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Prophylactic Use of the Closed Basket Weave Ankle Taping and Its Effects on Kinetics and Kinematics in the Lower Extremity

Matthew L. Santos-Vitorino

BARRY UNIVERSITY

SCHOOL OF HUMAN PERFORMANCE AND LEISURE SCIENCES

PROPHYLACTIC USE OF THE CLOSED BASKET WEAVE ANKLE TAPING AND ITS EFFECTS ON KINETICS AND KINEMATICS IN THE LOWER EXTREMITY

BY

Matthew L. Santos-Vitorino ATC, LAT

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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Matthew L. Santos-Vitorino entitled "Prophylactic use of the closed basket weave ankle taping and its effects on the kinetics and kinematics in the lower extremity." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Injury Sport Biomechanics and specialization in Athletic Training.

Dr. Sue Shapiro, Thesis Committee Chair

We, members of the thesis committee,
have examined this thesis
and recommend its acceptance:

Accepted:

Chair of Department of Sport and Exercise Sciences

Accepted:

Dean of School of Human Performance and Leisure Sciences

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Best wishes & God bless
Matthew L Santos-Vitorino ATC LAT

ABSTRACT

The purpose of this study was to determine if the closed basket weave ankle taping affected the kinematics and kinetics of the lower extremity in college athletes. This study also examined the different effects that the taping application had between men and women. 20 athletes participated in this study, and 19 had usable data for analyzing. Each participant who took part in the study performed a specified jumping maneuver while taped as well as un taped. The jumping maneuver was performed in a biomechanics laboratory that was equipped with forces plates and a Vicon motion analysis system. A repeated measures MANOVA was performed to determine statistical significance for both conditions. Results indicate that the application of ankle tape significantly decreased plantar flexion and dorsiflexion ($p<0.001$). Results also show that the application of tape significantly decreased the time to peak vertical ground reaction force ($p<0.05$). Lastly, results showed that due to the application of tape, men had to significantly increase the amount of knee range of motion during landing ($p<0.05$). Using the information provided by the results and linking it with previous research and muscle length-power relationship theory's can be formed which explain the changes that took place due to the taping application. Primarily, the idea that when range of motion is restricted the muscle involved with force absorption cannot work as designed, thus forces are transferred to other structures of the lower extremity. Though this theory seems most sound the results from the study do not support this claim leading to other means of explanation. Further examination of the data collected from each participant showed vast differences with the affects the application of ankle tape had on the many kinetic and kinematic variables of the lower

extremity. This fact ultimately shows that each participant is different and their accommodations to the taping application are specific to them and each of there individual needs, therefore no generalizable statements can be formed from the data provided which explains for the lack of uniform change.

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CHAPTER 1

INTRODUCTION

Ankle sprains are one of the most common injuries in sports. To combat this problem standard practice by most sports medicine clinicians is to either tape or brace the joint.[1] These forms of restrictive devices serve to decrease range of motion to lessen the risk of further injury. [1] The ankle taping system, as well as decreasing range of motion, has an effect on overall ankle proprioception.[2] The general consensus is that ankle injuries reoccur due to the loss of proprioception caused by initial injury.[2] Previous studies have concluded that limiting range of motion has no effect on athletes without previous medical history of ankle sprains and with these individuals who have a history of ankle instability.[3] But what effect does a decreased ankle range of motion due to active ankle taping have on any individuals performance? A study conducted at the University of Lethbridge suggested that increased lengthening of the muscle prior to explosive movement will assist in generating a larger amount of velocity.[4] In other words, increased range of motion does affect a joint's ability to generate force.

A study of literature on ankle sprains reported that taping and bracing lowered the occurrence of re-injury only when combined with an ankle strengthening program. The same study also found that decreased muscle strength left the athlete susceptible to ankle sprain due to the inability to pull the foot out of forced eversion and plantar flexion, the more common position of the foot when sprained.[5] Long standing literature does tell us that a joint that is immobile will have its surrounding musculature suffer from atrophy and decreases in propripoception.[6] Wolfs law states that a tissue will only adapt to the forces placed on it.[8] In terms of healing this means that the injured ankle ligaments and musculature will only get as strong as it needs to due to relying on the tape. On that same note, the musculature of the ankle will decrease in ability for the same reason; the ankle tape gives the body sense of false protection; therefore, the body will begin to do less and less depending on the situation as long as it has the ankle taping applied.

The human body, in terms of muscular contractions, follows a simple principle that power and muscular ability is related to tissue length.[3,4] This principle is evident in athletics and every day life alike. In the case of the lower extremity, this principle conveys that in order to produce the necessary amount of muscular force as well as absorb reactive forces from everyday life the body must be able to achieve a full range of motion. Ankle taping, which reduces range of motion impedes the body's natural kinematics. Seen in other body segments, when one joint is disabled or restricted, the body's available musculature takes on compensatory roles, therefore still producing the same end product in terms of force.

To review, it can be said that ankle sprains have always been and still are treated with ankle taping. We can also deduce that taping is a form of immobilization. But if we look at the effects of immobilization we can see that they are in fact opposite of the gains needed to both correct and prevent ankle injury. These protocols of taping and bracing have been used for many years because no study has been performed that associates the amount of power and proprioception an ankle has with a complete ankle taping on and off. If there were data that showed taping decreases ankle force, range of motion, proprioception , and velocity maybe that could be used to convey the idea that preventing injury with taping is a fallacy because, in fact, it is hindering all the natural properties of the joint itself.

STATEMENT OF PROBLEM

There is insufficient data showing the effects of a closed basket weave ankle taping on the kinetics and kinematics of the lower extremity. Many studies have focused on single aspects of kinetics or kinematics in the lower extremity or on one single joint alone, but little current data with the use of modern day technology has shown the need for ankle taping on the kinetic or kinematic level.

PURPOSE OF STUDY

The purpose of this study is to investigate the effects that prophylactic ankle taping has on the talocrural joint in terms of range of motion, force produced, and ground reaction force absorbed. This study will also investigate the effects ankle taping has on kinetic and kinematics of the lower extremity.

HYPOTHYSES

1. A closed basket weave ankle taping will significantly decrease the force production and range of motion of at ankle at the talocrural joint in plantar flexion and dorsi flexion compared to no taping.

2. A closed basket weave ankle taping will significantly increase the ground reaction force sustained by the lower extremity following a jumping and landing compared to no taping.

3. A closed basket weave ankle taping will significantly change the lower extremity moments in the human body during a jumping and landing in the sagittal plane.

4. A closed basket weave ankle taping will significantly decrease the plantar flexion-dorsi flexion moment of the ankle during landing following a jump.

5. The closed basket weave ankle taping will significantly decrease the amount of time to peak ground reaction force sustained following landing from a jump.

VARIABLES

Independent variables:

1. The closed basket weave basket taping condition

Dependent Variables:

1. The degree of range of motion performed at the talocrural joint measured by a goniometer
2. The amount of global force produced by the participant in the vertical direction.
3. The total amount of ground reaction force by the participant
4. The amount of compressive force at the talocrural joint in the vertical direction
5. The amount of compressive force at the tibiofemoral joint in the vertical direction.
6. The amount of compressive force at the acetabulofemoral joint in the vertical direction.
7. The joint moment at the talocrural joint in the sagittal plane.
8. The joint moment at the tibiofemoral joint in the sagittal plane during landing.
9. The joint moment at the acetabulofemoral joint in the sagittal plane during landing.

10. The functional range of motion at the tibiofemoral joint in the sagittal plane during landing and jumping.

11. The functional range of motion at the acetabulofemoral joint in the sagittal plane during landing and jumping.

12. The time to peak ground reaction force during a landing.

Control Variables:

1. Participant will all be currently involved in a collegiate soccer program.
2. All participants are free from ankle injury in the past 6 months. If ankle injury was sustained within six months, participation in the study is dependent on the primary researchers evaluation of previous medical history.

OPERATING DEFINITIONS

Active Range of Motion: joint motion that occurs from muscle contraction.[6]

Closed basket weave ankle taping (Gibney taping): is a technique that offers strong tape support and is primarily used in athletic training for newly sprained or chronically weak ankles.[6]

Coach Tape: (non elastic adhesive tape), is a tape that has great adaptability for use in sports because of its uniform adhesive mass, adhering qualities, lightness, and its strong backing materials.[6]

Dorsiflexion: bending toward the dorsum or rear, opposite of plantar flexion.[6]

Force: a product of mass times acceleration.[7]

Functional Range of Motion: the range of motion performed at a joint during a specific movement.

Goniometer: a device that can be used to measure joint angles and ranges of motion.[6]

Impulse : a change in momentum[7]

Moment: the tendency of force to produce rotation around an axis

Plantar flexion: bending in the plantar direction, opposite of dorsiflexion.[6]

Power: the end kinetic result of when work is divided by time.[20]

SAID principle: when the body is subjected to stresses and overloads of varying intensities, it will gradually adapt over time to overcome whatever demands are placed on it.[6]

Wolf's Law: states that both bone and soft tissue will respond to the demands placed upon them.[8]

Work: is the product of the force exerted on an object and the distance the object moves in the direction the force was applied.[20]

ASSUMPTIONS

1. It is assumed that the force plate, computer software, and statistical analysis programs are valid and reliable.

2. It is assumed that every ankle taping contains the same pieces and is performed according to standard protocols.

3. It is assumed that all reflective markers are place in accordance with the Vicon operating guide.

4. It is assumed that each participant will give the maximal and equal amount of effort each time while conducting the actions of this study.

LIMITATIONS

Limitations of this study include:

1. Participants are not able to perform given task
2. Participants do not complete the given task to their full capability
3. Participants were not excluded if they had a functional ankle instability
4. Participants were not excluded if they are current users of ankle taping.

DELIMITATIONS

1. The study design only used Division II soccer players from a southeastern Florida university.
2. This study design did not regulate physical activity or diet of the participants days prior to testing.
3. Limited to soccer player without ankle injury for 6 months.

SIGNIFICANCE OF STUDY

For years proper protocols have been to immobilize the ankle for a period of time after an ankle sprain. Many sports medicine clinicians use the ankle taping as a preventative measure with the idea that the decreased range of motion will prevent ankle instability due to eversion or inversion forces.

As recent studies show, immobilization of any joint leads to decreased muscular size, strength, and proprioception. Research also shows muscle with a full range of motion can produce a greater level of strength in terms of concentric and eccentric muscular activity. All of these studies indicate that ankle taping as a preventative measure will actually make the ankle more likely to become injured.

As allied health professionals begin to learn more and more from research, a large emphasis has been placed on the notion of evidence based medicine. In terms of athletic training and this study, a profound amount of time and money is spent on taping. With taping being such a common practice and one that is a foundation of athletic training the allied health community needs to know and understand if this classic practice is actually necessary and beneficial to athletes and athletic performance.

This study will investigate if ankle taping allows the ankle to produce a decreased amount of force, sustain a greater amount of ground reaction force, and shows differences in range of motion. This study will also show the muscular activity and impulse differences amongst the taped and untapped trials. This information is important to the sports medicine community for many reasons. Primarily, there may be negative effects of ankle taping as a preventative measure for ankle sprains that have not yet been analyzed and quantified in research. Secondarily, to show how the use of ankle taping may affect the global functions of the human body including range of motion, force production impulses, landing impulses, lower extremity joint moments and lower extremity joint loading.

CHAPTER 2

LITERATURE REVIEW

The purpose of this research study is to investigate whether the closed basket weave ankle taping decreases the degree of range of motion at the ankle and alters the amount of force that can be generated and absorbed at the ankle by the lower leg musculature.

The ankle is one of the most injured and manipulated joints commonly associated with athletics.[1-5,10] Ankle sprains make up between 10%-30% of all musculoskeletal injuries, 85% of all sprains, and 50% of all foot and ankle injuries.[3,10] Over the years many steps have been taken to fine tune how the modern day sports medicine clinician not only treats for these injuries, but helps to prevent them from accruing and reoccurring. Many studies through out the past 100 years have analyzed the different aspects surrounding ankle taping and how it affects the body's mechanics and performance.[1-3,9-11] Ankle taping is by far the most used device to combat ankle injuries.[1] Whether to treat acutely or as a prophylactic, ankle taping is the most efficient way to reduce the ankle's overall ranges of motion.[9] Though ankle dorsi-flexion and plantar-flexion are not directly linked with the vulnerability of the ankle, eversion and inversion in combination with the two frontal plane motions due increase the risk of injury.[5] Early studies of the ankle taping system looked at simple and more general things like: range of motion, speed, and performance.[1,2,4,5,9,10] More recent studies have moved to kinetics, kinematics, and the overall movements of the body's segments and how they work in relation to one another.[11] When analyzing the role of ankle taping, kinetics, and kinematics previous literature and information can be categorized so that understanding the subject material is clearer.

Ankle anatomy

The ankle, as described by Starkey and Ryan, is the junction of the distal tibia, fibula and the talus.[12] This articulation, known as the talocrural joint, or more commonly called the mortise, is held together superiorly by a syndesmosis joint between the tibia and fibula.[12] Beneath the talus lies the sub-talar joint, which is held together laterally by the calcaneal fibular ligament. Medially the subtalar joint is supported by the tibiocalcaneal ligament which is a part of the deltoid ligament complex.[12] In terms of musculature, the anterior of the lower leg is made up primarily of the tibialis anterior muscle which acts as a dorsi-flexor at the talocrural joint.[7,12] The posterior of the lower leg is comprised primarily of the gastroc-soleus complex.[7,12] The gastroc-soleus complex is made up of the gastronomes and soleus muscles, both are responsible for plantar flexion of the foot at the talocrural joint.[7,12] Lateral muscles of the lower leg include the three peroneals, which are in charge of eversion.[7,12] Lastly, the muscles that effect the ankle medially are found deep on the posterior aspect of the lower leg; these muscles are responsible for inversion of the foot at the sub-talar joint.[7,12] Though the muscles that control the motions of the lower leg are strong and can be trained to generate large amounts of force the dynamic stability of the talocrural joint is supported by only tendons and the subtalar joint by only two ligaments, compared to the five ligaments that support the talocrural joint. This anatomical arrangement leaves the two joints of the ankle complex at risk.

Previous knowledge and past studies

Many past studies have examined aspects of ankle taping and its relationship to range of motion, reaction time, and postural stability. A study out of the University of Wisconsin[13] examined muscle latencies during unexpected inversion stress. In this study, participants were placed upon an apparatus which at any given time had one side drop so the ankle could be inverted. Electromyography was used to read reaction time and level of activity. This study found that muscle latencies were not affected by bracing. This is important because this study examined bracing which is an application that is less often used,[1,2,10] and is proven to restrict range of motion less than taping.[6,9,10]This was a well-developed study to examine one of the stressors of ankle sprains. One study by DiStefano et al[14] examined ground reaction force after forced dorsi-flexion, then again after maximal plantar-flexion, while the participants were braced. This study is more relevant to the outside world because it looked at forces generated during plantar flexion, a motion predominantly used in athletics for power and locomotion. Distefino et al concluded that when the ankle is braced the landing ground reaction force increases.[14] An explanation for this data, not discussed in the study, could lead clinicians to believe in many different causes for this change. One obvious reason for the increase in ground reaction force during landing could be that the prophylactic ankle brace affected body kinematics so much that the new joint positioning could not allow the body to control the deceleration of the landing. Another explanation for the changes in ground reaction force in combination with the effects of kinematics could be an overall effect of the ankles inhibited range of motion. As stated in the introduction, the body depends on a full uninhibited range of motion to achieve maximal concentric and eccentric force.

More studies have been conducted using similar apparatuses like the one in the study at the University of Wisconsin. Ricard et al[1] studied the ankle to determine the role of tape on dynamic ankle inversion. They concluded that there was no significant difference between reactive muscle activity at the ankle joint, whether the joint was taped or not. An older study, from 1997, by Pederson et al[15] performed the same experiment except this time participants were taped and spatted (taping on top of footwear). This time results showed that there was significant difference between the rate of inversion with taping rather than no significance between taping and muscular activity. All previous studies reviewed were performed in controlled settings and the performed actions were somewhat uncharacteristic to those that could be performed in athletic situations. Riemann et al[16] tested the integrity of the ankle taping against force and performance. The study took a group of participants and tested their ground reaction force. The researchers then placed ankle tapings on them. Next, initial ground reaction force was measured using a force plate. The participants then ran on a treadmill for 20 minutes, and after running the ground reaction force was tested again. The study found that ankle tapings decreased the amount of time it took to reach peak force, as well as the fact that after 20 minutes the ankle tapings allowed faster force. They concluded that further research is needed to measure if this effect is detrimental over time. In each study described above a piece of knowledge or variable was missing, the knowledge of which could answer more questions about ankle taping.

This proposed study sets out to investigate the maximal initial force that can be generated and absorbed by the human body at the talocrural joint when an ankle taping is used. This study will examine the moments and forces at the tibiofemoral joint and the acetabulofemoral joint when a closed basket weave taping is in use. Previous studies have examined most of the ideas around force and ankle taping, but they have gone about it in a different way. This study will focus on the range of motion, forces generated, and forces sustained. This study will also look at the relationship of joint moments and if they differ when a closed basket weave ankle taping is applied. These focuses will be tested using similar instrumentation as previous studies. For range of motion, the use of a Goniometer[6] will be most suitable. As for the kinetic and kinematic data, a combination of previous methods will be used to look at force from many perspectives, rather than from one or two, as in previous studies.

Purpose of ankle taping

Ankle taping is a technique used by sports medicine clinicians. Allied health professionals utilize multiple taping methods on athletes and patients based on the needs of the patient and objectives of the professional.[10] The application of tape is determined by the clinician and decided by personal preference and experience.[10] The primary objective of ankle taping is to decrease the active range of motion allowed at the talocrural and subtalar joint.[1,6,11] With the decreased range of motion there is additional stability given to the patient that is going to allow for less opportunity for the weakened muscles and ligaments at the assigned joints to improperly function. The ankle taping can be used acutely after injury to stabilize the joint, add compression, and control edema.[6,10] After acute injury the use of ankle taping successfully keeps the talocrural joint in line and allows for a decreased of likelihood of further damage. Ankle taping after acute injury in terms of edema reduction and prevention is sustained due to the compressive nature of the taping application.[6] Ankle taping can be used for chronic instability to again, decrease range of motion, and for the most part, heighten one's level of proprioception[10]. However one study by Refshauge et al, concluded that taping did not improve proprioceptive acuity in a population that suffers from chronic inversion ankle sprains.[2] Long term use of ankle taping following injury is used to decrease the risk of reinjury by not allowing the ankle to move in to a range of motion that is unstable. Although ankle taping does improve mechanical stability, evidence shows a vast decrease in effectiveness on restriction of range of motion of unspecified bouts of exercise.[10] This inability to maintain function and mechanical stability during an extended period of exercise raises fundamental questions about the efficiency and efficacy of taping.[10] Ultimately, the purpose of ankle taping is to decrease range of motion and eliminate the abnormal or extensive movements that could ultimately lead to ankle injury or joint vulnerability.

The closed basket weave taping

The closed basket weave taping offers strong support and is primarily used for acutely sprained ankles and chronically weak ankles.[6] The closed basket weave is made up of different components which are applied to the skin respectively: anchors, horseshoes, stirrups, heel locks, figure 8's, and closing strips. Each component is designed to restrict a certain range of motion and/or apply a force to redirect the posture of the foot.[6] This method of ankle taping is the most common method used through out past studies. The closed basketweave ankle taping, commonly referred to as the Gibney basketweave technique, is the ankle taping technique taught and standardized at the university level.[2,6] The Gibney basketweave technique has been shown to be the best suited taping application due to its interwoven components which cover the hind foot and extend proximally on both the lateral and medial aspects of the lower leg.[11]

Effects of ankle taping on range of motion

All literature regarding ankle taping and range of motion agrees on one thing, that range of motion is decreased to an extent. [1,2,4,5,9,10] The issue that arises is how effective the taping is in terms of keeping initial integrity. Wilkerson stated that taping clearly looses some effectiveness after a certain amount of time, but still maintains a significant restraint on motion.[11] A further investigation by Paris et al examined the rate of breakdown in the ankle taping and at given amounts of time how much decreased range of motion still exsisted.[9] At the conclusion of their studies these researchers still determined that ankle taping limited range of motion more than commercial braces. Using the study by Paris et al[9] and the normal degrees of active range of motion from Thompson and Floyd[7], ankle taping limits range of motion for the following; plantar-flexion 51.2%, dorsi-flexion 7%, eversion 32%, and inversion 31%. Several factors have been suggested to affect the restrictive ability of the ankle taping: perspiration, skin mobility, the use of prewrap, adherent spray, and the taping technique it self all can affect the overall effectiveness of the ankle tape.[1]

Effects of ankle tape on force and muscular activity

Many studies have examined the effects of ankle taping and muscular activity in different ways. For the most part, these studies have looked at the musculature involved when the ankle is being inverted,[1,2,15] or entire lower extremity kinematics in a jumping task. [9,14] The study by Wilkstrom et al[17] used jumping tasks and single leg stances to test ankle bracing and postural stability. They concluded that braces did not enhance postural stability. Also in their article they assigned the responsibility of joint stabilization to the lower leg musculature. In the study by DiStefano et al,[14] it was concluded that ankle braces did not effect immediate force production at the ankle. But as previously reported, ankle braces do not limit the range of motion as much as taping the ankle.[9] The inversion focused studies concluded that muscle reaction time by stabilizing muscles was not affected by tape,[13] and the rate of ankle inversion was not affected by tape,[1,15] but all did determine that tape limited ranges of motion.[1,9,13,15] Most studies which discuss the effects of taping and muscle activation use electromyography to measure activity during contraction. Lohrer et al concluded that ankle taping caused a reduction in the angular velocity at the talocrural joint. This combined with a restricted displacement amplitude permitted greater peroneal activation per degree of range of motion. Essentially, Lohrer shows that a decreased range of motion caused by the taping application forces the body to contract at a greater rate per second due to the lack of distributed power production.[11] A similar study Konradsen et al reported a 50-65 millisecond delay between the initiation of inversion and onset of peroneal muscle activity. Like similar studies on the rate of peroneal muscle firing when the ankle is suddenly inverted, Konradsen found that the ankle taping application increased muscle latencies.[11]

Muscle length and power relationship

The idea that force is related to length of a muscle has been discussed for many years.[18] The first studies regarding these ideas started over 100 years ago when scientist proved that muscle length was key in determining maximum isometric power.[18] A more recent study in June, 2008 by Ruiter et al,[19] concluded that the force produced in concentric contractions was not as high when compared to isometric contraction. Instead it depends on the length of the muscle and which area of fibers were being used. The background of the muscle length and power relationship begins in the sarcomere. [18] The sarcomere is the smallest part of the muscle fiber, and is what actually moves during a muscle contraction.. The force generated by a muscle is due to the number of cross bridges that can be formed.[18] As a muscle lengthens, before over lengthening, there is a point where maximal cross bridge attachments can be had. Ideally, this is where the greatest amount of power can be generated. In addition to the concentric forces muscles produce, research shows that eccentric muscle function is crucial for producing shock-absorbing and energy efficient movements. These eccentric muscle contractions add stability and protection for the motions of human movement.[21] There is an inverse relationship between the force on a muscle and the velocity in which that muscle can be shortened. [22] In most behaviors involving muscle activity, the involved muscles spend just as much time lengthening as they do shortening.[22] This implies that a muscle will accommodate external sources evenly though out time. There is an overwhelming amount of research that focuses on these force-velocity properties of a shorting muscles, but little data has been complied for the force-velocity properties when a muscle is lengthening, as seen in an eccentric contraction.[22] Another attribute of muscle force production in combination with length dependency is the capacity to develop tension following active shortening.[22] The reduced ability for the muscle to develop force once shortened is often referred to as shortening deactivation. When a muscle is limited, and forced to be activated in a pre-shortened position the amplitude of muscle contraction is less than if it was contracting from a more lengthened position.[22]

Limiting range of motion and its effects on joints

In addition to studies performed on the ankle, many researchers have examined the effects of prophylactic bracing to other joints of the body. Another lower extremity joint often braced and studied is the knee. Similar to the ankle, the knee's ability to function correctly is based on range of motion and body kinematics. One study which examined lateral knee bracing and its effectiveness to prevent knee ligament injuries found that when knee bracing is found to be effective it drastically eliminates the joints ability to move through a range of motion freely. This inability to move through a range of motion freely, though maintaining integrity of the knee joints ligaments left many other knee functions and structures prone to injury. These adverse effects include; MCL loading with no elongation, joint axis shifting, non-congruent joint line contact, and slippage of the brace due to external forces.[23] These adverse effects result in affected lower limb kinematics.

Most knee studies had a purpose which dealt with bracing and ligamentous damage, but one study found focused on muscle activity. This study, which examined knee bracing and the effect on running gait showed that a braced knee showed significant changes in EMG activity for 9 of the 15 muscles that effect the knee in over 70% of the trials.[24] In both of the above examples of knee brace related studies, evidence showed that prophylactic knee braces significantly effects joint kinematics and muscle activity. This study is a good example of how limiting range of motion effects muscle activity. It is possible that similar effects may be seen when the ankle is restricted as well.

Previous studies do not focus on the global effects of ankle taping. Studies on ankle biomechanics in more recent years have increased in the research community. Studies that examine global effects of bracing usually targeted the knee and showed that there are compensatory and adverse effects at other joints.[23,24,25] One study out of the University of Indiana sought out to find how ankle braces might affect other joints in the lower extremity. These researchers found that kinematic studies of the past showed significant restrictions on ankle dorsi flexion and plantar flexion during landing, two motions crucial in natural landing kinematics.[25] When this researcher examined the effects at the knee when subjects ankles were braced he found that there were increased joint torques due to bracing, as well as increased internal and external rotational torques at the knee.[25] The study concluded that reduced motion at the ankle kept the lower leg in a fixed position during activity. This restricted state caused a stiff and more rigid landing which amplified joint torques to the next proximal joint.[25]

Range of motion on global muscular performance

Many studies, including the ones previously discussed in this chapter, focus on a specific form of restricted range of motion and/or effects of joint bracing. Current literature using modern testing protocols has examined the importance that range of motion has on the entire lower extremity when not inhibited by injury or an apparatus. Moran and Wallace looked at eccentric loading and range of motion at the knee in terms of athletic performance with no limiting devices. This study was used to find the different effects that jump variations had on the joint moments and ranges of motion for the entire lower extremity. The reasoning for this was to evaluate the effectiveness of certain jumps as testing criteria, given that the vertical jump is often a testing standard in research. The study found that joint loads and forces range greatly due most in part to varying lower extremity joint ranges of motion.[26] Moran and Wallace also noted, like previous literature in this chapter, that an increase in a joints range of motion may facilitate a greater amount of mechanical work, and a decrease would limit the amount of mechanical work.[26] After their study was concluded, Moran and Wallace found that jump types that allowed a greater amount of range of motion also had the greatest amount of eccentric loading and force production.[26] This study, with out the use of a limiting device, showed the practical reasoning for need of full ranges of motion at a specific joint.[26]

As for studies that examined the global effects that ankle bracing has on the human body, one study published in Clinical Biomechanics examined the effects of ankle bracing on motion of the knee and hip during a functional movement.[27] The aim of this research team was to see if the data supporting or refuting the use of prophylactic ankle supports was justified when applied to a functional movement. Just as in all other cited studies, there were significant effects on the subjects' knee and hip rotations. The more note worthy finding was that the use of an ankle brace caused the subjects to change there typical movement patterns to accommodate for loss of ankle rotation, a combination of sagittal plane movements with frontal plane movments.[27] This in turn, causes global adaptations in the torso and upper limbs.[27] This information shows that limiting range of motion has a systemic effect on the body and that in order to maintain function and performance less active muscles and joints must increase their level of involvement.

Ground reaction force and landing

Ground reaction force as described by Hamil and Knutzen, is the reaction force provided by the surface upon which someone is moving.[28] This force is sent through the body and by way of eccentric muscle contraction is absorbed and distributed.[18-22] When added to the theories of muscle length- power and shortening deactivation, a better understanding of ground reaction force is found. Ground reaction force received by the body when a person is landing or muscles are eccentrically contracted is significantly affected due to the change in range of motion. The amount of ground reaction force that can be absorbed through out a movement is dependent on the joint moment, a decreased range of motion may produce a decreased amount of contraction time, thus increasing the loading rate placed on the existing muscle. Researchers found that ground reaction force was higher in taped ankles during landing than in untaped ankles.[29] These researchers concluded that the increase in ground reaction force was due to the decrease in time from initial muscle contraction to peak value.[29] This team also noted that the most likely cause for this change was that the range of motion of eccentric muscles of the lower leg, which control landing, were fixed due to the tape.[29] Other studies which examined the effects of ankle taping or bracing and ground reaction force found similar findings, but very few provided further research. One study that found that there was no change in ground reaction force did go on to say that there was increased flexion at the knee during landing to compensate for the loss of range of motion at the ankle.[14] This same study concluded that the use of a prophylactic ankle device caused compensatory movement patterns.[14] Two studies, which are referenced often in more current literature show that ground reaction force has no significant negative effect when the ankles are taped or braced.[30,31] These studies also examined EMG activity in the lower limb and one of these studies showed a change in EMG activity between the testing groups.[30] Both of these studies concluded that further research was necessary to further understand the role restricted range of motion has on ground reaction forces. These two studies were conducted in the mid 1990's and since then more current and reliable studies have been performed to challenge these findings.

Recent awareness of bracing/taping negatives

As more research is done with newer equipment and more functional testing protocols, results are beginning to show negative trends for the use of restrictive devices at the ankle.[16,25,27,32] This exposure of new data is even seen in the non-research community. Dr. Philip Wagnar of the Palo Alto Daily News published a story in march of 2009 stating the need to be less dependent on the use of ankle braces in children due to the increased risk of injury at the knee.[33] To prove his claim was reputable, Dr.

Wagnar cited studies printed in the Journal of Athletic training, to show that a population of medical professionals such as athletic trainers who long have supported the use of ankle braces have now began to examine there own practices. This article was published to produce the public awareness of the potentially harmful effects ankle bracing has on the athletic population.[33]

Summary

Ankle injuries and the methods to prevent their reoccurrence is one of the most studied and continually improved focuses in sports medicine. Much has been done to study the effects of taping and bracing on the ankle kinetics and kinematics, and as technology has improved, so have the ways of examining the effects of ankle taping. Ankle taping serves several purposes, but mainly the limitation of one's range of motion is most important. Ankle taping limits range of motion of the talocrural and sub-talar joint for the following: plantar-flexion 51.2%, dorsi-flexion 7%, eversion 32%, and inversion 31%. This decreased range of motion alters the human body's natural kinematics; therefore, it can be deduced that to maintain normal movements other muscle and joints must take on compensatory roles. Previous studies have looked at the body's way of adapting to ankle taping and determined many things. It is known that initial ankle taping limits range of motion more than any other brace tested.

One study, concluded that ankle braces did not affect the force provided at the ankle when compared to a pre non-wearing brace test. Those authors used a brace that did not limit the range of motion as much as an ankle taping, so a perfect cross over of information cannot be made. As described by Ruiter et al,[19] there is a muscle length and power relationship. The exact specifications are disputed and argued over but, nevertheless, there is a direct correlation between the two. Ankle taping limits range of motion, and a full range of motion is needed to allow the muscle to reach its natural end ranges, produce maximum force and power, and sustain normal reactive forces.[6,7,18,19,21] Finally, the use of ankle bracing or taping has significant altering and negative effects on the knee and hip and can therefore force compensation and increased risk of injury for the remaining joints in the lower extremity.[22-27]

CHAPTER 3

METHODS

Participants

Participants of this study will consist of male and female soccer players from a southeastern Florida university. Participants for this study will be recruited by word of mouth. This study is entirely voluntary, and no one will be coerced into participating in this study against their will. Refusal to participate in the study or early withdrawal from the study will not affect the social status or attitudes toward the prospective participants in any way. Prospective participants must be free of ankle injury with in 6 months and be able to perform the following actions without any sign of struggle or discomfort: five minute jog at 3 miles per hour, jumping from a predetermined landmark, landing on to the floor after jumping. Participants in this study will be asked to report for testing times as assigned by the principal investigator, as well as find their own transportation to and from the testing facility.

Procedures

Participants were given an informed consent form to read and sign. This form provided, in detail, all procedures the participants will be asked to perform, as well as any contact information needed. Once consent was given and documented, participants will report to the Barry University Biomechanics Lab in the school of Human Performance and Leisure Sciences at their assigned times. Participants were asked to wear athletic type clothing. Participants were given a participant identification number and asked their previous level of taping usage and comfort level with ankle taping. Participants were given five minutes to take part in a warm-up. The warm-up was performed on a treadmill at 0 degrees of incline and a speed of 3 miles per hour. When the warm-up is completed, the participant was asked to perform active dorsiflexion and plantar flexion. These ranges of motion were measured and recorded using a goniometer. The goniometer used for this study was a 12-inch Jamar goniometer. A goniometer was used by placing the axis of the goniometer on the lateral maleolus at the inferior pole and the stationary arm along the length of the fibula, pointing towards the fibular head. The movable arm of the goniometer is placed along the length of the foot, parallel with the fifth metatarsal.[34] As the patient moves through a range of motion, the movable arm pivots around the axis staying in line with the fifth metatarsal.

Figure 1. Inferior pole of the Maleolus

Once an end range of motion is reached, the movable arm of the goniometer displays a corresponding range of motion in degrees. These measurements will establish the participant's base line measurements. Measurements will be taken a total of three times for dorsi flexion and plantar flexion, and an average was used when processing data.

Figure 2. Placement of the Goniometer

Next, the participant will be equipped with a series of reflective markers. These markers are placed on top the cloths and skin of the participant in accordance with the marker placement guide provided by the Vicon operating manual. Markers were placed bi-laterally on the participants': anterior superior iliac spine, posterior superior iliac spine, lateral aspect of the thigh, knee joint line, lateral aspect of the lower leg, lateral maleolus, calcaneous, and 2nd metatarsal.

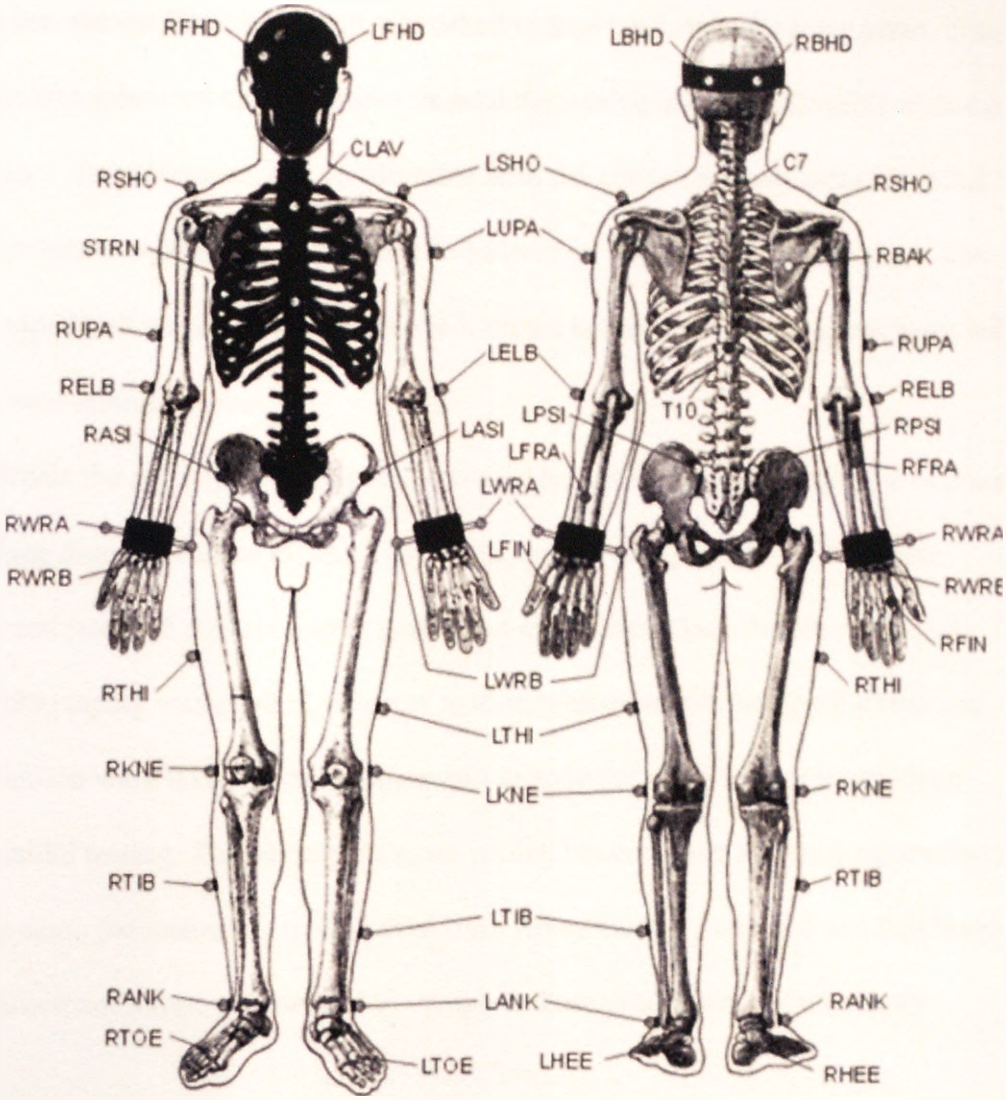

Figure 3. Marker placement sites for lower body

Next, the participants were asked to stand at a pre determined landmark. The participant was instructed to jump onto the floor in front of them which has been equipped with a force plate and land solely on their dominant leg. The participant's dominant leg was pre determined before testing, leg dominance is chosen by asking the participant which leg they feel more powerful during activity. Once contact with the force plate has been made, the participant transitioned the landing and proceed to jumping into the air. The participant was asked to land back onto the force plate. This procedure was practiced up to 10 times or until the participant is comfortable with the action. Once the participant was comfortable with the action the trials were recorded. This procedure was repeated three times so an average for the trails can be used. The order of taped and untapped trials were randomized before testing. The participant will be given two minutes to rest.

While the participant was at rest, a closed basket weave ankle taping was placed on the same dominant ankle in which the initial testing was performed. The same certified and licensed athletic trainer performed all tapings. Once the closed basket weave ankle taping was applied, range of motion measurements for dorsiflexion and plantar flexion were taken using a goniometer exactly the same way as it was done prior to initial testing. The participant again proceed to complete the jumping motion to the exact same parameters as in the initial trial. Approximately one and one half hours of the participant's time was needed to complete these procedures appropriately.

Taping procedure

Application of the closed basket weave ankle taping for this study was performed as follows: the foot was placed on a table in front of the clinician; adherent spray was applied to the distal lower leg, ankle, and foot. Next, pre-wrap was applied from the mid-calf to the base of the fifth metatarsal. Two anchor strips were applied at the mid-calf and another two at the base of the foot. Following the anchor strips, a stirrup strip was placed from the medial aspect to the lateral aspect. Next, a horseshoe strip was applied over the stirrup strip. This process of stirrup followed by a horseshoe, was repeated three times. After the stirrups and horseshoes, two sets of heel locks were applied, alternating the beginning sides. Then, a figure 8 was applied beginning from the medial aspect of the lower leg finishing on the anterior of the lower leg. Lastly, closing strips were applied from the foot end to the calf until complete.

Figure 4. Application Of the Closed Basket Ankle taping

All procedures performed in this study were described for the participants in the consent form. There are no alternative procedures or treatment choices available for the participants other than the ones written. No changes or adaptations will be made to the methods of this study.

Materials used

Taping materials used for this study include: Cramer tuf-skin, Muller heel and lace pads, skin lube, pre-wrap, and 1.5 inch cloth adhesive tape. For testing range of motion a 12-inch Jamar goniometer will be used.

Instrumentation

To measure ground reaction force, an AMTI force plate (Watertown, MA) installed in the floor of the biomechanics lab was used. This force plate is operated simultaneously with a 7 camera Vicon nexus motion capture analysis system (Centennial, CO). The Vicon system data was processed using Vicon nexus (Centennial, CO) software and presented using Vicon Polygon (Centennial, CO).

Validity & Reliability

As previously shown, past studies have examined the relationship between ankle range of motion and force production while taped or braced in many different facets. In the study by Wilkstrom et al,[17] participants were asked to jump on a mat and have there vertical displacement measured. For that specific study, vertical displacement was used as a measure of force. Other studies focusing on force, like DiStefano et al,[14] had their participants jump and land on a force plate which was installed in the floor, and then they had to jump back into the air. This study used a measure of ground reaction force to measure the forces generated at the ankle. In both studies, the participants were asked to perform a vertical jump, and that power output was used to express the force generated by the musculature of the lower extremity.

When assessing range of motion, numerous instruments can be used. The most used instrument to assess range of motion in athletic training as well as one of the easiest, is the goniometer. A goniometer is a tool made of plastic measuring less than 12 inches in length and 5 inches in width. Many studies have sought to validate the goniometer, and many studies have. Gajdosik and Bohannon state that, for the extremities of the body a goniometer is the preferred instrument for measuring range of motion.[35] Another study by Rheault et al, compared a new age fluid based goniometer to the ones tested by Gajdosik and Bohannon. Their study concluded that the universal goniometer previously examined by Gajdosik and Bohannon was still more reliable than the new fluid goniometers.[36] Current texts for the education of athletic training practices also describe the use of the goniometer as being the accepted clinical way of assessing range of motion.[6,34] To maintain intra-tester reliability all procedures using the goniometer measurements will be taken by one single certified athletic trainer.

Data collection & Analysis

The design for this study involves the use of a one group repeated measures. Data will be collected throughout a period of 100 days. Participants will only be required to attend the study on one single day. Data will be entered in pre made data collection sheets and within the Nexus software. Collected data will be processed and analyzed using a one tailed T-test from the SPSS software. Three two-way MANOVA's will be used to find significant differences in the range of motion, impulses, moments and forces between the scores from the pre-test and post-test.

Participant information is noted by a two digit participant identification number. A master roster of the participants' true identities, as well as their corresponding identification numbers will be kept in a locked drawer in the principle investigators' office. For all purposes, this study will use the participant's identification numbers when referring to their given data in written text. Scores will be published in terms of group means. No participant's actual identity will be made public following their participation. Data collected will be shared with the participants if requested. No collected data will be made available to the coaching staffs or athletic departments for any of the participants in the study.

CHAPTER 4

RESULTS

Participants

Of the 20 original participants who signed up for this study, data was successfully collected from 19 (n=19). Participant data was collected over the course of an 8 week period on dates and times conducive to the participants and other participant demographics.

Statistical analysis

This study used a mixed-model, repeated-measures statistical design (MANOVA). This format had two between-subject factors: Gender and comfort level, and one with-in subject factor, taped and not taped. The use of a mixed-model, repeated measures format allows us to compare the differences between the results of the taped and not taped trials within the total participant population as well as between gender.

Due to the fact that only 2 participants (1 male & 1 female), rated themselves comfortable with the application of ankle taping, comfort level was removed from the statistical analysis.

Kinematics – Dorsiflexion and Plantar Flexion

There was no significant interaction between gender and the taped condition on the combined dependent variable of dorsiflexion and plantar flexion: $F(2,16) = .899$, $p > .05$. There was no significant main effect for gender: $F(2,16) = .2154$, $p > .05$. There was a significant main effect for the tape condition: $F(2,16) = 105.55$, $p < .001$.

Follow up univariate tests found significant differences within the taped and not taped groups for both dependant variables. Dorsiflexion and plantar flexion in the taped condition were significantly lower than in the non-taped condition. Dorsiflexion F(1,17)= 74.58, P<.001; Plantarflexion F(1,17)= 199.94, P<.001. Both of these dependent variables had effect sizes > .800 (see table 1).

Table 1. Plantar flexion & Dorsiflexion

	Gender	Mean	Std. Deviation	N
Dorsiflexion not taped	Male	12.4	3.34	10
	Female	12.33	3.937	9
	Total	12.37*	3.531	19
Dorsiflexion taped	Male	5.2	2.573	10
	Female	7	1.871	9
	Total	6.05*	2.392	19
Plantarflexion not taped	Male	46.1	5.744	10
	Female	51.22	3.898	9
	Total	48.53**	5.491	19
Plantarflexion taped	Male	23.2	7.48	10
	Female	27.89	6.99	9
	Total	25.42**	7.448	19

Note* significantly different at p<0.05 ** significantly different at p<0.05

When analyzing knee and hip functional range of motion, this study found no significant interaction between tape and gender: F(2,16)= 1.038, p >.05. There was no significant main effect for tape: F(2,16)=6.138, p < .05. However, there was a significant main effect for gender: F(2,16)=4.62, p > .05. Follow up tests found that knee functional range of motion was significantly higher in men than in women: F(1,17)=9.815, p <.001. There was no significant difference between hip range of motion between genders: F(1,17)=4.24, p > .05 (see table 2).

Table 2. Knee & Hip functional range motion

	Gender	Mean	Std. Deviation	N
KNEE FUNCTIONAL ROM	Male	60.816667	13.6101347	10
	Female	51.847778	7.326225	9
	Total	56.568246	11.7320706	19
KNEE FUNCTIONAL ROM T	Male	63.8425	11.5385709	10
	Female	46.626667	10.2194936	9
	Total	55.687632	13.8196328	19
HIP FUNCTIONAL ROM	Male	54.176	23.0818967	10
	Female	43.727963	18.1285377	9
	Total	49.22693	21.0042288	19
HIP FUNCTIONAL ROM T	Male	63.729	17.40589	10
	Female	42.0178	15.94195	9
	Total	53.4447	19.70997	19

Kinetics

Results of the MANOVA for the vertical ground reaction force (VGRF), during jumping and landing show no significant interaction between gender and tape: $F(6,12)=1.43$, $p > .05$. There was no significant main effect between gender: $F(6,12)=1.47$, $p > .05$ and no significant main effect for tape: $F(6,12)=2.47$, $p > .05$ (see table 3).

Table 3. Vertical ground reaction forces during jumping and landing

	Gender	Mean	Std. Deviation	N
VGRF TC TO NT	Male	7.224	3.479379	10
	Female	5.245926	1.5030187	9
	Total	6.287018	2.8437205	19
VGRF TC TO T	Male	6.276	2.99693	10
	Female	4.5378	1.76898	9
	Total	5.4526	2.58393	19
VGRF G TO NT	Male	19.019833	3.5973224	10
	Female	23.186111	8.3624072	9
	Total	20.993333	6.4898506	19
VGRF G TO T	Male	19.343	4.3704362	10
	Female	22.846667	8.1371356	9
	Total	21.002632	6.496829	19
VGRF G L NT	Male	35.077333	4.0416403	10
	Female	33.442593	9.7725744	9
	Total	34.302982	7.1635576	19
VGRF G L T	Male	36.231	4.2264418	10
	Female	32.447778	8.8323479	9
	Total	34.438947	6.8825285	19
VGRF TC L NT	Male	7.398833	3.2717547	10
	Female	6.447222	2.0734057	9
	Total	6.94807	2.7388259	19
VGRF TC L T	Male	7.881	4.7289638	10
	Female	8.037778	2.7863048	9
	Total	7.955263	3.826024	19
VGRF TF L NT	Male	30.824833	4.4260789	10
	Female	32.723889	7.7428043	9
	Total	31.724386	6.1146578	19
VGRF TF L T	Male	31.676	5.2770114	10
	Female	33.406667	8.0023497	9
	Total	32.495789	6.5706006	19
VGRF AF L NT	Male	27.6435	4.7805089	10
	Female	28.719259	5.5301828	9
	Total	28.15307	5.0322544	19
VGRF AF L T	Male	26.937	4.1027309	10
	Female	28.414444	5.9911917	9
	Total	27.636842	4.9943658	19

Table 4. VGRF multivariate tests

Effect			Error df	Sig.	Partial Eta Squared
Between Subjects	Intercept	Pillai's Trace	12	0	0.989
		Wilks' Lambda	12	0	0.989
		Hotelling's Trace	12	0	0.989
		Roy's Largest Root	12	0	0.989
	Gender	Pillai's Trace	12	0.27	0.423
		Wilks' Lambda	12	0.27	0.423
		Hotelling's Trace	12	0.27	0.423
		Roy's Largest Root	12	0.27	0.423
Within Subjects	Tape	Pillai's Trace	12	0.086	0.552
		Wilks' Lambda	12	0.086	0.552
		Hotelling's Trace	12	0.086	0.552
		Roy's Largest Root	12	0.086	0.552
	Tape * Gender	Pillai's Trace	12	0.282	0.416
		Wilks' Lambda	12	0.282	0.416
		Hotelling's Trace	12	0.282	0.416
		Roy's Largest Root	12	0.282	0.416

In terms of lower extremity moments during landing, there was no interaction between taping and gender: $F(3,15)=1.32$, $p > .05$. There was no significant main effect for gender: $F(3,15)=1.79$, $p > .05$. There was no significant main effect for taping: $F(3,15)=.8$, $p > .05$ (see table 5).

Table 5. lower extremity moments

	Gender	Mean	Std. Deviation	N
ANKLE MO NT	Male	1.989667	0.6315402	10
	Female	2.071296	0.3768987	9
	Total	2.028333	0.5141105	19
ANKLE MO T	Male	2.112	0.6679953	10
	Female	1.985556	0.4718345	9
	Total	2.052105	0.5711935	19
KNEE MO NT	Male	3.145167	0.8495171	10
	Female	2.407111	0.9775917	9
	Total	2.795561	0.9638142	19
KNEE MO T	Male	2.966	0.3728628	10
	Female	2.245111	0.9692008	9
	Total	2.624526	0.789785	19
HIP MO NT	Male	3.5143	1.1968553	10
	Female	3.463519	1.9656587	9
	Total	3.490246	1.5601797	19
HIP MO T	Male	4.665	1.4612647	10
	Female	3.156667	1.5841007	9
	Total	3.950526	1.6678212	19

Note: the key for variable abbreviations found in Appendices

Time to peak VGRF during landing

When studying the variable of time to peak VGRF, gender, and taping, there was no significant interaction between tape and gender: $F(1,17)=2.03$, $p > .05$. There was no significant main effect for gender: $F(1,17)=.83$, $p > .05$. There was a significant main effect found for taping: $F(1,17)=25.78$, $p < .05$. Time to peak VGRF was significantly shorter in the taped condition (see table 6).

Table 6. Time to Peak VGRF

	Gender	Mean	Std. Deviation	N
TTP	Male	0.06317	0.016638	10
	Female	0.07611	0.022913	9
	Total	0.0693	0.020392	19
TTP T	Male	0.0465	0.009812	10
	Female	0.04644	0.020791	9
	Total	0.04647	0.0155	19

In summary, these results show that the closed basket weave ankle taping significantly decreases plantar flexion and dorsiflexion at the talocrual joint. The closed basket weave ankle taping significantly increase joint range of motion and joint moments in males at the knee. Lastly, the application of tape at the ankle significantly decreases the time to peak VGRF during landing.

The results also show that the application of ankle taping did not significantly effect the VGRF's sustained by the body. Also, moments at the hip and ankle were not affected.

CHAPTER 5

DISCUSSION

Purpose of study

The purpose of this study was to investigate the effects that prophylactic ankle taping has on the talocrual joint in terms of range of motion; force produced, and ground reaction force absorbed in a jump landing activity. The study also investigated the effects ankle taping has on kinetic and kinematics of the lower extremity. Dependent variables included: range of motion in plantar flexion, dorsi flexion, force production at talocrual, force at talocrual, VGRF at take off, VGRF, force at tibiofemoral, force at acetabulofemoral, ankle moment, knee moment, hip moment, knee functional range of motion, hip functional range of motion, time to peak VGRF.

Findings

This study set out to find many things about the closed basket weave ankle taping and the effects it has on the kinetics and kinematics in the lower extremity. Investigating the first hypothesis, that closed basket weave ankle taping will significantly decrease the force production and range of motion of an ankle at the talocrural joint in plantar flexion and dorsi flexion compared to no taping, significant and non-significant results were found. Similar to the findings from Paris et al.[9], the application of the closed basket weave ankle taping significantly decreased the range of motion for both plantar and dorsiflexion. This finding is clinically significant because it shows that the natural kinematics of the talocrual joint is affected. As stated in previous literature, a restricted range of motion effects the taped joint as well as surrounding joints biomechanics.[17,22-27] This finding simply forms a foundation for the rest of this study's clinical significance.

Another significant finding in this study found was that the time from initial contact to peak vertical ground reaction force (VGRF) sustained was significantly decreased. As suggested in the fifth hypothesis, the closed basket weave ankle taping significantly decreased the amount of time to peak ground reaction force sustained following landing from a jump.

This finding agrees with that of Saeki et al., who in 1995 found that ankle tape decreased landing time. He suggested that this significant change could affect VGRF absorption. When analyzing the landing motion kinetically and kinematically, we see that the ability to control ones landing and stay stable throughout the landing is dependent on the bodies' ability to eccentrically contract. As previous research states[18,19,22], eccentric contraction of the lower extremity musculature during landing absorbs the forces being applied to the body. If we correlate that to the length power relationship, which states a greater amount of length within the muscle fiber elicits a greater amount of force, we can extract that a decreased degree of range of motion allows for less than normal lengthening of a muscle fiber and therefore a decreased amount of force production from that given muscle. The significance of the decrease in time to peak VGRF, in the current study, shows us that the period of time the body had to eccentrically contract was limited due to the taping application. Furthermore, if the amount of time to eccentrically contract was decreased than the body's ability to absorb the sustained forces was most likely effected. All this being said one of three conclusions could be made. One, the role of the ability muscle as a stabilizer is now limited, thus the stabilizer role of the muscle must be performed by another structure within the body. Two, the amount of force generated by the restricted muscle has to be increased over a smaller muscle volume. Finally, a larger amount of VGRF is now being sustained by the body on to structures not involved typically in the landing process. This final idea seems the most ideal, yet as findings of this study continue to be explained one will see that the increase in forces sustained by the remaining structures could not be demonstrated.

Unlike previous studies, which found that VGRF was increased with the application of an ankle taping,[29] this study found no significant difference between subjects in any of the VGRF variables. These findings go against the hypothesis which stated that the application of a closed basket weave ankle taping would significantly increase the ground reaction force sustained by the lower extremity following a jumping and landing compared to no taping.

Further analysis of the data provides possible explanations for these findings. One primary reason for the lack of significant difference between groups could be due to the small sample size. Another reason for the insignificance could also be related to testing measure itself. The jump sequence performed might not have been the best representation of a purposeful jump and landing found in athletics. Either way, this finding poses a more in-depth line of questioning concerning VGRF sustained during a jump and landing in terms of muscular compensation as well whether the body actually adapts and alters its natural jumping and landing motion to deal with the application of tape. As we know from research and past studies in the fields of biomechanics and physical rehabilitation,[6,10,11,14,17] ankle taping is used as a proprioceptive tool. The body may in fact use the information from the neuromuscular propriocepters to adapt to the decrease of range of motion and function other muscles differently according to the demand placed on the body by the given task. Basically this idea is stating that the body not only uses propriocepters to give information to the affected joint, but actually uses the information from the affected joint to assist with functions and rely signals to other joints.

The study by DiStefano et al.[14] found braces were affective in limiting plantar and dorsi flexion, but VGRF was not affected. That same study stated that the cause for the lack of change in VGRF was probably due to a change in knee flexion. In the current study we can see that this explanation holds true in the case of males. Males in the current study increased their knee flexion when taped and not taped. Potential reasoning for why this finding wasn't seen throughout the sample in all lower extremity joints is that short period use of a prophylactic ankle device does not allow for any developed compensatory movement patterns, seeing as the majority of lower extremity kinematics were unchanged with the application of tape.

Concerning the lower extremity moments at the respective joints, the current study found no significant differences when comparing the effects of ankle taping. This finding goes against the hypothesis stated that a closed basket weave ankle taping would significantly change the lower extremity moments in the human body during a jump and landing in the sagittal plane. Again, these findings pose new questions about the effects of ankle taping. If no significant changes are found with lower extremity moments, than what effect does the decrease of range of motion have on the body?

Using the principles of the muscle length-power relationship it was assumed that the musculature which acts on the talocrual joint during landing is having to overcome the lack of full range of motion as well as the decreased eccentric contraction capabilities to still keep up with and maintain the desired amount of VGRF absorption. Though the reasoning for why the changes occur in lower extremity seem sound, no support was discovered in the remaining test of the study. Further examination of the data as well as the biomechanics of the lower extremity show one main insight that can explain for the results found through out the entire study. This fact simply is that every participant is different, and each compensated for the application of tape in different ways. Due to vast differences in body type, movement patterns, mass, and neuromuscular control, each participant showed individually specific effects of tape.

Examination of individual changes due to the application of tape, though not found significant, are interesting to investigate in their own right. The idea of research and statistics is to take a sample population, and by comparing means be able to create general statements. Ideally this strategy sounds extremely effective, yet at times, findings from studies dealing with human physiology and motion get washed away due to the presence of large individual differences. It appears that in this study, participants adapted very differently to the application of tape. Therefore group means were ineffective in representing the changes within the participants. With this reason in mind results which are not deemed significant when compared to means should also be looked at individually.

Further evaluation of individual results found astonishing results. In one example a participant had at least 15% increases in VGRF at the ankle, knee range of motion, hip range of motion, knee and ankle moment. This same participant had a 23% loss in vertical force production at the ankle, all due to the application of tape. Another participant had decreases in all force production categories, increases in all VGRF categories as well as increases in both functional ranges of motion and losses in time to peak VGRF. At least 5 participants saw individual trials vary at least 15% for all the VGRF categories as well as 10% changes, whether increases or decreases, in the joint moment categories. On larger scale every participants had at least two categories which changed at least 15%, and in some cases upwards of 25%. Yet, due to need for research to be generalizable, these important kinetic and kinematic changes in each of these participants reaction to the taping application might go unseen. Another negative affect of looking only at means is the inclusions of enormous outliers. (see table 7 for example of individual data)

For example, in several categories the between trial differences were as much as 214% greater or smaller. This larger variation between trials cause the mean of that given participant to lend a value that is skewed to the data. Unfortunately, research is designed to benefit a greater population than who is being studied at that given period so specific causes and effects are lost, that is a casualty of generalization.

Table 7 . Comparison of two participants

	UNTAPED			TAPED		
FORCE ANKLE	3.74	5.48	3.19	7.24	5.17	7.72
FORCE GLOBAL	32.63	30.77	23.77	23.09	23.62	21.99
VGRF GLOGAL	44.06	42.37	45.39	37.77	29.69	33.6
VGRF ANKLE	4.3	3.9	4.34	6.96	5.2	5.92
VGRFKNEE	40.73	39.56	43.56	34.31	25.76	30.21
VGRF HIP	32.81	32.78	35.71	29.29	23.32	26.41
ANKLE MO	2.09	1.76	2.71	1.61	1.92	1.52
KNEE MO	3.18	3.98	4.66	2.87	2.96	2.97
HIP MO	4.59	4.13	7	4	1.51	1.53
KNEE ROM	57.92	56.54	57.43	49.01	56.38	48.17
HIP ROM	48.04	48.08	49.11	50.32	50.77	54.67
TTP VGRF	0.08	0.11	0.08	0.05	0.07	0.07

Because the only difference between men and women was found in the knee range of motion, with men showing larger knee flexion in the taped condition. Examining the difference between men and women's range of motion seems appropriate. Examining the physiologic differences between men and women in the lower extremity, research shows us that the structure of the male and female body do differ as well as produce significantly different biomechanics. A study by Erland Colliander found that both males and females elicit a greater amount of torque by their quads and hamstrings during simultaneous eccentric contraction. This study also found that females display a greater ratio between quad and hamstring strength both eccentrically and concentrically.[37] Simply, the later finding means that females have a greater difference in terms of balance between there quads and hamstrings. A similar study more recently examined the changes in EMG of men and women while squatting on a single leg. This study is similar in the idea that these researchers want to see the importance of certain bodily structures during a single legged movement. This study found that men had 3 times the hamstring activity than did women through out the entire squatting motion.[38] Both of these studies as well as previous literature examined the bone structure of men and women to find the underlying differences.

Comparing the data between men and women from this study alone we see that men increased knee range of motion 3 degrees when comparing taped to not taped trials. Women on the other hand decreased knee range of motion 5 degrees. Men and women responded to the application of tape entirely opposite to one another. Even though this data is not statistically significant, for the purposes of clinical implications this data is extremely important. This data shows that women compensate for the loss of ankle range of motion and eccentric contraction capabilities by decreasing knee flexion, where as men compensate by increasing knee flexion.

When comparing these findings to my own we can conclude that women's predisposition to quad tightness and lack of quad/hamstring ratio leads them to land with a more strait leg as well as not transitioning their landing in to knee flexion. Again using the muscle length- power relationship, it can be said that the lack of range of motion in the knee while landing results in the bodies inability to eccentrically absorb VGRF's sustained during landing. Furthermore, these high levels of VGRF then have to be absorbed by tissues irregular to the landing process, as stated before.

Participants in this study were asked to answer if they had sustained an ankle injury in the past 6 months as well as if they had taped their ankle before, and whether they had become comfortable with it. Even though all but three participants answered yes, to having had their ankle-taped prior, only two participants could honestly say it was something they were comfortable with. This data was to insufficient to have been run statistically with the other results, but it is my opinion that if only 10% of the sample population felt comfortable with the taping application that could translate to only 10% nationwide. And, if this is true does that mean 90% of the athletes being taped daily are uncomfortable while participating in sport?

Findings from this study show that the closed basket weave ankle taping significantly decreases active plantar flexion and dorsi flexion in the talocrual joint. The more interesting finding was that the application of the closed basket weave ankle taping significantly decreased the amount of time from initial contact to peak vertical ground reaction force. Linking the first two significant findings, this study suggests that a decrease in active range of motion significantly effects the bodies' natural eccentric muscle contraction, which is needed during the landing motion. In this instance, this study also showed that the vertical ground reaction force is not affected by the application of tape. The aim of this study was to find differences in the lower extremity kinetics and kinematics when one uses ankle taping, though no direct significant difference was seen with VGRF, significant differences were seen in ranges of motion. This finding further demonstrates the biomechanically altering effects the closed basket weave ankle taping has, because of the application of tape the body does need to make significant changes to adapt.

Using findings from this study along with previous studies it can be said that ankle taping alters the natural kinematics of the human body with out adding unwanted vertical ground reaction forces. Though the effects of the closed basket weave ankle taping are not seen to change forces on the body's lower extremity, the alterations to movement patterns should be further studied in order to find out what potential detrimental effects it might have. Furthermore, the ankle taping itself, which prevents eversion, inversion, pronation, and supination, may have an effect on the body's non-vertical components.

Clinical implications

Despite having fewer significant results than hoped for, the clinical implications of this data are limitless. The fact that the data shows no trend among athletes concerning the tape application in turn supports the idea that athlete are truly different, and should justly be treated. Using the example shown in table 7 , the ankle taping does actually effect the human body and how it responds to jumping. Seeing that two separate bodies reacted entirely different from one another, it can be said that ankle tapings should be entirely different from one another. Furthermore, if taping can be performed differently to accommodate for the differences among athletes than the idea that athletes should be evaluated in manner that determines what extent of ankle taping is appropriate is not a far cry. As stated in literature review, 85% of all sprains in the body are ankle sprains, and the ankle can sprain in countless different ways. If allied health professionals could determine by: A, using an in depth evaluation prior to taping to determine the athletes individual response to the application of tape , B clinicians having discipline and control during taping enough to regulate and properly position the foot in the best possible way in terms of support without giving added restrictions that could lead to effect biomechanics. Finally C, this information could actually allow clinicians to make the decision to not tape at all preventing the potentially harmful effects the taping could have when applied to an individual. All three of these routes, which all can benefit the athlete population, are accomplished through thorough evaluation and impeccable clinical skills.

If we use the information provided from this study and apply it to athlete performance, the probable consequences are remarkably alarming. The data shows that the force absorbing mechanism in the lower extremity if not working correctly, and the force was not translated into higher vertical ground reaction force. The question now posed, where is the force?, the force is being placed on the same muscle in the lower extremity which now are working harder than usual. Continuation of sustaining these increased forces, especially on an untrained body, could only lead to the increased risk of further ankle sprain, muscle strain, stress fracture, and several other overuse/ compensation type injuries.

Limitations

This study had several limitations, which limited the clinical significance. First, the sample size was too small to generate statistical power. Second, the taping application was applied only moment prior to testing, no time for adaptations or for the tape to loosen as in a game or practice. Finally, only soccer athletes were used for this study. A more diverse sample group may have lead to different and more generalizable results.

Recommendations/ Future Work

Based on the findings, further research in this subject matter should include; a larger sample size, analysis of full body kinetics and kinematics, the use of video recording to qualitatively analyze the jump effectiveness, and electromyography readings of the lower extremity musculature. All of the above modifications would add to the study's power and over all ability to apply to all allied health fields. For example, a study by Osternig and Roberstson[24] found that there are significant electromyographical changes when studying knee braces. This theory could just as easily be studied with ankle taping.

A future consideration could also examine the effect time has on the ability to absorb VGRF. Going back to data from Paris et al.[9] ankle taping loses tensile ability through activity. If taping loses tensile strength than the body is gaining range of motion unevenly over time. Future work might examine the VGRF sustained on the lower extremity while a participant is taped, and the testing measures are repeated in respect to set time intervals. Advances in taping and bracing research will eventually lead to a better understanding of the biomechanics of the human body as well as what muscular and neurological effects restricting range of motion actually has.

Incorporating both quantitative and qualitative methods on analysis future studies might even include not only longitudinal approaches but sessions with sport psychologist to see if the application of tape has a emotional and psychological effect on the athlete making them more or less aware of there perceived support.

Lastly, ankle taping prevents a lot more than restrictions with plantar flexion and dorsi flexion. Future studies, in order to be more complete, should examine the electromyography and ground reaction forces in all planes and in all muscle which act in those planes.

Conclusion

In conclusion, this study's results indicate that the closed basket weave ankle taping significantly affects ankle range of motion, and time to peak VGRF. Increases in VGRF were not seen with the application of the same taping. Investigations of these results along with knowledge of the physical laws, which act in the body, suggest that the use of ankle taping has far more biomechanical effects than assumed. Though this study did not find significant increases in VGRF or significant changes in the entire movement patterns of the lower extremity, inspection of individual results show that the restriction of range of motion at the ankle has large and varying effects specific to each individual.

The findings of this study further provide foundation into the effects of the ankle taping, and further research as well as new testing instruments are needed to find additional clinical significance for the prophylactic use of the ankle tape. There will always be a need to further understand ankle taping and how it effects the body in terms of biomechanics and performance because if it vast applications and constant uses in athletics. In the age of evidence-based medicine, no longer will elder practices be used with out in depth investigation. Results from this study provide a frame work for allied health professionals to use as they develop new ways to evaluate ankle injury and determine the proper course of action taking in to count all the factors which effect the human body.

APPENDICIES

APPENDIX A
CONSENT FORM

Barry University
Informed Consent Form

Your participation in a research project is requested. The title of this study is " Prophylactic use of the closed basket weave ankle taping and its effects on kinetics and kinematics in the lower extremity". The research is being conducted by Matthew Santos-Vitorino ATC, LAT, a graduate student in the Sport and Exercise Science department at Barry University, and is seeking information that will be useful in the field of biomechanics and athletic training. The aims of the research are to investigate the effects that the closed basket weave ankle taping has on the kinetics and kinematics in the lower extremity. In accordance with these aims, the following procedures will be used: participants must currently be free of injury. Participants will need to report the Barry university biomechanics laboratory on a designated date and time. Participants will be given an identification number and state whether or not they are used to ankle taping. Participants will warm up on a treadmill for five minutes. Next, active ankle dorsi flexion and plantar flexion will be measured with a Goniometer. Participants will then proceed in performing a jump from a predetermined area on the floor, and land on a force plate. While landing on the force plate the participant will be asked to recoil and jump again back on to the force plate. Following a rest period, a closed basketweave ankle taping will be applied by a certified clinician. Once the taping application has been completed the participant will perform the same measuring and jumping protocol. Each participant will be given up to 10 practice trials before data is recorded. We anticipate the number of participants to be 30.

If you decide to participate in this research, you will be asked to do the following: on a single day, you will be asked to go to the Barry University biomechanics laboratory. While at the lab you will be asked to run on a treadmill for five minutes to serve as a warm-up. After the treadmill warm-up you will have range of motion measurements made using a device called a Goniometer. A Goniometer is used by placing the axis of the goniometer on the lateral maleolus and the stationary arm along the length of the fibula. The movable arm of the goniometer is placed along the length of the foot, aligning with the fifth metatarsal. As the patient moves through a range of motion, the movable arm pivots around the axis staying in line with the fifth metatarsal. Once an end range of motion is reached, the movable arm of the goniometer displays a corresponding range of motion in degrees. Once range of motion has been established you will be asked to jump from the floor, and with your dominant leg land on to a plate which is built in to the floor, upon landing you will need to jump in to the air and land on the plate again. Once this is completed a closed basket weave ankle taping will be applied to your ankle and you will be asked to perform the jumps all over again.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects on your social standing within the university.

The risks of involvement in this study are minimal and include ankle sprains. The following procedures will be used to minimize these risks: a proper warm-up, detailed instruction, and direct supervision. Although there are no direct benefits to you, your participation in this study may help the sports science community in understanding the effects of ankle taping on force.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file in the researcher's office. Your signed consent form will be kept separate from the data. All data will be destroyed after 7 years; collected data will be used for future studies and written work.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me, Matthew Santos-Vitorino ATC, LAT, at (413) 221-0642, or my supervisor, Dr. Sue Shapiro at (305) 899-3490 or the Institutional Review Board point of contact, Barbara Cook, at (305)899-3020. If you are satisfied with the information provided and are willing to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Matthew Santos-Vitorino ATC, LAT, and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to participate in this experiment.

______________________ ___________

Signature of Participant *Date*

______________________ ___________ ______________________

____

Matthew Santos-Vitorino *Date* *Witness*
Date

(Witness signature is required only if research involves pregnant women, children, other vulnerable populations, or if more than minimal risk is present.)

APPENDIX B
DATA COLLECTION SHEET

Data Collection Form

Prophylactic use of the closed basket weave ankle taping and its effects on kinetics and Kinematics in the Lower Extremity"

Particiant ID ______

Gender ______

Tapes conistantly Y/N

	Untaped				Taped			
	trial 1	trial 2	trial 3	average	trial 1	trial 2	trial 3	average
Dorsiflexion								
Plantar Flexion								
Force production talocrural								
Force production global								
GRF global								
GRE talocrural								
GRF tiiofemeral								
GRF acetabulofemoral								
Ankle moment								
Knee momennt								
Hip moment								
Knee function range of motion								
Hip functional range of motion								
Time to peak GRF								

APPENDIX C
SIGN UP SHEET

SIGN UP SHEET
MATTS STUDY

DATE NAME CELL PHONE#

FEB 10
10AM____
1130AM______________________________________
1PM____

FEB11
10AM____
1130AM______________________________________
1PM____

FEB 17
10AM____
1130____
1PM____

FEB 24
10AM____
1130AM______________________________________
1PM____

MAR 3
10AM____
1130AM______________________________________
1PM____

MAR 4
10AM____
1130AM______________________________________
1PM____

MAR 10
10AM____
1130AM______________________________________
1PM____

APPENDIX D
INDEPENDENT VARIABLE KEY

INDEPENDENT VARIABLE KEY

M- MALE 1
F-FEMALE 2

1- COMFORTABLE
2- NOT COMFORTABLE

DF NT- DORSIFLEXION NOT TAPED
DF T - DORSI FLEXION TAPED
PF NT- PLANTAR FLEXION NOT TAPED
PF T- PLANTAR FLEXION TAPED
VGRF TC TO NT- VGRF TALOCRUAL TAKEOFF NOT TAPED
VGRF TC TO T- VGRF TALOCRURAL TAKEOFF TAPED
VGRF G TO NT- VGRF GLOBAL TAKEOFF NOT TAPED
VGRF G TO T- VGRF GLOBAL TAKEOFF TAPED
VGRF TC L NT- VGRF TALOCRURAL LANDING NOT TAPED
VGRF TC L T- VGRF TALOCRURAL LANDING TAPED
VGRF G L NT- VGRF GLOBAL LANDING NOT TAPED
VGRF G L T- VGRF GLOBAL LANDING TAPED
VGRF TF L NT- VGRF TIBIOFEMORAL LANDING NOT TAPED
VGRF TF L T- VGRF TIBIOFEMORAL LANDING TAPED
VGRF AF L NT- VGRF ACETABULOFEMORAL LANDING NOT TAPED
VGRF AF L T- VGRF ACETABULOFEMORAL LANDING TAPED
ANKLE MO NT- ANKLE MOMENT NOT TAPED
ANKLE MO T- ANKLE MOMENT TAPED
KNEE MO NT- KNEE MOMENT NOT TAPED
KNEE MO T- KNEE MOMENT TAPED
HIP MO NT- HIP MOMENT NOT TAPED
HIP MO T- HIP MOMENT TAPED
KNEE FUNC ROM- KNEE FUNCTIONAL ROM
KNEE FUNC ROM T- KNEE FUNCTIONAL ROM TAPED
HIP FUNC ROM- HIP FUNCTIONAL ROM
HIP FUNC ROM T- HIP FUNCTIONAL ROM TAPED
TTP- TIME TO PEAK
TTP T- TIME TO PEAK TAPED

APPENDIX E
FINAL AVERAGES

Participants	Gender	Comfort	DF NT	DF T	PF NT	PF T	VGRF TC TO NT
1	1	2	17	5	47	20	11.38
2	1	2	10	4	40	21	6.76
4	1	2	7	3	40	17	7.30
5	1	2	15	11	49	21	6.12
6	1	2	9	3	55	40	2.89
7	1	2	11	4	40	27	7.89
8	1	2	12	5	43	30	3.18
9	1	2	14	3	48	23	7.59
10	1	1	12	6	44	14	4.90
11	1	2	17	8	55	19	14.24
12	2	2	9	6	50	21	7.32
13	2	2	20	8	57	25	5.14
14	2	1	11	5	47	23	4.15
15	2	2	11	10	50	30	4.64
16	2	2	9	5	55	39	3.02
17	2	2	11	9	47	31	4.30
18	2	2	18	8	55	38	7.62
19	2	2	10	5	53	23	4.99
20	2	2	12	7	47	21	6.04

VGRF TC TO T	VGRF G TO NT	VGRF G TO T	VGRF G L NT	VGRF G L T
4.15	17.39	16.46	31.24	30.14
7.64	19.26	19.45	34.34	34.75
5.93	16.60	16.89	43.83	43.20
5.56	17.42	16.88	35.71	39.41
2.98	12.60	12.60	30.53	36.07
7.67	24.00	25.30	34.53	38.26
3.79	18.64	17.92	31.07	31.21
7.98	24.95	27.15	34.06	31.84
3.96	18.39	18.75	38.84	37.76
13.1	20.95	22.03	36.63	39.67
1.92	18.28	20.56	31.94	24.65
5.51	18.64	19.23	43.28	43.63
5.74	17.67	17.97	29.84	37.87
3.36	42.55	43.49	16.03	17.79
2.25	17.37	17.43	28.31	35.03
5.71	29.06	22.90	43.97	33.69
5.56	20.87	21.85	40.23	37.52
3.77	18.04	17.56	24.60	22.11
7.02	26.20	24.63	42.79	39.74

VGRF TC L NT	VGRF TC L T	VGRF TF L NT	VGRF TF L T	VGRF AF L NT
12.99	5.95	25.43	20.15	20.50
5.67	6.76	31.03	32.46	27.54
6.95	7.62	40.37	39.36	36.40
5.33	5.36	31.09	35.79	29.66
4.12	7.01	26.00	30.63	22.30
7.32	8.42	30.77	32.52	26.90
5.49	3.92	28.69	28.67	23.53
7.73	6.34	28.34	28.12	29.70
4.91	6.55	35.52	35.37	32.50
13.48	20.88	31.02	33.69	27.41
6.61	6.69	28.42	22.89	25.06
8.38	6.01	39.26	40.90	33.17
7.33	6.71	26.49	34.93	24.25
4.49	10.20	39.67	40.73	32.98
4.29	10.51	23.77	28.35	23.43
4.18	6.02	41.28	41.28	33.77
9.83	12.60	33.80	34.50	31.32
4.91	4.00	21.69	19.78	19.87
8.00	9.60	40.13	37.30	34.63

KNEE FUNC ROM	KNEE FUNC ROM T	HIP FUNC ROM	HIP FUNC ROM T	TTP	TTP T
51.64	76.99	26.10	74.41	0.06	0.05
82.40	60.3	84.40	60.92	0.090	0.063
41.90	47.46	21.55	29.33	0.050	0.046
66.91	77.55	80.88	87.72	0.060	0.033
59.98	64.15	47.12	66.22	0.050	0.03
73.08	81.43	47.21	63.22	0.067	0.046
55.50	51.03	57.99	51.41	0.047	0.053
71.91	55.91	58.16	49.16	0.053	0.043
40.62	59.38	35.33	70.42	0.095	0.055
64.23	64.225	83.02	84.48	0.060	0.046
57.19	34.66	73.04	53.47	0.085	0.05
54.43	57.21	53.73	60.25	0.047	0.036
57.07	56.9	52.63	55.5	0.080	0.053
53.18	55.31	52.25	52.99	0.037	0.03
45.39	50.81	21.36	28.64	0.100	0.01
57.30	51.18	48.41	51.92	0.090	0.063
39.22	38.83	19.25	20.28	0.080	0.04
43.25	29.34	24.39	20.5	0.103	0.083
59.61	45.4	48.48	34.61	0.063	0.053

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