N, tape 79.68N, FAS brace 31.94N, and tape 75.96N). This would benefit those with FAI by decreasing the forces placed on the ankle.

Knee Anterior Joint Forces (N)

The stabilizers restricted Knee Anterior Joint Forces (N) in the FAS group more than the stabilizers in the FAI group (FAS brace 49.45N, tape 80.66N; FAI brace 11.90N, tape 4.43N). Even though knee anterior joint forces were not statistically significant, a difference was found between the groups. This would suggest that those with FAI will not benefit from using a stabilizer.

Landing Kinetics

No significant main effect was found in joint kinetics between any of the ankle stabilizer conditions. There were no significant differences between the two stabilizers and the no stabilizer condition. Caulfield and Garrett (2004) found that those with FI showed peak lateral forces 13ms earlier than those in the healthy control. Even though we did not measure timing of the peak forces, we would expect to find differences in timing of the GRF. We also did not measure pre landing/post landing angle. We also would expect to find a difference.

Ankle Medial/Lateral Joint Forces

The results of this study found that there were significant differences in ankle medial/lateral joint forces between the two groups. The FAI group (m = 115.06, sd = 169.15) had greater medial ankle joint forces when compared to the FAS group (m = 4.08, sd = 104.07). There could be a possibility that participants in the FAI group tried to compensate landing medially rather than laterally because of fears of performing a single leg jump on their involved ankle. A majority of the ankle injuries to those in the FAI group occurred 2-3 years ago. Participants could have been intimidated with the height of the platform which could have prevented them from landing naturally. Konradsen (2002) looked at kinesthesia and joint position sense involving those with FAI. It was found that changes in joint position sense and kinesthesia are found in participants with FAI. Participants in this study were asked to look straight ahead and not down at the floor. This could potentially decrease their joint position sense and kinesthesia which could be a reason why they with more medial forces that those with FAS.

Knee Medial/Lateral Joint Forces

Significant differences where found in knee medial/lateral joint forces between the two groups; FAS group (m = 14.08, sd = 215.35) and those with FAI (m = 196.55, sd = 299.41). The FAI group landed with greater medial knee joint forces than the FAS group regardless of stabilizer condition. Although no other study has measured joint forces during landings of those with FAI and FAS, Caulfield and Garrett's (2004) results also showed that those with FAI landed with greater medial GRF than those with healthy ankles. In the present study, no significant differences were found between stabilizers and the groups. Those with FAI landed with greater medial knee forces. Again, this could be the FAI compensating to avoid landing laterally in order to avoid injury and pain.

Ankle Abduction/Adduction Moments

Significant differences were also found in ankle abduction/adduction moments between the two groups; FAS (m = 112.16, sd = 63.91) and those with FAI (m = 71.20, sd = 55.30). Those with FAI landed with a lower abduction (or eversion) moment than those with FAS. FAI participants may be at greater risk of another inversion ankle sprain. Those with FAI may have chronic symptoms after the ankle injury has healed (Garrick, 1977; DeMaio, Paine, & Drez. Jr., 1992; Hartsell & Spaulding, 1997; Freeman, 1965; Hartsell, 2000). Some of the symptoms include slowed reflex response time of the peroneals (Mattson, & Brostrom, 1990), slowing of the tibialis anterior muscles to sudden plantar flexion and inversion stress (Ebig, Lephart, & Burdett, 1997) and inadequate ability to detect movement compared to those with FAS (Forkin, Koczur, Battle, & Newton, 1996). These results could indicate that those with FAI have different landing characteristics than those with FAS.

Clinical Implications

Our results show that there is a difference between the two groups regardless of the stabilizer being used. Athletic trainers, physicians, coaches, and athletes need to be aware of the risk involved in having FAI. A stabilizer alone may not reduce the risk of further ankle injuries. Therefore, it is recommended that improved strength and rehabilitation could also be beneficial to those experiencing FAI.

Recommendations for Future Studies

Based on the findings of the present study, future studies should focus on

- The effects of stabilizers on time to peak GRF, and joint forces.
- Studies can also include more stabilizers and the differences between those stabilizers examining time to peak force.
- A larger sample size needs to be used in order to produce more power. In this study, only fourteen participants were used, seven with FAS and seven with FAI. The observed power was at .356. This indicated that a larger sample size needed to be used.
- Future studies need to include those participants with recent ankle sprains. In this study, participants were excluded if they had a lower extremity injury in the past year. Maybe a shorter period of time between time of injury and data collection would be beneficial.
- To control for the fear factor, a smaller platform should be used. In this study a larger platform (.60m) was used.
- More braces should be included.
- Stress X-Rays should be used to examine how much laxity a participant has in their ankle.
- Future studies should use examine the participant's ankle strength. A Biodex machine can be used to measure ones ankle strength.

- Future studies should look at the effects of orthotics on drop landings with and without a stabilizer.
- Electromyography (EMG) should also be included.

Conclusions

Based on the results of this study, the following conclusions can be made:

- Stabilizers had no effect on ankle or knee ROM, joint forces or moments between those participants with FAI or FAS during a one-footed drop landing.
- There are no significant differences in ankle or knee ROM between participants with FAI and those with FAS during a one-footed drop landing.
- The FAI group landed with greater medial ankle joint forces, medial knee joint forces, and less abduction ankle moments than participants with FAS.

References

Alves, J.W., Alday, R.V., Ketcham, D.L., & Lantell, G.L. (1992). A comparison of the passive support provided by various ankle braces. *J. Orthop. Sports Phys. Ther. 15, 10-18.*

Arnold, B.L., & Docherty, C.L. (2004). Bracing and rehabilitation—what's new. *Clin Sports Med, 23(1), 83-95.*

Beriau, M.R., Cox, W.B., & Manning J. (1994). Effects of ankle braces upon agility course performance in high school athletes. *Journal of Athletic Training, 29, 247-230.*

Beynnon, B.D., Murphy, D.F., Alosa, D.M. (2002). Predictive factors for lateral ankle sprains: A Literature Review. *Journal of Athletic Training, 37(4),* 376-380.

Bocchinfuso, C., Sitler, M.R., & Kimura, I.F. (1994). Effects of two semirigid prophylactic ankle stabilizers on speed, agility, and vertical jump. *J. Sport Rehabil. 3, 125-134.*

Brostrom, L. (1964). Sprained ankles: I. Anatomic lesions in recent sprains. *Acta Chir Scand, 128, 483-495.*

Brown, C., Ross, S., Mynark, R., & Guskiewicz, K. (2004). Assessing Functional Ankle Instability with Joint Position Sense, Time to Stabilization, and Electromyography. *J. Sport Rehabilitation, 13, 122-134.*

Burks, T.T., Bean, B.G., Marcus, R., & Barker, H.B. (1991). Analysis of athletic performance with prophylactic ankle devices. *Am. J. Sports Med., 19, 104-106.*

Burns, J., Scherlitz, J., & Luessenhop, S. (1996). The stabilizing effect of orthotic devices on plantar flexion/dorsal extension and horizontal rotation of the ankle joint. *Int. J. Sports Med., 17, 614-618.*

Callaghan, M.J. (1997). Role of ankle taping and bracing in the athlete. *Br J Sports Med., 31(2), 102-108.*

Caulfield, B., Crammond, T., O'Sullivan, A., Reynolds, S., & Ward, T. (2004). Altered Ankle-Muscle Activation During Jump Landing in Participants With Functional Ankle Instability of the Ankle Joint. *Journal of Sports Rehabilitation, 13, 189-200.*

Caulfield, B., & Garrett, M. (2004). Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. *Clinical Biomechanics, 19, 617-621.*

Cordova, M.L., Ingersoll, C.D., & Palmieri, R.M. (2002). Efficacy of prophylactic ankle support: an experimental perspective. *Journal of Athletic Training, 37, 446-457.*

Decker, M.J., Torry, M.R., Wyland, D.J., Sterett, W.I., & Steadman, J.R. (2003). Gender differences in lower extremity kinematics, kinetics and energy absorption during landing. *Clinical Biomechanics, 18, 662-669.*

DeMaio, M., Taine, R., & Drez Jr., D. (1992). Chronic lateral ankle instability-inversion sprains: part II. *Sprts Med. Rehabil. Ser., 15, 241-248.*

Devita, P., & Skelly, W.A. (1992). Effect of landing stiffness on joint kinetics and energies in the lower extremity. *Med. Sci. Sports Exerc., 24, 108-115.*

Dufek, J.S., & Bates, B.T. (1990). The evaluation and prediction of impact forces during landings. *Med Sci Sports Exerc., 22, 370-377.*

Ebig, M., Lephart, S.M., & Burdett, R.G. (1997). The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. *J Orthop. Sports Phys. Ther., 26, 73-77.*

Feuerbach, J.W., & Grabiner, M.D. (1993). Effect of the aircast on unilateral postural control: amplitude and frequency variables. *J. Sports Med. Phys. Fitness, 17, 149-154.*

Feuerbach, J.W., Grabiner, M.D., & Koh, T.J. (1994). Effect of an ankle orthosis and ankle ligament anesthesia on ankle joint proprioception. *Am. J. Sports Med. 22, 223-229.*

Fink, B., & Mizel, M.S. (2001). Specialty Update: What's New in Foot and Ankle Surgery. *The Journal of Bone & Joint Surgery, 83(5), 791.*

Freeman, M.A. (1965). Instability of the foot after injuries to the lateral ligament of the ankle. *J Bone Joint Surg Br., 47, 669-677.*

Freeman, M.A., Dean, M.R., & Hanham, I.W. (1965). The etiology and prevention of functional instability of the foot. *J of Bone Joint Surg Br., 47B, 678-685*.

Forkin, D.M., Koczur, C., Battle, R., & Newton, R.A. (1996). Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. *J Orthop Sports Phys Ther., 23, 245-250.*

Garn, S.N. & Newton, R.A. (1988). Kinesthetic awareness in subjects with multiple ankle sprains. *Phys Ther.,68, 1667-1671.*

Garrick, J.C. (1977). The frequency of injury, mechanism of injury and epidemiology of ankle sprains. *Am. J. Sports Med., 5, 241-242.*

Gauffin, H., Tropp, H., & Odenrick, P. (1988). Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. *Int J Sports Med., 9, 141-144.*

Glick, J.M., Gordon, R.R., & Nishimoto, D. (1976). The prevention and treatment of ankle injuries. *Am J Sports Med., 4(4), 136-141.*

Goldie, P.A., Evans, O.M., & Bach, T.M. (1994). Postural control following inversion injuries of the ankle. *Arch Phys Med Rehabil., 75, 969-975.*

Greene, T.A. & Hillman, S.K. (1990). Comparison of support provided by a semi-rigid orthosis and adhesive taping before, during and after exercise. *J. Sports Med. Phys. Fitness, 18, 498-506.*

Greene, T.A., & Wright, C.A. (1990). A comparative support evaluation of three ankle orthosis before, during and after exercise. *J. Orthop. Sports Phys. Ther., 11, 253-266.*

Gross, M.T., Clemence, L.M., & Cox, B.D. (1997). Effect of ankle orthoses on functional performance for individuals with recurrent lateral ankle sprains. *J. Orthop. Sports Phys. Ther. 25, 245-252.*

Gross, M.T., Everts, J.R., Roberson, S.E., Roskin, D.S., & Young, K.D. (1994). Effect of Donjoy ankle ligament protector and Aircast sport-stirrup orthoses on functional performance. *J. Orthop. Sports Phys Ther., 19, 150-156.*

Gross, M.T., Bradshaw, M.K., Ventry, L.C., et al. (1987). Comparison of support provided by ankle taping and semi-rigid orthosis. *J Orthop Sports Phys Ther., 9(1), 33-39.*

Gross, T.A., Lapp, A.K., & Davis, J.M. (1991). Comparison of Swede-O-University Ankle Support and Aircast Sport-Stirrup orthoses and ankle tape in restriction eversion-inversion before and after exercise. *J Orthop Sports Phys Ther, 13(1), 11-19.*

Hals, T.M., Sitler, M.R., & Mattacola, C.G. (2000). Effect of a semi-rigid ankle stabilizer on performance in persons with functional ankle instability. *J. Orthop. Sports Phys. Ther., 30, 552-556.*

Hartsell, H.D. (2000). The effects of external bracing on joint position sense awareness for the chronically unstable ankle. *J. Sports Rehabil., 19, 279-289.*

Hartsell, H.D. & Spaulding, S.J. (1997). Effectiveness of external orthotic support on passive soft tissue resistance of the chronically unstable ankle. *Foot Ankle Int., 18, 144-150.*

Hertel, J. (2002). Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *Journal of Athletic Training, 37(4)*, 364-375.

Hertel, J. (2000). Functional instability following lateral ankle sprain. *Sports Med., 29, 361-371.*

Hockenbury, R.T., & Sammarco, G.J. (2001). Evaluation and Treatment of Ankle Sprains. *Physician & Sports medicine, 29(2), 57.*

Hoppenfeld, S. (1976). Physical Examination of the Spine and Extremities. Norwalk, Connecticut: Appleton-Centrury-Crofts.

Hopper, D.M., McNair, P., & Elliott, B.C. (1999). Landing in netball: effects of taping and bracing the ankle. *Br J Sports Med, 33, 409-413.*

Hubbard, T.J., & Kaminski, T.W. (2002). Kinesthesia is not affected by chronic ankle instability status. *Journal of Athletic Training, 37(4),* 481-486

Hume, P.A., & Gerrard, D.F. (1998). Effectiveness of external ankle support: bracing and taping in rugby union. *Sport Med., 25(5), 285-312.*

James, S.L., Bates, B.T., & Osternig, L.R. (1978). Injuries to runners. *American Journal of Sports Medicine, 6, 40-49.*

Jerosch, J., Thorwesten, T., Frebel, T., & Linnenbecker, S. (1997). Influence of external stabilizing devices of the ankle on sport-specific capabilities. *Knee Surgery. Sports Traumatol. Arthrosc., 5, 50-57.*

Jerosch, J., & Bischof, M. (1996). Proprioceptive capabilities of the ankle in stable and unstable joints. *Sports Exerc Inj., 2, 167-171.*

Jerosch, J., Thorwesten, L., Bork, H., & Bischof, M. (1996). Is prophylactic bracing of the ankle cost effective. *Orthopedics, 19, 405-414.*

Juvenal, J.P. (1972). The effects of ankle taping on vertical jumping ability. *Athl. Train., JNATA, 7, 146-149.*

Karlsson, J., Sward, L., & Andreasson, G.O. (1993). The effect of taping on ankle stability: practical implications. *Sports Med., 16, 210-215.*

Konradsen, L. (2002). Factors contributing to chronic ankle instability: kinesthesia and joint position sense. *Journal of Athletic Training, 37, 381-385.*

Konradsen, L., & Magnusson, P. (2000). Increased inversion angle replication error in functional ankle instability. *Knee Surg Sports Traumatol Arthrosc., 8, 246-251.*

Konradsen, L., Olesen, S., & Hansen, H.M. (1998). Ankle sensorimotor control and eversion strength after acute inversion injuries. *Am J Sports Med., 26, 72-77.*

Konradsen, L, Voigt, M., & Hojsgaard, C. (1997). Ankle inversion injuries: the role of the dynamic defense mechanism. *Am J Sports Med., 25, 54-58.*

Leanderson, J., Wykman, A., & Eriksson, E. (1993). Ankle sprain and postural sway in basketball players. *Knee Surg Sports Traumatol Arthrsc., 1, 203-205.*

Lentell, G., Baas, B., Lopez, D., McGuire, L., Sarrels, M., & Snyder, P. (1995). The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle joint. *J Orthop Sports Phys Ther., 21 (4), 206-215.*

Lynch, S. (2002). Assessment of the injured ankle in the athlete. *Journal of Athletic Training, 37(4),* 406-412.

Lynch, S.A., & Renstrom, P.A.F.H. (1999). Treatment of Acute Lateral Ankle Ligament Rupture in the Athlete: Conservative Versus Surgical Treatment. *Sports Medicine, 27 (1), 61.*

Mackean, L.C., Bell, G., & Burnham, R.S. (1995). Prophylactic ankle bracing vs. taping: effects on functional performance in female basketball players. *J. Orthop. Sports Phys. Ther., 22, 77-81.*

Macpherson, K., Sitler, M., Kimura, I., & Horodyski, M. (1995). Effects of a semirigid and softshell prophylactic ankle stabilizer on selected performance tests among high school football players. *J. Orthop. Sports Phys. Ther, 21, 147-152.*

Madras, D., & Barr, J.B. (2003). Rehabilitation of the functional ankle stability. *Journal of Sport Rehabilitation, 12*, 133-142.

Magee, D.J. (1997). *Orthopedic Physical Assessment.* (3rd ed.). Philadelphia: W.B. Saunders Company.

Maidment, J.S. (1990). The effect of ankle prophylactic devices on agility. Springfield College, Physical Education, Springfield M.A.

Martin, N., & Harter, R.A. (1993). Comparison of inversion restraint provided by ankle prophylactic devices before and after exercise. *J. Athl. Training, 28, 324-328.*

Mattson, E., & Brostrom, L.A. (1990). The increase in energy cost of walking an immobilized knee or an unstable ankle. *Scand. J. Rehabil. Med., 22, 51-53.*

Mattacola, C.G., & Dwyer, M.K. (2002). Rehabilitation of the ankle after acute sprain or chronic instability. *Journal of Athletic Training, 37(4),* 413-429.

Mayhew, J.L. (1972). Effects of ankle taping on motor performance. *Athl. Train. JNATA, 70, 10-11.*

McCaw, S., & Cerullo, J. (1999). Prophylactic ankle stabilizers affect ankle joint kinematics during drop landings. *Medicine & Science in Sports & Exercise, 31(5),* 702-707.

McKay, G., Goldie, P.A., Payne, W.R., et al. (2001) Ankle injuries in basketball players: injury rate and risk factors. *British Journal of Sports Medicine, 35(2),* 103-108

McNitt-Gray, J.L., Hester, D.M.E., Mathiyakom, W., & Munkasy, B.A. (2001). Mechanical demand and multi-joint control during landing depend on orientation of the body segments relative to the reaction force. *Journal of Biomechanics, 34, 1471-1482.*

McNitt-Gray, J. (1991). Kinematics and impulse characteristics of drop landings from three heights. *International Sports Biomechanics, 7, 201-223.*

Melville, J.G., & Watt, D.G. (1971). Muscular control of landing from unexpected fall in man. *Journal of Physiotherapy, 219, 729-737.*

Mizrahi, J., & Susak, Z. (1982). Analysis of parameters affecting impact force attenuation during landing in human vertical free fall. *Eng Med., 11, 141-147.*

Murphy, D.F., Connolly, D.A.J., & Beynnon, B.D. (2003). Risk factors for lower extremity injury: a review of literature. *British Journal of Sports Medicine, 37, 13-29.*

Myburgh, K.H., Vaughan, C.L., & Isaacs, S.K. (1984). The effects of ankle guards and taping on joint motion before, during, and after a squash match. *Am J Sports Med, 12(6), 441-446.*

Nigg, B.M., & Bobbert, M. (1990). On the potential of various approaches in load analysis to reduce the frequency of sports injuries. *Journal of Biomechanics, 23, (Suppl. 1), 3-12.*

Noyes, F.R., Basset, R.W., Grood, E.S., & Butler, D.L. (1980). Arthroscopy in acute traumatic hemarthrosis of the knee. Incidence of anterior cruciate tears and other injuries. *J. Bone Joint Surg., 62A, 687-695.*

Oggero, E., Pagnacco, G., Morr, D.A., et al. (1997). The mechanics of drop landing on a flat surface-a preliminary study. *Biomed Sci Instrum., 33, 53-58.*

Olmsted-Kramer, L.C., & Hertel, J. (2004). Preventing Recurrent Lateral Ankle Sprains: An Evidence-Based Approach. Athletic Therapy Today, 9(6), 19-22.

Ozguven, H.N., & Berme, N. (1988). An experimental and analytical study of impact forces during human jumping. *J Biomech, 21, 1061-1066.*

Palmieri, R.M., Ingersoll, C.D., Cordova, M.L., & Kinzey, S.J. (2002). The spectral qualities of postural control are unaffected by 4 days of ankle-brace application. *Journal of Athletic Training, 37 (3),* 269-274.

Panzer, V.P., Wood, G.A., Bates, B.T., et al. (1988). Lower extremity loads in landings of elite gymnasts, in deGroot G, Hollander A, Huijing P, et al. (eds): *Biomechanics XI-B.* (pp 727-735). Amsterdam, Free University Press.

Paris, D.L. (1992). The effects of the Swede-o, New Cross, and McDavid ankle braces and adhesive ankle taping on speed, balance, agility, and vertical jump. *J Athl. Train., 27,253-256.*

Perrin, P.P., Bene, M.C., Perrin, C.A., & Durupt. D. (1997). Ankle trauma significantly impairs posture control- a study in basketball players and controls. *Int J Sports Med., 18, 387-392.*

Pienkowski, D., McMorrow, M., Shapiro, R., Caborn, D.N.M., & Stayton, J. (1995). The effect of ankle stabilizers on athletic performance: a randomized prospective study. *Am. J. Sports Med., 23, 757-762.*

Prentice, W.E. (2003). *Arnhiem's Principles of Athletic Training (11th ed.).* St. Louis, MO: Times Mirror/ Mosby, 1514.

Refshauge, K.M., Killbreath, S.L., & Raymond J. (2000). The effect of recurrent ankle inversion sprain and taping on proprioceptive at the ankle. *Med Sci Sports Exerc., 32, 10-15.*

Robertson, D.G.E., Caldwell, G.E., Hamill, J., Kamen, G., & Whittlesey, S.N. (2004). *Research Methods in Biomechanics.* Chicago, IL: Human Kinetics.

Robinson, J.R., Frederick, E.C., & Cooper, L.B. (1986). Systematic ankle stabilization and the effect on performance. *Med. Sci. Sports Exerc., 18, 625-628.*

Rossi, M.J., Lubowitz, J.H., & Guttmann, D. (2003). The skier's knee, *Arthroscopy, 19, 75-84.*

Rovere, G.D., Clarke, T.J., Yates, C.S., et al. (1988). Retrospective comparison of taping and ankle stabilizers in preventing ankle injuries. *Am J Sports Med, 16(3), 228-233.*

Rozzi, S.L., Lephart, S.M., Sterner, R., & Kuligowski, L. (1999). Balance training for persons with functionally unstable ankles. *J Orthop Sports Phys Ther, 29, 478-486.*

Saffran, C.R., Kaminski, T.W., Hatzel, B.M., Horodyski, M.B., & Dodd, S.L. (1999). The effects of ankle bracing on functional performance. *J. Athl. Train., 34, S-93.*

Safran, M. et al (1999). Lateral ankle sprains: a comprehensive review. Part 2: treatment and rehabilitation with an emphasis on the athlete. *Medicine and Science in Sports and Exercise. 31(7) S438-S447.*

Salci, Y., Kentel, B.B., Heycan, C., Akin, S., & Korkusuz, F. (2004). Comparison of landing maneuvers between male and female college volleyball players. *Clinical Biomechanics, 19, 622-628.*

Santos, M.J., McIntire, K., Foecking, J., & Liu, W. (2004). The effects of ankle bracing on motion of the knee and the hip joint during trunk rotation tasks. *Clinical Biomechanics, 19(9), 964-971.*

Self, B.P. & Paine, D. (2001). Ankle biomechanics during four landing techniques. *Medicine and Science in Sport and Exercise, 33(8), 1338-1344.*

Shapiro, S.R., Jones, B., & Knapik, J. (1994). Ankle sprain prophylaxis: an analysis of the stabilizing effects of braces and tape. *Am. J. Sports Med., 22, 78-82.*

Shapiro, M.S., Kabo, J.M., Mitchell, P.W., Loren, G., & Tsenter, M. (1994). Ankle sprain prophylaxis: an analysis of the stabilizing effects of braces and tape. *Am. J. Sports Med., 22, 78-82.*

Simpson, K.J., & Kanter, L. (1997). Jump distance of dance landings influencing internal joint forces: I. Axial forces. *Med Sci Sports Exerc., 29(7), 916-927.*

Smith, R.W., & Reischl, S.F. (1986). Treatment of ankle sprains in young athletes. *American Journal of Sports Medicine, 14, 465-471.*

Stacoff, A., Kaelin, X., Stuessi, E. (1988). Impact in landing after a volleyball block, in deGroot G, Hollander A, Huijing P, et al. (eds): *Biomechanics XI-B.* (pp. 694-700). Amsterdam, Free Univeristy Press.

Staples, O.S. (1975). Ruptures of the fibular collateral ligaments of the ankle. *J Bone Joint Surg., [AM], 57, 101-107.*

Steel, J.R., & Milburn, P.D. (1989). A kinetic analysis footfall patterns at landing in netball. *Aust J Sci Med Sport, 21, 10-13.*

Steussi, E., Tigernamm, H., Gerber, H., Raemy, H., & Stacoff, A. (1987). A biomechanical study of the stabilization effect of the Aircast ankle brace. *Int. Ser. Biomech., 6A, 159-164.*

Surve, I., Schwellnus, M.P., Noakes, T., & Lombard, C. (1994). A fivefold reduction in the incidence of recurrent ankle sprains in soccer players using the sport-stirrup orthosis. *Am. J. Sports Med., 22, 601-606.*

Taunton, J.E., McKenzie, D.C., & Clement, D.B. (1988). The role of biomechanics in the epidemiology of injuries. *Sports Medicine, 6, 107-120.*

Thacker, S.B., Stroup, D.F., Branche, C.M., et al. (1999). The prevention of ankle sprains in sports: a systematic review of the literature. *Am J. Sports Med., 27(6), 753-760.*

Thomas, C.L. (Ed.). (1997). *Taber's Cyclopedic Medical Dictionary*. (18th ed.). Philadelphia: F.A. Davis Company.

Thonnard, J.L., Bragard, D., Willens, P.A., Plaghki, L. (1996). Stability of the braced ankle. A Biomechanical Investigation. *American Journal of Sports Medicine, 24 (3)*, 356.

Tropp, H., Odenrick, P., & Gillquist, J. (1985). Stabilometry recordings in functional and mechanical instability of the ankle joint. *Int J Sports Med., 6, 180-182.*

Tuggy, M.L. & Ong, R. (2000). Injury risk factors among telemark skiers. *Am J. Sports Med., 28, 83-89.*

Valiant, G.A., & Cavanagh, P.R. (1985). A study of landing from a jump: Implications for the design of a basketball shoe. In: Winter DA, Norman, RW, Wells PR, et al. (Eds): *Biomechanics IX-B.* (pp. 117-122). Champaign, IL, Human Kinetics.

Verbrugge, J.D. (1996). The effects of semirigid air-stirrup bracing vs. adhesive ankle taping on motor performance. *J. Orthop. Sports Phys. Ther., 23, 320-325.*

Verhagen, E., van der Beek, A.J., & van Mechelen, W. (2001). The Effect of Tape, Braces and Shoes on Ankle Range of Motion. *Sports Med., 31(9), 667-677.*

Wiley, J.P. & Nigg, B.M. (1996). The effect of an ankle orthosis on ankle range of motion and performance. *J. Orthop. Sports Phys. Ther., 23, 362-369.*

Wilkerson, G.B. (2002). Biomechanical and neuromuscular effects of ankle taping and bracing. Journal of Athletic Training, 37, 436-445.

Wilkerson, G.B. (1991). Comparative biomechanical effects of the standard method of ankle taping and a taping method designed to enhance subtalar stability. *Am. J. Sports Med., 19-588-595.*

Williams, K.R. (1993). Biomechanics of distance running. In M.D. Grabiner (Ed.), Current issues in biomechanics (pp. 3-31). Champaign, IL: Human Kinetics.

Willems, T., Witvrouw, E., Verstuyft, J., Vaes, P., & De Clercq, D. (2002). Proprioception and muscle strength in subjects with history of ankle sprains and chronic instability. *Journal of Athletic Training, 37, 487-493.*

Winter, D. (2005). *Biomechanics and Motor Control of Human Movement* (3rd ed.). Hoboken, NJ: Wiley.

Yaggie, J.A., & Kinzey, S.J. (2001). A comparative analysis of selected ankle orthoses during functional tasks. *J. Sport Rehabil., 10, 174-183.*

Yeung, M.S., Chan, K.M, So, C.H., & Yuan, W.Y. (1994). An epidemiological survey on ankle sprain. *British Journal of Sports Medicine, 28, 112-116.*

Zhang, S., Bates, B.T., & Dufek, J.S. (2000). Contributions of lower extremity joints to energy dissipation during landings. *Med Sci Sports Exerc, 32(4), 812-819.*

Appendices

Appendix A

Functional Ankle Instability Questionnaire

Part 1: Functional Ankle Instability Questionnaire

1. Concerning your purported ankle instability, does this injury involve only

    one ankle? **Y N**

    If yes, did the initial episode involve your ankle "rolling inward"? **Y N**

    If no, do not continue to fill out this questionnaire.

2. Which ankle suffers the instability? **R L**

3. Did the initial injury to your ankle require crutches, immobilization or both,

    of any form (cast, braces, etc.)? **Y N**

4. Have you had any fractures (breaks) in either of your ankles? **Y N**

5. Is the injured/unstable ankle functionally weaker, more painful, "looser,"

    and less functional than your involved ankle? **Y N**

6. Do you ever have episodes of your ankle "giving way" or "rolling over"

    during daily activity (athletic or otherwise)? **Y N**

7. Do you attribute your current instability to past injuries to the affected

    ankle? **Y N**

8. Have you had an episode of injury ("your ankle was hurt," "you were in

    great pain") to the affected ankle within the last 3 months? **Y N**

9. Have you been walking around unassisted without a "limp," for at least

    the past 3 months? **Y N**

10. Are you currently involved in a "formal" rehabilitation program for

    the affected ankle? **Y N**

If you answered yes, please describe here.

____

____

11. Can you describe a symptom(s) of your ankle "giving way"?

Part 11: Clinical Examination of Ankle Stability

Is there swelling present?	**Y**	**N**
Is there ecchymosis present?	**Y**	**N**
Anterior Drawer Test		
Right ankle	+	-
Left ankle	+	-
Talar Tilt Test		
Right ankle	+	-
Left ankle	+	-

Cleared for participation in the study:

Signature: ____

*To qualify as functional ankle instability, questions 3, 5, 6, 7, and 9 should be answered "yes." Questions 4, 8, and 10 should be answered "no," and no clinical signs of mechanical instability can be present.

Appendix B

How to tape an ankle (Prentice, 2003)

Closed basket weave (Gidney) technique. The closed basket weave, or Gibney, technique offers strong tape support and is primarily used in athletic training for newly sprained or chronically weak ankles.

Materials needed: One roll of $1^1/_2$ (3.8 cm) tape, underwrap, and tape adherent.

Position of the athlete: The athlete sits on the table with the leg extended and the foot at a 90-degree angle.

Site preparation: Ankle taping applied directly to the athlete's skin affords the greatest support; however when applied and removed daily, skin irritation will occur. To avoid this problem, apply underwrap material. Before taping, follow these procedures:

1. Clean foot and ankle thoroughly.
2. Apply a coat of tape adherent to protect the skin and offer an adhering base.
3. Apply a gauze pad coated with friction-reducing material such as grease over the instep and to the back of the heel.
4. If the underwrap is used, apply a single layer. The tape anchors extend beyond the underwrap and adhere directly to the skin.
5. Do not apply tape if skin is cold or hot from a therapeutic treatment.

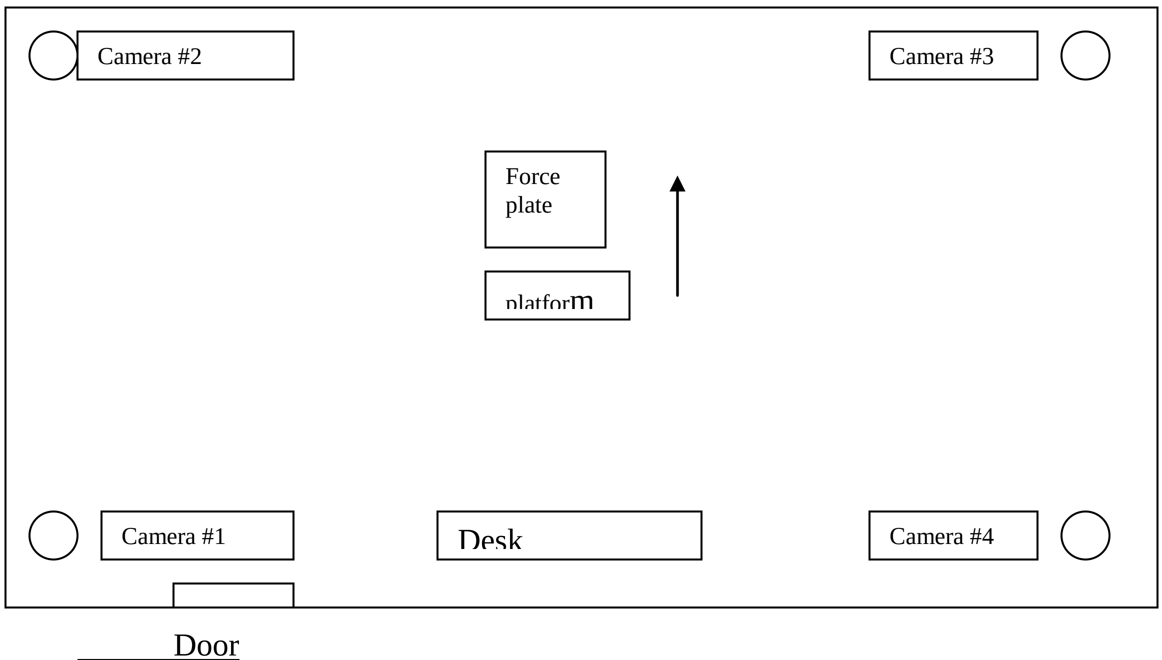
Procedure:

1. Place one anchor piece around the ankle approximately 5 or 6 inches (12.5 or 15 cm) above the malleolus just below the belly of the gastrocnemius muscle. Place a second anchor around the instep directly over the styloid process of the fifth metatarsal.

2. Apply the first strip posteriorly to the malleolus and attach it to the ankle anchor. NOTE: When applying strips, pull the foot into eversion for an inversion strain and into a neutral position for an eversion strain
3. Start the first Gibney directly under the malleolus and attach it to the foot anchor.
4. In an alternation series, place three strips and three Gibney on the ankle with each piece of tape overlapping at least half of the preceding strip.
5. After applying the basket weave series, continue the Gibney strips up the ankle, thus giving circular support.
6. For arch support, apply two or three circular strips laterally to medially.
7. After completing the conventional basket weave, apply two or three heel locks to ensure maximum stability.

Appendix C

Diagram of Biomechanics Lab


Camera #2
Camera #3
Force
plate
platform
Camera #1
Desk
Camera #4
Door

Appendix D
Anthropometric parameter measurement procedures

Anthropometric parameter measurement procedures.

The following lists anthropometric parameter measurement procedures, as taken from Dynamics of Human Gait.

ASIS Breadth	Use a beam caliper to measure the horizontal distance between the right and left anterior superior iliac spines of the pelvis
Thigh Length	Use a sliding caliper to measure the vertical distance between the superior point of the greater trochanter of the femur and the superior margin of the lateral tibia. Complete the same procedure for both right and left legs.
Midthigh Circumference	Place a tape measure perpendicular to the long axis of the thigh and at the level midway between the greater trochanter and the tibial plateau, and measure the circumference of the thigh. Complete the same procedure for both right and left legs.
Calf Length	Use a sliding caliper to measure the vertical distance between the superior margin of the lateral tibia and the lateral malleolus. Complete the same procedure for both right and left legs
Calf Circumference	Place a tape measure perpendicular to the long axis of the lower leg, and measure the maximum circumference of the calf. Complete the same procedure for both right and left legs.
Knee Diameter	Use a spreading caliper to measure the maximum breadth of the knee across the femoral epicondyles. Complete the same procedure for both right and left legs.
Foot Length	Use a beam caliper to measure the distance form the posterior margin of the heel to the tip of the longest toe. Complete the same procedure for both right and left legs.
Malleolus Height	With the subject standing, use a sliding caliper to measure the vertical distance from the standing surface to the lateral malleolus. Complete the same procedure for both right and left legs.
Malleolus Width	Use a sliding caliper to measure the maximum distance between the medial and lateral malleoli. Complete the same procedure for both right and left legs.
Foot Breadth	Use a beam caliper to measure the breadth across the distal ends of metatarsals I and V. Complete the same procedure for both right and left legs.

Appendix F

Journal Article

Joint Kinematics and Kinetics during Drop Landings under Braced and Taped Conditions in Persons with Functional Ankle Instability

Hayley McKelle Ulm, Graduate Student, Barry University,

hmusoccer11@hotmail.com

Joint Kinematics and Kinetics during Drop Landings under Braced and Taped Conditions in Persons with Functional Ankle Instability.

Context: The most common injury among athletes is lateral ankle sprains. In order to protect and prevent ankle injuries, ankle braces and/or tape is commonly used by athletes. **Objective:** To determine the differences in ankle stabilizers as measured by ankle and knee joint ROM, peak vertical GRF, and ankle and knee joint forces and moments between participants with healthy ankles (FAS) and those with functional ankle instability (FAI). **Design and Setting:** This study was conducted at Barry University, Miami Shores, FL. **Participants:** A total of fourteen participants were used (seven with healthy ankles, seven with FAI) (age 23.5 ± 4.36 yrs; weight 69.94 ± 12.37 kg; height 171.89 ± 10.23 cm). Participants were asked to drop off a box .60m high on a force plate .11m away from the platform a total of three times, one jump using a Mueller Ankle Brace, one jump with the ankle taped and one jump without any external stabilizer. The participants were required to stick the landing for a total of five seconds. A repeated measures 2 x 3 MANOVA (groups x stabilizers) was used. The dependant variables for this study were ankle dorsiflexion range of motion (ROM), ankle abduction, knee flexion ROM, peak vertical ground reaction forces (GRF), ankle anterior and medial joint forces, knee anterior and medial joint forces, ankle flexion and abduction moments, and knee flexion moments. Alpha was set at $\leq .05$. **Results:** There were no significant differences between stabilizers in either group. In the main effect for group, ankle medial joint forces ($F(1,36) = 6.095$, $p < .05$); knee medial joint forces ($F(1,36) = 4.844$, $p < .05$); and ankle abduction moments ($F(1,36) = .4.754$, $p < .05$) were significantly different between FAI

and FAS groups. **Conclusions:** Stabilizers had no effects on ankle and knee ROM, joint forces or moments between FAI and FAS groups. No significant differences in ankle or knee ROM between FAI and FAS groups. FAI had greater medial ankle joint forces, medial knee joint forces and less abduction ankle moments than those with FAS. **Key Words:** Functional Ankle Instability (FAI), Functional Ankle Stability (FAS), Stabilizer, Tape Ankle, GRF, joint kinematics, joint kinetics

Introduction:

The most common ankle injury among athletes is the lateral ankle sprain.[1-3] According to Hubbard and Kaminski,[4] 85% of ankle sprains occur during inversion movements of the ankle. Ankle taping is an accepted as an effective stabilizer as it helps restrict joint range of motion (ROM). Ankle braces are also known to reduce ankle ROM.[5] However, research has suggested that ankle braces impinge on the normal kinematics of the ankle during drop landings.

The purpose of this study was to determine the differences in ankle stabilizers (brace, tape and no appliance) by measuring ankle and knee joint ROM, ground reaction forces (GRF), and joint forces and moments in those with functional ankle stability (FAS) and those with functional ankle instability (FAI).

Some researchers state that ankle stabilizers, such as a brace or tape, restrict ankle range of motion (ROM) and therefore create more stress on the knees and hip. [6] Others state that ankle stabilizers help reduce ankle injuries by reducing ankle ROM.[7] Many researchers say that ankle stabilizers should only be used by those athletes who have been diagnosed with functional ankle instability (FAI).

Methods

Participants

Fourteen participants (age 23.5 ± 4.36 yrs; 69.94 ± 12.37 kg; 171.89 ± 10.23 cm), who were recreationally active participants in vigorous activity three times per week for 30 minutes, were included in this study. Seven of the participants were without any previous ankle injuries and were placed in the functional ankle stability group (FAS) (mean age 22.57 ± 2.88; weight 72.29 ± 12.57; height 174.34 ± 10.07) and seven participants had functional ankle instability (FAI) (mean age 20.57 ± 5.56; weight 61.78 ± 12.68; height 145.87 ± 10.55) and had no ankle or knee injuries in the past year. Before the day of data collection, participants filled out the Functional Ankle Instability Questionnaire.[4] Participants were placed in the FAI group if they answered “yes” to questions 3, 5, 6, 7, and 9 and “no” to questions 4, 8, and 10. Questions answers “yes” ask if the injury require crutches or any form of immobilization, if the injury or unstable ankle was functionally weaker, more painful or loser than the uninvolved ankle, if the injury can attribute to current instability or past injuries to the affected ankle, and if the participant has been walking around unassisted without a “limp”, for at least the past 3 months. Questions answers “no” ask if the participant had any fractures or breaks to the ankle, if the participant had an episode of injury to the affected ankle within the past 3 months and if the currently involved a “formal” rehabilitation program to the affect ankle. If participants answered “no” to these questions and have had no lower extremity injuries in the past 6 months, they were placed in the FAS group. All participants were students at Barry University in Miami Shores, Florida.

Instrumentation

Ankle Brace

A Mueller Ankle Soccer Brace (Mueller Sports Medicine, INC, Prairie du Sac, WI) was used in this study. The Mueller Ankle Soccer Brace is designed with supportive steel strings in order to protect the ankle from inversion ankle sprains. It is used by national soccer teams as well as athletes in sports such as racquetball, gymnastics, cheerleading, running and wrestling. It can fit either foot.

Ankle Tape

The ankle taped used in this study was 1 ½ inch Coach Johnson and Johnson Athletic tape (New Brunswick, NJ). Johnson and Johnson athletic tape is known for its tensile strength. It is breathable, lightweight and comfortable to the athlete.

Ankle Taping Technique

The Gibney ankle tape method was used in this study.

Videography

The Vicon Peak Performance Motion Measurement System 8.2 (Vicon Peak Performance Technologies, Inc., Centennial, CO) was used. Ground reaction forces were collected with an AMTI force plate (Watertown, MA). Four JVC 60 Hz cameras (JVC Professional Products, Denver, CO) were used; two were placed diagonally to the left and right of the participant and two cameras were placed to back right and back left of the participants.

Procedures

Participants were students at Barry University. Each participant participated in physical activity at least 30 minutes a day three times a week. Volunteers were asked to fill out the Functional Ankle Instability Questionnaire form[4] in order to determine which students could be used in the study. One national board certified athletic trainer (ATC) was utilized to determine the mechanical ankle stability by performing the anterior draw test and the talar tilt test. The same ATC was used to evaluate ankle stability for every participant.

The participants were asked to wear dark shorts and a dark t-shirt for data collection. When they arrived, they were asked to read and sign a consent form. Before the trial, participants were asked to warm up on a stationary bike for ten minutes. Anthropometric parameter measurements were taken before the day of data collection. After the warm-up, reflective markers were placed bilaterally on the lateral malleolus, the 2nd metatarsal, calcaneus, lateral condyle, anterior superior iliac spine (ASIS), and the sacrum. A tibial wand was placed on the biggest circumference of the gastrocnemius and a femoral wand was placed on the middle of the thigh.

Each participant was tested under the three different stabilizer conditions (brace, tape, no stabilizer). The conditions were randomized for each participant. Participants were given no more than five practices trials. When ready, the participant performed a single leg drop landing off a platform .60m high onto the center of the force plate. Participants stood with arms flexed to shoulder height and the heel of their involved foot resting against the front edge of the platform. The same technique was used in a research study performed by McCaw and Cerullo[5] and was designed to minimize horizontal motion. Participants were asked to drop off the box onto the force plate three different times under the three different conditions. The platform was placed .11m from the force plate. During the trial if the participants did not land on the center, they repeated the jump immediately. The participants were instructed to stick the landing for at least five seconds for a trial to be considered successful. If the participant was not able to keep his/her balance for five seconds, used their other leg for stabilization, or had a double landing on the force plate, they were asked to repeat the trial. After each successful trial, a different stabilizer was used. Each participant's involved ankle was taped by a certified athletic trainer. The trainer used the standards set in Prentice's *Principles of Athletic Training*.[8] Each participant was fitted with a brace according to their shoe size.

Design and Analysis

A repeated measures 2 x 3 MANOVA (groups x stabilizers) was used. The dependant variables for this study were ankle dorsiflexion range of motion (ROM), ankle abduction ROM, knee flexion ROM, peak vertical ground reaction forces (vGRF), peak anterior and medial ankle joint forces, peak anterior and medial knee joint forces, peak ankle dorsiflexion and abduction moments, and peak knee flexion moments. Alpha was set at $\leq .05$.

Results:

See Table 1 for participant demographics. Data for the kinematic dependant variables are found in Table 2. Means and standard deviations for the kinetic dependent variables are found in Table 3.

No significant interaction was found between groups and stabilizer condition ($F(22, 52) = 0.56$, $p > .05$, power =0.36). No significant differences were found between stabilizers as a main effect ($F(22, 52) = .69$, $p > .05$, power = .45. There was a significant main effect for group ($F(22, 52) = 2.39$, $p = .03$). A follow-up one-way MANOVA was run which indicated that medial ankle joint forces ($F(1,36) = 6.095$, $p < .05$), medial knee joint forces (F(1,36) = 4.844, $p < .05$), and ankle abductor moments (F(1,36) = .4.754, $p < .05$) were significantly different between groups. Participants with FAI tended to land with greater medial ankle force (mean = 115 N), greater medial knee force (mean =197 N), and a lower abductor ankle moment (mean = 112 Nm) than those with FAS.

Table 1. Participant Demographic Information

		FAS	
	Age	Weight	Height
mean	22.57	72.29	174.34
st. dev	2.87	12.57	10.07

		FAI	
	Age	Weight	Height
mean	20.57	61.78	145.87
st. dev	5.56	12.68	10.55

Table 2. Means and Standard Deviations for Kinematic Dependant Variables

Ankle dorsiflexion (deg.)	Brace	Tape	Without
FAS (n = 7)	30.12 ± 10.28	29.27 ± 5.57	31.17 ± 7.59
FAI (n = 7)	29.78 ± 8.35	28.26 ± 8.27	30.82 ± 12.53
Ankle abduction (deg.)			
FAS (n = 7)	25.56 ± 12.46	23.65 ± 6.68	34.60 ± 9.47
FAI (n = 7)	30.36 ± 14.05	24.86 ± 11.69	28.96 ± 8.33
Knee flexion (deg.)			
FAS (n = 7)	38.43 ± 6.80	43.05 ± 5.95	39.28 ± 7.68
FAI (n = 7)	33.72 ± 8.65	37.43 ± 9.69	35.54 ± 11.82

Table 3. Peak GRF and Ankle and Knee Joint Forces and Moments

Peak vertical GRF (N)

	Brace	Tape	Without
FAS (n = 7)	2590.95 ± 377.19	2635.64 ± 364.42	2655.07 ± 372.55
FAI (n = 7)	2488.73 ± 343.26	2485.52 ± 345.71	2325.21 ± 506.53

Ankle peak anterior joint forces (N)

FAS (n = 7)	-535.28 ± 128.79	-428.18 ± 234.91	-504.14 ± 168.97
FAI (n = 7)	-473.37 ± 109.41	-448.20 ± 137.22	-368.52 ± 201.86

negative numbers (-) denote posterior forces

Ankle peak medial joint forces (N)

FAS (n = 7)	44.59 ± 154.01	-19.72 ± 43.40	-12.63 ± 87.17
FAI (n = 7)	88.95 ± 147.60	134.06 ± 202.14	122.16 ± 177.35

negative numbers (-) denote lateral forces

Knee peak anterior joint forces (N)

FAS (n = 7)	531.00 ± 170.99	499.79 ± 171.96	580.45 ± 104.65
FAI (n = 7)	470.93 ± 234.63	487.26 ± 262.73	482.83 ± 224.79

Knee peak medial joint forces (N)

FAS (n = 7)	108.28 ± 364.96	-13.77 ± 47.62	-52.26 ± 52.34
FAI (n = 7)	243.06 ± 358.85	183.56 ± 318.50	163.04 ± 254.13

negative numbers (-) denote lateral forces

Ankle peak abduction moments (Nm)

	Brace	Tape	Without
FAS (n = 7)	104.86 ± 68.12	120.29 ± 22.65	111.53 ± 91.21
FAI (n = 7)	43.61 ± 46.79	78.43 ± 66.36	91.56 ± 46.55

Ankle peak flexion moments (Nm)

FAS (n = 7)	126.25 ± 86.87	128.70 ± 83.18	190.67 ± 116.10
FAI (n = 7)	129.68 ± 91.51	126.29 ± 103.13	138.61 ± 111.40

Knee peak flexion moments (Nm)

FAS (n = 7)	36.55 ± 89.91	40.28 ± 54.47	56.10 ± 103.27
FAI (n = 7)	51.31 ± 86.14	29.64 ± 76.67	50.33 ± 61.15

There were no other significance differences to report among the other dependant variables between the groups. Ankle dorsal/plantar flexion ROM ($F(1, 36) = .057$, $p > .05$); ankle abduction/adduction ROM ($F(1,36) = .001$, $p > .05$); knee flexion/extension ROM ($F(1,36) = 3.088$, $p > .05$); peak vertical GRF ($F(1,36) = 2.614$, $p > .05$); ankle anterior/posterior joint forces ($F(1,36) = 1.283$, $p > .05$); knee anterior/posterior joint forces ($F(1,36) = .830$, $p > .05$); ankle flexion/extension ($F(1,36) = .307$ $p > .05$); knee flexion/extension moment ($F(1,36) = .000$, $p > .05$).

Discussion:

There was no significant interaction between stabilizer condition and group membership on ankle and knee ROM, joint forces, or joint moments. Regardless of stabilizer condition, participants seemed to land with similar patterns. Even though in our study ankle and knee ROM and peak vertical GRF measures were not statistically significant there are notable clinical differences The brace and tape reduced dorsiflexion ROM in both groups (FAS: brace -1.05°, tape -1.60°; FAI: brace -1.04°, tape -2.56°) as compared to the no stabilizer condition. The brace and tape reduced abduction ROM in the FAS group more than the stabilizers in the FAI group (FAS: brace -9.04º, tape -10.95º; FAI: brace increased ROM by 1.40 and decreased ROM by 4.10º in the tape) as compared to the no stabilizer condition. According to our study, the Mueller brace and tape did not limit ROM in the FAI group and may not help reduce recurring ankle sprains for those participants with FAI. Compared to the no stabilizer condition, the peak vertical GRF of the FAI group increased under the Mueller brace and taped condition (FAI: brace +163.52N, tape +163.31N) whereas the peak vertical GRF in the FAS group decreased in the Mueller brace and taped condition (FAS: brace -64.12N, tape -19.43N). Lower peak

GRFs would indicate greater shock absorption. Therefore it appears that the Mueller brace and tape may have negatively affected the FAI group.

This study found significant differences in medial ankle joint forces between the two groups regardless of stabilizer condition. The FAI group (m = 115.06, sd = 169.15) had greater medial ankle joint forces when compared to the FAS group (m = 4.08, sd = 104.07). There could be a possibility that participants in the FAI group tried to compensate by landing more medially because of fears of performing a single leg landing on their involved ankle. A majority of those in the FAI group's ankle injuries occurred 2-3 years ago. Participants could have been intimidated with the height of the platform that could have prevented them from landing naturally. Konradsen looked at kinesthesia and joint position sense involving those with FAI.[10] It was found that changes in joint position sense and kinesthesia are found in participants with FAI. Participants in this study were asked to look straight ahead and not down at the floor. This could potentially decrease their joint position sense and kinesthesia that might explain why they landed with more medial forces than those with FAS. Perhaps, if we measured joint position at contact, more information could have been provided.

Significant differences were found in peak medial knee joint forces between the FAS group (*m* = 14.08, *sd* = 215.35) and the FAI group (*m* = 196.55, *sd* = 299.41). The FAI group landed with greater peak medial knee joint forces than the FAS group regardless of stabilizer condition. Although no other study has measured joint forces during landings of those with FAI and FAS, Caulfield and Garrett's results showed that those with FAI landed with greater medial GRF than those with healthy ankles which might indicate that they landed with medial knee forces.[9] Again, this could be the FAI compensating to avoid landing laterally in order to avoid injury and pain.

Other possibilities for the differences in medial knee forces include Q-angles and proprioception. Women have been known to have greater Q- angles than men, which could force women to land with greater peak medial knee forces. Out of the 14 participants in this study, 6 were women, with 2 in the FAS group and 4 in the FAI group. This could have predisposed the participants to greater medial knee forces. Inhibited proprioception, which has been linked with FAI, may have caused participants in the FAI group to land with greater medial knee forces because they were not sure of their joint position at landing. They may have compensated by erring on the medial side.

Significant differences were also found in ankle abduction moments between the two groups (FAS (m = 112.16, sd = 63.91) FAI (m = 71.20, sd = 55.30). Those with FAI landed with a lower abduction (or eversion) moments than those with FAS. The lower eversion moments may predispose the FAI to another inversion ankle sprain. Those with FAI may have chronic symptoms after the ankle injury has healed.[7, 11-14] Some of the symptoms include slowed reflex response time of the peroneals,[15] slowing of the tibialis anterior muscles to sudden plantar flexion and inversion stress [16] and inadequate ability to detect movement compared to those with FAS.[17]

Other clinically notable results included measures of peak anterior ankle forces, peak anterior knee forces, peak ankle dorsiflexion moments, and peak knee flexor moments. Compared to the no stabilizer control condition, the peak anterior ankle joint forces in the Mueller brace condition increased in the FAI group more than the stabilizers in the FAS group (FAI: brace +104.85N, tape +79.68N, FAS: brace +31.94N, and tape -

75.96N). This would suggest that the Mueller Brace did not seem to be effective in limiting peak anterior joint forces. In the taped condition, peak anterior ankle forces were lowered in the FAS group but much higher in the FAI group. The stabilizers decreased peak knee anterior joint forces in the FAS group more than the stabilizers in the FAI group (FAS: brace -49.45N, tape -80.66N; FAI: brace -11.90N, tape +4.43N) as compared to the no stabilizer condition. This would suggest that those with FAI may not benefit from using a stabilizer. The stabilizers decreased peak ankle flexion moments (Nm) in the FAS group to a greater degree than in the FAI group (FAS: brace -64.42, tape -61.97; FAI: brace -8.93, tape -12.32) as compared to the no stabilizer condition. This would suggest that the brace and tape benefited both the FAS and FAI groups in the reduction of ankle dorsiflexion moments. Again, however, the greater effect was seen in the FAS group. The stabilizers decreased peak knee flexion moments in the FAS group; but in the FAI group the Mueller brace increased peak knee flexion moments and the tape decreased these moments as compared to the no stabilizer condition (FAS brace -19.55Nm, tape -15.82Nm; FAI brace +.98, tape -20.69Nm). This would suggest that the Mueller brace and tape was effective for the FAS group. However in the FAI group the Mueller brace did not make a difference between the braced condition and the no stabilizer condition.

We found significant differences in medial ankle and knee forces and ankle abduction moments between the two groups regardless of the stabilizer being used. Athletic trainers, physicians, coaches, and athletes need to be aware of the risk involved in having FAI. Therefore, it is recommended that improved strength and rehabilitation could also be beneficial to those experiencing FAI.

References:

1. Fink B, Mizel MS. Specialty Update: What's New in Foot and Ankle Surgery. *The Journal of Bone & Joint Surgery*, 2001; 83(5): 791.

2. Lynch SA, Renstrom PAFH. Treatment of Acute Lateral Ankle Ligament Rupture in the Athlete: Conservative Versus Surgical Treatment. *Sports Medicine*, 1999; 27(1): 61.

3. Thonnard JL, Bragard D, Willens PA, Plaghki, L. Stability of the braced ankle. A Biomechanical Investigation. *American Journal of Sports Medicine,* 1996; 24(3): 356.

4. Hubbard TJ, Kaminski TW. Kinesthesia is not affected by chronic ankle instability status. *Journal of Athletic Training*, 2002; 37(4): 481-486.

5. McCaw S, Cerullo J. Prophylactic ankle stabilizers affect ankle joint kinematics during drop landings. *Medicine & Science in Sports & Exercise,* 1999; 31(5): 702-707.

6. Hopper DM, McNair P, Elliott BC. Landing in netball: effects of taping and bracing the ankle. *Br J Sports Med.* 1999; 33: 409-413.

7. Hartsell HD, Spaulding SJ. Effectiveness of external orthotic support on passive soft tissue resistance of the chronically unstable ankle. *Foot Ankle Int.* 1997; 18: 144-150.

8. Prentice WE. *Arnhiem's Principles of Athletic Training (11th ed.).* St. Louis, MO: Times Mirror/ Mosby; 2003; 1514.

9. Caulfield B, Garrett M. Changes in ground reaction force during jump

landing in subjects with functional instability of the ankle joint. *Clinical Biomechanics*, 2004; 19: 617-621.

10. Konradsen L. Factors contributing to chronic ankle instability: kinesthesia and joint position sense. *Journal of Athletic Training*, 2002; 37: 381-385.

11. Garrick JC. The frequency of injury, mechanism of injury and epidemiology of ankle sprains. *Am. J. Sports Med*,1977; 5: 241-242.

12. DeMaio M, Paine R, Drez Jr D. Chronic lateral ankle instability- inversion sprains: part II. *Sprts Med. Rehabil. Ser.* 1992; 15: 241-248.

13. Freeman MA. Instability of the foot after injuries to the lateral ligament of the ankle. *J Bone Joint Surg Br.* 1965; 47: 669-677.

14. Hartsell HD. The effects of external bracing on joint position sense awareness for the chronically unstable ankle. *J. Sports Rehabil.* 2000; 19: 279-289.

15. Mattson E, Brostrom LA. The increase in energy cost of walking an immobilized knee or an unstable ankle. *Scand. J. Rehabil. Med.* 1990; 22: 51-53.

16. Ebig M, Lephart SM, Burdett RG. The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. *J Orthop. Sports Phys. Ther.* 1997; 26: 73-77.

17. Forkin DM, Koczur C, Battle R, Newton RA. Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. *J Orthop Sports Phys Ther.* 1996; 23: 245-250.