THE EFFECT OF PROPHYLACTIC DEVICES AND FATIGUE ON STATIC AND DYNAMIC BALANCE

THESIS

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It is not the critic who counts, not the man who points out how the strong man stumbled, or where the doer of deeds could have done better. The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood, who strives valiantly, who errs and comes short again and again, who knows the great enthusiasms, the great devotions, and spends himself in a worthy cause, who at best knows achievement and who at the worst if he fails at least fails while daring greatly so that his place shall never be with those cold and timid souls who know neither victory nor defeat.

-Theodore Roosevelt

"ICFTB"

-Eugene, Timmy, Tashi, Alanna

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ABSTRACT

THE EFFECT OF PROPHYLACTIC DEVICES AND FATIGUE ON

STATIC AND DYNAMIC BALANCE

by

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May 2010

SUPERVISING PROFESSOR: JACK RANSONE

Context: Prophylactic devices and fatigue may affect both static and dynamic balance.
Objective: To determine the effect of prophylactic devices and fatigue on static and dynamic balance.
Design: Randomized controlled trial.
Setting: Athletic Training Research Laboratory.
Patients or Other Participants: Twenty-four healthy and physically active males and females (age = 22.3 ± 2.9 yrs, height = 171.3 ± 11.7 cm, mass = 72.5 ± 18.0 kg).
Intervention(s): In 3 testing sessions, participants wore either ankle tape, an ankle brace, or remained barefoot while performing a fatigue protocol using the Biodex Isokinetic Dynamometer set for plantarflexion and dorsiflexion of the ankle. The barefoot condition served as the control.
Main Outcome Measure(s): We assessed static and dynamic balance using the NeuroCom Equitest Balance System (Clackamas, OR) both pre and post fatigue. Additionally, range of motion for the ankle inversion, eversion, plantarflexion, and dorsiflexion was measured.
Results: A Sensory Organization Test was used to measure the static balance of each subject before and after fatigue for all three conditions. The effects of treatments of fatigue on barefoot balance (82.5 ± 4.9), ankle taping (82.7 ± 5.9) and ankle bracing (82.6 ± 4.8) were compared to pre-test scores of baseline barefoot balance (84.0 ± 3.6), ankle taping (83.6 ± 4.9), and ankle bracing (82.8 ± 5.4) conditions. No differences existed in the SOT composite scores were observed. A Motor Control Test was used to measure the dynamic balance of each subject before and after fatigue for all three conditions as well.

The effects of treatment of fatigue on dynamic balance for barefoot (137.7 ± 24.7), ankle taping (132.4 ± 15.3) and ankle bracing (133.5 ± 16.3) conditions were analyzed and compared to pre-test scores of barefoot (132.5 ± 9.9), ankle taping (129.5 ± 12.2) and ankle bracing (133.5 ± 12.8) conditions. No significant difference was observed in pre to post fatigue conditions, $F(2,46) = 1.3$, $p = 0.261$, Power = 0.188. For the barefoot trials, mean MCT scores were 132.5 ± 9.9 for the pre-test, and slightly increased to only 137.7 ± 24.7 for the post-test.

Conclusions: No differences were seen among the three conditions (barefoot, tape, and brace) for the SOT and MCT composite scores. No significant differences were seen among the pre to post fatigue balance assessment for the SOT and MCT composite scores.

Key Words: balance, postural control, isokinetic, exercise, ankle support

CHAPTER I

THE EFFECT OF PROPHYLACTIC DEVICES AND FATIGUE ON STATIC AND DYNAMIC BALANCE

Balance is a critical component to normal function for physically active persons. There are various sensory and motor components of the nervous system that function collectively during balance. When these systems are disturbed or altered, muscle activity increases to facilitate balance.[1] Proprioception is defined as the ability of the body to sense its own position within space, or having an awareness of joint position.[2,3] Proprioception is one of the sensory systems influencing postural balance by facilitating a control in the movement of the center of pressure.[4] The terms balance and proprioception are not synonymous, although proprioception and functional ankle stability are often correlated, with functional ankle stability being defined as reliable static and dynamic support of a joint.[5-12]

Muscular fatigue has been shown to alter the effects of the sensory and motor components during balance.[1,13,14] Muscle fatigue is a reduction in the maximal force capacity of the muscle that may be due to exercise.[1,14-16] Muscle fatigue occurs at 50% of maximum muscle force output.[14] The effects of muscle fatigue may lead to an increased injury rate due to the decreased loss of sensory and motor components during balance.[13] An injury is that of which resulted in the loss of participation from physical activity for at least one day. Although fatigue is expected to occur, it can be inferred that the use of prophylactic devices may play a role in the maintenance of balance after fatigue by increasing the sensory component of balance.[8,11]

The effect that fatigue has on balance has been previously researched involving various fatigue protocols and measurements of balance.[17-21] Fatigue has been found to have an adverse affect on balance.[20,21] Additionally, prophylactic devices have been found to increase balance.[22] Prophylactic devices may increase static and dynamic postural balance by an external stability method.[23,24] Although previous research has failed to determine the effectiveness of prophylactic ankle taping and ankle bracing on balance after lower extremity fatigue. Ankle plantarflexors and dorsiflexors contribute to the control of postural sway.[14] Ideally, both prophylactic methods would result in maintenance of balance after fatigue of these plantarflexors and dorsiflexors.

Purpose of the Study

The purpose of this investigation was to examine the effect of ankle braces and ankle taping on postural stability following a bout of lower extremity fatigue in uninjured subjects.

Research Hypothesis

1. It is hypothesized that ankle braces are more effective than ankle taping on maintaining balance following lower extremity fatigue in uninjured subjects.

2. It is hypothesized that ankle braces and ankle taping are more effective that no support on maintaining balance following lower extremity fatigue in uninjured subjects.

Operational Definitions

1. Center of gravity is the average location of the weight of an object or person.
2. Center of pressure is the average location of the pressure within the mass.
3. The terms balance and postural stability are interchangeable.
4. Functional ankle instability can be identified by a feeling of "giving way" of the ankle.[12]
5. Limit of stability (LOS) is the furthest distance in any direction that a person can lean away from midline without altering the base of support.

Delimitations

Certain delimitations were set by the principal investigator of the study that may have affected the results and conclusions drawn. The following delimitations were acknowledged:

1. Subjects, between the ages 18 and 30 years old, served as subjects due to the availability of this population.
2. Healthy, physically active subjects were used in this investigation and were determined healthy by no lower extremity injury in the past year.
3. The prophylactic treatment in this investigation was delimited to the McDavid Ultralite (Woodridge, IL) laced ankle brace.

Limitations

The limitations set in this study reflect the effect of the delimitations on the collection and interpretation of the data and the ability to expand the scope of inference beyond the sample population. Generalizations made from the results were compromised by the following limitations:

1. Inferences cannot be made outside of the test population. Generalizations to adolescent and geriatric aged individuals cannot be established.
2. This study was limited to the inability to have injured subjects, including those that have had a lower extremity injury within the past year. This study was limited to subjects whom are physically active.
3. Results of this investigation will only be applicable to lower extremity activities and cannot be generalized to upper extremity exercise.
4. Variations of ankle taping or non-laced prophylactic ankle braces may elicit varying results from tested supports.

Assumptions

For the purpose of this study, the researcher accepted the following assumptions.

1. The subjects were healthy based on the information provided on the demographic and health history questionnaire, which was given honestly and accurate.
2. The subjects put forth maximal effort and followed directions as given. The warm-up and fatigue protocol for each subject was sufficient to allow maximal effort in phases of testing.

3. The investigators attitude and assistance were not biased towards a particular individual or testing order.

Significance of the Study

A significant number of lower extremity injuries occur within sports participation and physical activity, making it important to understand how they can be prevented. Preventing sports injuries will allow physically active persons to continue their sports participation and daily activities without the obstruction of injury. The high incidence of sports injuries that may arise as the result of poor balance attests to the importance of understanding how to maintain balance throughout physical activity. Previous research has shown that prophylactic taping and bracing may have an effect on maintaining both a sensory and mechanical function maintaining dynamic postural stability.[25] Ankle bracing has been shown to have a positive effect on proprioception.[4] It can be inferred that ankle bracing and taping may be used to maintain balance after fatigue.

Many investigations have shown that fatigue has a negative effect on balance.[25] The mechanisms that factor into muscle fatigue depend on the task being completed.[15] Investigations comparing the effects that various prophylactic devices have on balance are unequivical. By examining research observations, it can be hypothesized that prophylactic devices such as taping and bracing have a positive effect on postural balance after fatigue. This will aid clinicians in the awareness of the affects fatigue can have on balance while conducting sideline postural control exams. Additionally, it may allow clinicians to select ideal prophylactic devices that are suitable for the individuals that they may work with on a daily basis.

CHAPTER II

REVIEW OF RELATED LITERATURE

Numerous investigations have reported a decreased postural control and balance following intensive bouts of exercise, leading to neuromuscular fatigue. Fatigue is a natural neuromuscular phenomenon that occurs during sports participation. Previous research has shown that lower extremity neuromuscular fatigue may have an adverse effect on postural control.[20,26,28,29] Additionally, poor postural control and balance has been linked to various athletic injuries and has been proven to be one aspect affected, following traumatic brain injury.[20] It is assumed that postural control and balance will decrease following intensive bouts of exercise. The visual, vestibular, and somatosensory systems are vital components of postural control and allow for adaptation of balance during body movement. Maintenance of proper stabilization of the ankle is achieved by a combined effort of surrounding muscles.[20] The ankle and the hip movements are both essential for the control of balance. The hip movements demonstrate their leadership in the role of maintaining balance when the ankle is injured.[30] The purpose of this investigation was to determine the effectiveness of the use of prophylactic devices, such as ankle braces and ankle taping, on maintaining balance post neuromuscular fatigue, which may be involved with a decreased lower extremity injury rate. Identifying clinically significant differences of fatigue on postural control allow practitioners to identify various prophylactic techniques that could be used to prevent injuries or reduce injury rates. Gathering such evidence also allows clinicians to be aware of the affects fatigue can have on balance while conducting sideline postural control exams.

Injury Rates

Ankle injuries are a hindrance commonly found in sports participation and the most common type of injury to the lower extremity.[31] The most frequent type of ankle injury is an inversion or lateral ankle sprain (LAS).[2,8,12,24] A LAS may develop from various risk factors such as ligamentous stability, muscular strength, postural sway, muscle reaction time, as well as the anatomy of the foot.[31] Frequently, LAS occurs during plantar flexion and inversion.[32] Additionally, extrinsic factors such as playing surface, sports equipment, and environmental factors may cause injury. Intrinsic factors may also predispose one to injury and may include physical and psychological characteristics of the participant.[33] When the ankle is plantarflexed and inverted, the joint is vulnerable for injury if the neuromuscular system cannot restore normal position.[34] Mohammadi et al.[2] evaluated three preventative measures, including proprioceptive training, strength training, and orthotic wear, to reduce inversion ankle sprains for 80 male soccer players with a previous ankle sprain. Proprioceptive training was shown to be the most effective in reducing the recurrence of an ankle sprain. Proprioceptive training may encompass balance training, which may include static tests, sandals, stability pads, and various balance systems such as the NeuroCom Equitest. An increase in proprioception about the ankle may increase the onset of activation of muscles throughout the ankle, which will enhance the correction of ankle position, therefore increasing postural control. A decrease in proprioception at the ankle joint may, therefore, lead to an increased injury rate. Functional ankle instability, or the feeling of giving way, has been a common reported deficit found post ankle sprain.[12] This may also be due to a decrease in proprioception at the ankle. Evidence shows that there is also a resulting peroneal muscle weakness due to inversion injuries.[35] This weakness may contribute to a decrease in stability of the ankle and therefore decrease the postural control, resulting in increased injury rates.

Injury rates increase as a result of muscle fatigue and it has been identified that individuals with increased postural sway velocity, or a decrease in balance, are at an increased risk for ankle injury.[36,37] The ability to maintain postural control may lead to a decrease in lower extremity injury. From an economic standpoint, ankle injuries are a financial burden costing hundreds of dollars per sprain.[31] Clinicians are therefore encouraged to understand predisposed conditions for ankle injury so that prevention methods may be established.

Lower Extremity Neuromuscular Fatigue

There are two forms of fatigue: peripheral and central. Central fatigue involves the voluntary neural drive, whereas peripheral fatigue includes a metabolic inhibition of contractile process and excitation-contraction coupling failure.[14] Muscle spindle proprioceptors play a role in maintaining postural control, therefore, a decrease in balance is expected after neuromuscular fatigue.

A decrease in postural control may be the result of fatigue.[20,26-29] Gribble and Hertel[27] identified that fatigue of hip abductors and adductors caused decreases in postural control whereas invertors and evertors did not. Explanations for this phenomenon may be due to the extent or the role that each muscle plays in postural control. Invertors and evertors of the lower extremity are less powerful, therefore may contribute less to overall postural control. Muscle plantarflexors and dorsiflexors, however, are more powerful and may contribute more to overall postural control.

Postural control is made up of visual, vestibular and somatosensory components of the central nervous system which work together and provide feedback to the body about the position. Vuillerme et al.[28] investigated the effect of calf fatigue on postural control with three visual conditions in twelve students and found that after gastrocnemius and soleus muscle fatigue there is a decreased postural control during quiet bipedal standing in the absence of vision. This alteration of the sensory proprioceptive and motor systems could be used to explain the increased center of pressure along the medio-lateral axis during the no vision trial.

Investigations involving ground reaction forces like center of pressure (CoP), center of gravity (CoG), and postural sway are unequivical.[21,26] Center of pressure refers to the average location of the pressure within a mass and the center of gravity refers to the average location of the weight of an object or person. During minimal movements of the body, CoP and CoG tend to be similar. If CoP and CoG appear to be similar during minimal movements, there is a possibility that while looking at static postural control, investigating CoP and CoG may be redundant. Gribble and Hertel examined CoP and found minimal significant increase from pre-fatigue to post faituge.[26] Along with CoG and CoP, postural sway along the medio-lateral and antero-posterior axis has been explored. There is evidence that there are significant shifts of the CoP along the medio-lateral axis.[21,26] Vuillerme et al.[28] found no significant changes along the medio-lateral axis. They investigated the magnitude of the effect of calf muscle fatigue on bipedal standing. The differences in the outcomes of these studies may be due to the particular fatigue protocol that was used.

There is substantial evidence that suggests fatigue of the lower extremity does have an effect on balance, although there are discrepancies as to the length of time the fatigue lasts.[17-20] One study in particular investigated this issue with 36 male athletes who participated in high contact sports and were asked to perform, on separate occasions, two exercise protocols and then measured their postural control at 3, 8, 13, and 18 minutes post exercise.[20] They found that fatigue may affect postural control up to 13 minutes after fatigue protocol completion. This is an important find in regards to deciding when it is appropriate to test the postural control of persons with suspected concussions. Other studies found that there was no significant difference in postural control due to fatigue because of the rapid recovery time from a fatigued state.[17-19] In contrast, Fox et al.[20] found clinically significant differences in postural control at 3 minutes and 8 minutes following fatigue. Another study found that time of day effected dynamic postural control and found that postural control is greater at the start of the day.[38] This suggests that the components of postural control may fatigue throughout the day although further research is warranted.

Fatigue Protocols

Various protocols have been implemented to induce neuromuscular fatigue. Muscle fatigue is a reduction in the maximal force capacity and may occur at 50% of maximum muscle force output.[1,14-16] Shaw et al.[25] used a 3 station fatigue protocol which involved agility drills, stationary lunges, and quick jumps. Subjects were considered fatigued after completion of the three stations. Sandrey et al.[39] used an isokinetic dynamometer to fatigue ankle everter muscles with concentric-eccentric eversion exercise. Jonston et al.[36] used a fatigue protocol that consisted of specific fatigue to the tibialis anterior with the use of an isokinetic dynamometer for closed kinetic chain antagonistic exercise. Another study's fatigue protocol consisted of completing toe-lifts until subjects were no longer able to complete the exercise.[28] A third study used a fatigue protocol which consisted of a cycling exercise.[29] Twelve university students performed a 15 minute cycling exercise at a power output of 200W on a standard friction loaded cycle ergometer. The fatigue was determined with metabolic and psychological parameters such as heart rate and rate of perceived exertion.

Prophylactic Devices

A prophylactic device is an external factor used to provide stability to a particular joint in an attempt to reduce injuries. Prophylactics may include taping and various forms of bracing. The effects of the external tools are to provide support for the ankle, not to increase performance in any way.[23] Ankle tape and prophylactic ankle braces have been used to provide a sensory and mechanical function to support the ankle which may include restriction of inversion and eversion of the ankle, yet allowing functional motion for normal mechanics.[32,40] Hardy et al.[41] examined 36 subjects wearing semi-rigid and lace up braces while performing a dynamic balance reach task and found that there was no disruption of the task from the external devices worn. Prophylactics may provide an increase in proprioception at the ankle joint, which may help to increase postural control.[36,42] Proprioception is the combined neural input to the central nervous system from the mechanoreceptors that are found in joints and muscles. These mechanoreceptors respond to changes in pressure and tension of the joint from dynamic movement.[43] Prophylactic devices have been used as a means of preventing ankle injury, specifically ankle sprains.[44] Ankle foot orthoses (AFO) have been used to improve postural alignment, lateral weight shift, and to decrease body sway.[22] Vuillerme et al.[45] studied eight healthy subjects and found that AFO allowed for a limited postural perturbation during quiet standing. Ankle taping is a widely used method for prevention of ankle re-injury. Ankle taping involves strategically placed tape about the ankle that will reduces extreme ranges of motion.[46] Tilting angular velocities at the ankle are also decreased with the application of tape.[47] There has been debate as to whether ankle tape holds during activity because sweat accumulation moistens the tape and decreases the adhesiveness of the tape.[32] Ankle braces are devices that are durable yet fit for the general population and can be tightened during activity and is also commonly used as a prophylactic device. Ankle braces are constructed from a range of materials such as nylon or canvas to provide support for the ankle.[48] Semi-rigid braces are commonly used to restrict inversion, while lace-up, or soft, braces are effective in decreasing extreme plantar flexion and dorsiflexion, which ultimately reduces injury.[41] Sharpe et al.[37] studied 38 female soccer players over a five year period and compared ankle taping and a canvas lace-up brace to determine which was more effective in reducing the occurrence of ankle re-injury. The results of this study showed that ankle bracing was more effective than taping in reducing the number of ankle sprain recurrence. Wikstrom[42] compared soft and semirigid braces in twenty-eight subjects with FAI and found that both braces improved stability, but there were no differences between the two different braces. Verburgge[49] compared adhesive taping and Air-stirrup bracing for a subjective preference for 26 male athletes who performed a series of athletic moves showed that the taping was less comfortable, however, neither taping nor bracing hindered the athletic performance. Nishikawa et al.[50] compared a semi-rigid brace, a lace-up brace, and tape for the restriction of plantarflexion, dorsiflexion, inversion, and eversion for eleven volunteers. The results showed that the semi-rigid was less effective than lace-up and tape in restricting plantarflexion-dorsiflexion movements.

Tests for Functional Ankle Instability

Various tests have been used to test for functional ankle instability such as single leg hop for distance, co-contraction test, shuttle run, and agility hop test.[12] Testing for functional ankle instability has lead to resulting performance deficits found in the lateral movement tests, but not in the sagittal plane movements. Functional performance tests may be used to determine the level of dysfunction and to examine the effectiveness of rehab protocols after the ankle sprain and resulting functional ankle instability. Buchanan et al.[12]

compared 20 subjects with functional ankle instability and 20 healthy subjects on their performance on the single leg hop and single leg hurdle tests. The performance on the tests revealed no difference between groups, but when asked if the subjects felt as though the ankle was unstable during the test, there was a greater difference with those with FAI replying yes. The limit of the study was that not all persons with FAI have the same functional limitations.

Analysis of Balance

Maintenance of accurate stabilization of the ankle is achieved by a combined action of neighboring ankle muscles.[20] Balance has been defined as the act of maintaining, achieving, or restoring a state of balance during any posture or activity.[51] A measurement tool that is most often used to measure aspects of postural control is a force plate. Force plates measure ground reaction forces by measuring postural sway and elliptical velocity, movement on medio-lateral and antero-posterior axes, and center of pressure, while standing.

A reliable instrument used to measure postural control via multiple force plates is called the NeuroCom Equitest Balance System (Clackamas, OR). The reliability and validity of the NeuroCom System measurements of postural stability has been extensively documented.[52-55] The test-retest reliability of the NeuroCom System has also been established.[53-55] Liston et al.[55] examined 20 stroke patients and found the test-retest reliability data for complex balance and dynamic tests rather than static balance measurements to be valid indicators of functional balance performance. The NeuroCom

Equitest has the capability of assessing various tests such as the Sensory Organization Test (SOT) and the Motor Control Test (MCT). The SOT is an assessment that incorporates six conditions: fixed surface with normal vision, fixed surface with eyes closed, fixed surface with sway-referenced vision, sway referenced surface with normal vision, sway reference surface with eyes closed, and sway referenced surface with sway referenced vision. Each condition is measured three times. The six condition assessment allows for isolation of the somatosensory, visual, and vestibular inputs to balance. The MCT is an assessment that identifies abnormalities in the timing and strength of the autonomic response and coordination in each leg in adapting to quick, unexpected support surface translations, either forward or backward. Each of the MCT conditions is also measured three times. The NeuroCom has an increased sensitivity to slight changes in balance, and therefore is a choice postural control device. The NeuroCom has been used in various studies as a comparison tool due to the established tests for evaluation of postural control.[56] The NeuroCom tests the balance of the individual with both feet on the platform. Normal individuals have difficulty with single leg balance with both eyes open and eyes closed, and the NeuroCom is used as a research tool with this taken into account.

The Biodex Stability System (BSS; Shirley, NY) is another instrument that is used to objectively measure balance. The BSS has a non-traditional platform in a circular shape that is able to move in both the anterior-posterior and medial-lateral axes together. Pereira et al.[57] used the BSS to measure postural control in trials with the knee extended and in a slight flexed position and found that the flexed knee resulted in slightly greater postural control. Akbari et al.[31] used the BSS to measure sway index as well as limits of stability in conjunction with clinical tests such as the Functional Reach Test and the Star-Excursion Balance Test. Subjects included 30 male athletes with right side leg dominance and grade I and II ankle sprain. It was determined that during the Functional Reach Test, there was a greater amount of displacement, or a greater loss of stability, with single leg versus double leg standing. They discovered that there was a strong relationship between the scores of the balance testing for determining balance impairments post ankle injury.

Special tests such as the Balance Error Scoring System (BESS) or Rhomberg's balance test are also techniques used to evaluate postural control. The problem with using these types of techniques is that they could potentially produce false results due to fatigue levels of the athlete. The force plate measurements, such as from the NeuroCom, may be more sensitive than the BESS to changes of postural control due to fatigue.[20] Broglio et al.[58] examined the influence of ankle support on balance and compared the SOT and the BESS to determine the level of postural control for nineteen healthy volunteers. The ankle taping was found to have a negative effect on balance when measuring with the BESS. The BESS is unable to manipulate the three components of postural stability such that the NeuroCom measures, and therefore balance is only partially investigated by the BESS.

Isokinetic Analysis

Isokinetic exercise involves variable resistance to a movement at a constant rate of velocity without limitations to joint range of motion. Isokinetic dynamometers have been used to measure muscular fatigue at various joints of the body and usually involves measurement of a 50% reduction of maximal contraction.[59] Isokinetic exercises are movements that are performed at a controlled speed. Isokinetic dynamometers are tools that move at a constant speed that is pre-set by the clinician and allow for the resistance to be accommodated by the effort the subject exercises, which will also be accommodated by the fatigue of the individual.

The Biodex 4 Isokinetic Dynamometer (Biodex Medical Systems, Inc., Shirley, NY) is a tool used to collect data interpretation from isokinetic testing. The Biodex system is a reliable tool that is able to objectively measure various elements regarding isokinetic exercise with outputs such as peak torque, power, time, and various deficits.[60 61]

Fox et al.[35] used the KinComIII Isokinetic Dynamometer to test plantarflexion, dorsiflexion, inversion, and eversion ankle movements at 90°/s for 20 subjects with FAI and 20 healthy subjects. Results were inconclusive as to if there were dorsiflexion, inversion, and eversion deficits for those with FAI, although they did find a deficit with plantarflexion. The tests that involved inversion and eversion at 30-240°/s found a difference between torque with those with FAI.[20]

Conclusions

The problem with ankle sprains has been established.[2,8,12,24,34,42] Ankle sprains may be a result of fatigued ankle musculature due to heavy bouts of exercise typically in the athletic participation. Creating fatigue from an isokinetic device, such as the Biodex, allows researchers to obtain a clinical setting similar to the fatigue from sports participation. Additionally, the measurement of balance, using the NeuroCom, allows clinicians to manipulate the conditions to alter the various systems used by the body when performing a balance task.

Future implications for a decrease in neuromuscular balance may include adding proprioceptive and strength training to the muscles of the lower extremity to the daily routine of activity to delay the fatigue. Additionally, wearing prophylactic devices such as ankle braces and taping may improve the proprioception within the ankle and therefore increase postural control. Understanding the role of prophylactic devices in maintaining balance after fatigue allows clinicians to assist in the prevention of ankle injuries.

CHAPTER III

METHODOLOGY

The purpose of this study was to compare the effectiveness of ankle braces and ankle taping in maintaining static and dynamic balance after fatigue in healthy subjects.

Subjects

A total of 24 subjects were recruited for this study. These subjects were physically active male and female volunteers between the ages 18 and 30. Exclusion criteria for subjects included any lower extremity injury within the past year, neurologic conditions, and uncorrected problems with vision. A lower extremity injury includes any medical disorder that has resulted in the loss of participation in physical activity for at least one day. Prior to participation, all subjects read and signed an informed consent document (Appendix A). Prior to the investigation, subjects also completed a medical history questionnaire to determine their potential for participation as well as a brief questionnaire pertaining to their exercise habits (Appendix B). Additionally, a brief orthopedic exam was done to each subject by a certified athletic trainer (ATC). The subjects were physically active individuals, according to the American College of Sports Medicine (ACSM) Guidelines for the Physically Fit (Appendix C).[63] These exercise recommendations require being physically active by doing moderately intense cardiovascular exercise for 30 minutes a day, 5 days a week or doing vigorously intense cardiovascular exercise 20 minutes a day, 3 days a week. The Texas State University-San Marcos Institutional Review Board approved the study prior to data collection.

Tests/Instruments

The instrument used to measure balance for this study was the Neurocom Equitest Balance System (Clackamas, OR). This device was used to assess the ability of the sensory and autonomic motor system to contribute to balance and recover from support surface disturbances. This system was used to quantify the equilibrium as well as reaction time with numerical scores to represent each trial. At the conclusion of the study, a database file compiled all the results and graphically represented the outcome of the study.

Each subject was tested on the Neurocom Equitest for their barefoot baseline measurement at the start of the study with no prophylactic device. They were required to stand on the forceplate and complete a Sensory Organization Test (SOT) and a Motor Control Test (MCT). The SOT is an assessment that incorporates six conditions: fixed surface with normal vision, fixed surface with eyes closed, fixed surface with sway-referenced vision, sway referenced surface with normal vision, sway reference surface with eyes closed, and sway referenced surface with sway referenced vision.[62] Each of the six conditions was tested two times for each of the subjects. The MCT is an assessment that identifies abnormalities in the timing and strength of the autonomic response and coordination in each leg in adapting to quick, unexpected support surface translations, either forward or backward. For this test, there were small, medium, and large translations of the Neurocom force platform.

Each subject completed the fatigue protocol using the Biodex 4 Isokinetic Dynamometer (Biodex Medical Systems, Inc., Shirley, NY) with each of the three conditions. The Biodex was used to objectively measure each subjects maximum force output for a maximum of 500 repetitions of plantarflexion and dorsiflexion at the ankle.

Each subject wore a McDavid ankle brace (McDavid 195R Ultralite Ankle Guard; Woodridge, IL), ankle tape, and had a control balance measurement in which they were barefoot. The order of treatment (taping/bracing/barefoot) was randomly counterbalanced for each subject. The McDavid ankle braces were fitted to each individual subject according to their shoe size, ranging in size from extra small to extra large (Appendix D). The ankle braces were fitted to each individual subject by a certified athletic trainer (ATC). The ankle braces were applied according to manufacturer guidelines.

The ankle taping method consisted of using 1.5 inch Johnson & Johnson tape with one layer of pre-wrap underneath (Appendix E). The ankle taping consisted of a standard technique, which was consistent for each subject as administered by an experienced ATC.

Procedures

Twenty four healthy subjects were selected based on meeting various selection criteria. A detailed questionnaire was used to narrow down the subjects to those that have not

sustained a lower extremity injury in the past year. Both undergraduate and graduate students at Texas State University-San Marcos were prospects of this study.
All subjects reported to the test site prior to initiating the treatment and subsequently submit their demographic and medical histories. The physical data included height, weight, ankle range of motion, and sex. Ankle range of motion included inversion, eversion, plantarflexion, and dorsiflexion. During all testing sessions, participants were instructed to wear appropriate clothing (gym shorts, tennis shoes, t-shirt, and socks) so that physical measurements may be obtained. During the initial assessment, participants were given a counterbalanced treatment order to eliminate a learning effect. All subjects were tested for balance on the Neurocom for both the SOT and the MCT a total of six times, with no shoes on. The Neurocom was used before and after the fatigue protocol for each subject for each of the three randomly selected conditions (control, taping, and bracing).

The fatigue protocol consisted of a pre-selected workout doing plantar flexion and dorsiflexion movements on the Biodex 4 Isokinetic Dynamometer (Shirley, NY) until fatigue is achieved at a velocity of 120°/s. Fatigue was set at the point where there was a 50% reduction of the force generating capacity for 5 repetitions of plantarflexion and dorsiflexion in a row. During completion of the fatigue protocol, each subject was asked to provide a rating of perceived exertion (RPE) (Appendix F).[64] Each subject endured the fatigue protocol a total of 3 times, on 3 separate dates, with at least 48 hours of rest between testing. Verbal motivation was given by the investigator consistently to each subject during the fatigue protocol.

Design and Analysis:

The statistical design was a repeated measures ANOVA. The demographic data generated in this investigation was originated from the health history questionnaire and the initial screening session. The data was used to describe the tested sample in terms of health and fitness status.

The dependent variables for this study were the SOT and MCT balance composite scores valued by a numerical number determined by the Neurocom EquiTest. The independent variables for this study were: (1) ankle bracing, (2) ankle taping, and (3) barefoot conditions.

When cleared for participation, each subject received a thorough explanation of the experimental procedures before completing the treatment. Permission to conduct this investigation was received by individual subject informed consent (Appendix A) and the Texas State Institutional Review Board (Appendix G). The subjects for this study were 24 randomly selected, healthy participants without a history of lower leg injury. Each participant did a balance measurement baseline test three times before each of three treatments. One baseline was completed with an ankle brace and one with ankle tape. A baseline with no prophylactic device, or barefoot served as the control measurement. Subjects completed each of the three treatment conditions in a random order. Each subject then completed a warm up consisting of 3 minutes on the stationary bike, followed by 1 minute of jumping jacks and 1 minute of jumping rope. Next, each subject completed the fatigue protocol with a Biodex workout until complete fatigue is achieved, or their maximal exertion of plantar flexion and dorsiflexion motion fell below 50% for a series of 5 plantar flexion/dorsiflexion movements in a row. The final step was to do another balance measurement. The subjects completed the fatigue protocol 3 times with each of the three categories (brace, tape, and control). The subjects' balance was measured both before and after the fatigue using a Neurocom EquiTest.

Stata Data Analysis System – Version 10 (StataCorp LP, College Station, TX) was used for the statistical analysis. The statistical tests for this study included a two-way repeated measures ANOVA. A post hoc analysis was used to determine the presence of a main effect, and the alpha level for this study was set at 0.05 for the analysis.

CHAPTER IV

MANUSCRIPT

INTRODUCTION

It is important to understand how to maintain balance during physical activity. The inability to maintain balance during sports activities has been associated with increased injury rates. Specifically, there is an extremely large number of ankle sprains seen with physical activity, so it is necessary to explore prevention methods to reduce this large number.[4,6,8-10,12,23] The high incidence of sports injuries may be due to insufficient balance. Poor balance, or postural instability, may be the foundation for ankle injury.[7,23] The ankle provides a base of support for the body and serves as a key component in postural control and the maintenance of balance.[6] Balance and postural control have been described as the coordination of muscle, joint, visual and vestibular receptors used to maintain the center of mass within the body.[14] Multiple factors within the body, such as the sensory and motor systems, are used to maintain balance.[1] Previous research shows that prophylactic ankle taping and bracing may have an effect of maintaining sensory and mechanical function at the ankle, which assist maintenance of neuromuscular stability.[25] Prophylactic devices commonly used in the athletic setting are ankle braces as well as various methods of ankle taping reduce the incidence of ankle injury.[23] Prophylactic devices, such as ankle braces and ankle tape, may reduce ankle injury, limiting ankle range of motion.[4] Ankle bracing has been shown to have a positive effect on proprioception.[2-4,23] Proprioception the awareness of the body within space and is one of the sensory inputs that control posture and balance.[2,4,6,13] Additionally, ankle taping may be used to increase cutaneous input, and as a method of improving proprioception.[3] An improvement in proprioception, therefore, may allow for an increase in balance.[6]

Fatigue is one of the leading factors that contributes to lower extremity injuries. These injuries are most commonly seen during athletic practices or competitions when the muscles of the lower extremity are unable to handle the demands of the physical activity.[25] A decrease in neuromuscular control, motor control strategies, postural control, balance and proprioception may be caused by fatigue.[1,13,20] A lack of proprioception sense may produce a decreased onset of muscle activation at the ankle joint which may allow excessive joint motions, creating injury.[2] When there is damage to the proprioceptive systems, injuries such as functional ankle instability may result.[6,11]

It is essential to determine the effect of fatigue and prophylactic devices on balance due to the frequent occurrence of lower extremity injuries from physical activity.[4,6,8-10-12,23] Athletes often wear protective or prophylactic equipment, such as ankle braces or athletic taping in an attempt to lessen the chance of injury. It can be inferred that ankle bracing and taping may be used to maintain balance after fatigue based on the research that prophylactics may increase proprioception. This study examines how prophylactic devices affect static and dynamic balance after fatigue.

Key Words: isokinetic, exercise, proprioception, equilibrium, postural control

METHODS

Subjects

Twenty-four healthy and physically active males and females (N_f= 15, N_m= 9, 22.3 ± 2.9 yrs, 171.3 ± 11.7 cm, 72.5 ± 18.0 kg) volunteered to participate in this investigation. The inclusion criterion included subjects, between the ages of 18 and 30 years old, who were physically active and have had no lower extremity injury in the past one year. A lower extremity injury included any injury that has resulted in the loss of participation in physical activity for at least one day. Physically active subjects self reported their activity as doing moderately intense cardiovascular exercise according to the American College of Sports Medicine (ACSM) Guidelines for the Physically Fit.[63] Prior to participating in the study, all subjects read and signed an informed consent form. The study was approved by the University Institutional Review Board. Ankle demographics were completed on the range of motion for the plantar flexion, dorsiflexion, inversion, and eversion in each of the three conditions (tape, brace, and barefoot) for each subject (Table 1).

Table 1. Demographic Values for Range of Motion (Mean ± SD, in degrees)

	Barefoot	Tape	Brace
ROM-Plantarflexion	57.9 ± 9.2	49.1 ± 10.6	49.0 ± 9.9
ROM-Dorsiflexion	6.3 ± 4.7	5.9 ± 3.6	5.5 ± 4.7
ROM-Inversion	20.1 ± 6.2	17.1 ± 6.2	15.4 ± 5.3
ROM-Eversion	9.4 ± 3.7	7.3 ± 4.3	7.3 ± 4.2

Instrumentation

The Neurocom Equitest Balance System (Clackamas, OR) was used to assess the ability of the sensory and autonomic motor system to contribute to balance and recover from support surface disturbances by quantifying equilibrium and reaction time. The warm up used a Schwinn Evolution Comp stationary bike (Airdyne Resistance Systems Inc., Boulder, CO). A Biodex 4 Isokinetic Dynamometer (Biodex Medical Systems Inc, Shirley, NY) was used to perform concentric plantarflexion and dorsiflexion of the ankle in order to fatigue the ankle joint. Each subject wore a McDavid ankle brace (McDavid 195R Ultralite Ankle Guard; Woodridge, IL) fitted according to their shoe size, ankle tape, and had a barefoot control balance measurement. The ankle taping method was a standard inversion taping technique, which consisted of using 1.5 inch Johnson & Johnson tape with one layer of pre-wrap underneath (Appendix E). The ankle taping was consistent for each subject and was administered by a certified athletic trainer (ATC). The primary investigator was present for all data collection and conducted every data collection session according to step by step procedures (Appendix G).

Procedures

Each subject reported to the research laboratory on 3 separate occasions. During the initial session, a health questionnaire, physical activity log, and subject information sheet (Appendix H) were reported. The principal investigator verified that the subject was eligible to participate according to the exclusion criteria. Each subject was fitted with a NeuroCom safety harness in which they were required to wear throughout the testing session. Each subject received a counterbalanced treatment of either ankle tape, ankle brace, or barefoot with a latin square design.

For each of the 3 conditions, the subjects received a static and dynamic balance assessment on the NeuroCom. The Sensory Organization Test (SOT) was the first balance assessment and six conditions were conducted with two trials each, providing a composite score ranging from 0 (fall) to 100. Following the SOT, the Motor Control Test (MCT) was completed with a randomly assigned order of either forward and backward translations in combinations with small, medium, and large perturbations of the NeuroCom force platform. The SOT and MCT balance testing was completed before and after the fatigue protocol for each of the three conditions (barefoot, tape, brace).

Each subject completed a warm up prior to the fatigue protocol during each of the three testing sessions which included 3 minutes on a Schwinn Evolution Comp stationary bike, followed by 1 minute of jumping jacks, and 1 minute of jump rope. Immediately following the warm up, the subjects were asked to sit in the Biodex chair for the fatigue protocol. The primary investigator used a manufacturer suggested seated position to fatigue the plantar flexors and dorsiflexors of each foot with the foot strapped to a pedal with the knee at a 90 degree angle. The subjects were shown a Rating of Perceived Exertion (RPE) scale that was placed within reading distance. Each subject was asked to rank their level of perceived exertion during their testing. A pilot study with ten physically active subjects aged 18 to 30 were used to determine that an amount of 500 repetitions was sufficient for a protocol that allowed for enough repetitions for the subjects to reach fatigue. The fatigue protocol was set at concentric/concentric for 120 degrees per second, and was limited by 500 repetitions. The subjects were given verbal encouragement by the principal investigator and research assistant to motivate them throughout the protocol. Once the subject completed five consecutive repetitions that fell below 50% of the maximum peak torque recorded from the testing protocol, it was determined that the subject was fatigued and they were asked to stop with the exercise. The number of repetitions, as well as the rating of perceived exertion, was recorded for each subject. The fatigue protocol was completed on the contra-lateral leg to ensure that each subject underwent the fatigue protocol for both legs. After each testing session, the subjects were encouraged to complete a cool down and seek medical aid if they were experiencing any discomforts. Additionally, testing sessions were spread out by 48 hours to prevent delayed onset muscle soreness from affecting the outcome of the balance assessment.

This study was designed to identify the effects that prophylactic devices and fatigue have on postural control, or balance. Two composite balance scores (SOT and MCT) were obtained prior to and post fatigue of three conditions (tape, brace, barefoot). The composite scores for the SOT and MCT for both the pre and post fatigue balance assessments were determined from the NeuroCom software. The SOT composite score was derived from the equilibrium scores from all trials for each of the six conditions. The MCT composite score was derived from the latency scores measured in msec.

Statistical Analysis

The means and standard deviations of the three test conditions for pre fatigue and post fatigue SOT and MCT scores were used for statistical comparison. Data analysis on pre and post fatigue SOT and MCT composite scores nested within the three conditions (tape, brace, and barefoot) was performed using repeated measures ANOVA. Stata – Version 10 (StataCorp LP, College Station, TX) software was used to perform the statistical analyses. Significance was set at $p \leq 0.05$. Cohen's d was calculated to determine the size of effect on the difference between pre and post fatigue for balance scores from the SOT and MCT with 95% confidence intervals.[65]

Results

Table 2 summarizes the descriptive values for the balance measures of the SOT and MCT. A repeated measures ANOVA was performed to determine the effect of fatigue on static balance with ankle taping and ankle bracing as scored by the SOT. The SOT composite scores represent overall balance for 6 separate conditions, and the higher number indicates a better balance score. The effects of treatment of fatigue on barefoot lower leg static balance (82.5 ± 4.9), ankle taping (82.7 ± 5.9) and ankle bracing (82.6 ± 4.8) were compared to pre-test scores of baseline static balance for barefoot (84.0 ± 3.6), ankle taping (83.6 ± 4.9) and ankle bracing (82.8 ± 5.4) conditions. No significant difference in SOT were observed among the barefoot, tape, or brace trials, $F(2,44) = 0.2$, $p = 0.819$. Also, no significant differences in SOT were observed between the pre fatigue and post fatigue conditions, $F(1,22) = 2.5$, $p = 0.131$, Power = 0.309. Lastly, there was no interaction between the bracing and fatigue conditions, $F(2,44) = 0.79$, $p = 0.458$, Power = 0.172.

Table 2. Descriptive Values for the Balance Measures (Mean ± SD)

Sensory Organization Test (SOT) Scores			
	Barefoot	Tape	Brace
Pre-Fatigue	84.0 ± 3.6	83.6 ± 4.9	82.8 ± 5.4
Post-Fatigue	82.5 ± 4.9	82.7 ± 5.9	82.6 ± 4.8
Motor Control Test (MCT) Scores			
	Barefoot	Tape	Brace
Pre-Fatigue	132.5 ± 9.9	129.5 ± 12.2	133.5 ± 12.8
Post-Fatigue	137.7 ± 24.7	132.4 ± 15.3	133.5 ± 16.3

A second ANOVA with repeated measures was performed to determine the effect of fatigue, ankle taping and ankle bracing on dynamic balance as quantified by the MCT. The MCT composite scores indicate latency, so the lower numbers indicate a quicker reaction time. The effects of treatment of fatigue on dynamic balance for barefoot (137.7 ± 24.7), ankle taping (132.4 ± 15.3) and ankle bracing (133.5 ± 16.3) conditions were analyzed and compared to pre-test scores of barefoot (132.5 ± 9.9), ankle taping (129.5 ± 12.2) and ankle bracing (133.5 ± 12.8) conditions. No significant difference was observed in pre to post fatigue conditions, $F(2,46) = 1.3$, $p = 0.261$, Power = 0.188. For the barefoot trials, mean MCT scores were 132.5 ± 9.9 for the pre-test, and slightly increased to only 137.7 ± 24.7 for the post-test. Likewise, for the tape trials, mean MCT scores were 129.5 ± 12.2 for the pre-test and slightly increased to 132.4 ± 15.3 for the post-test. However, for the braced trials, mean MCT scores were 133.5 ± 12.8 for the pre-test, and remained similar at 133.5 ± 16.3 for the post-test.

The effect size analysis for the SOT scores for pre and post fatigue barefoot balance scores was d=0.36 (95% CI -1.06 to 2.32), tape scores was d=0.17 (95% CI -1.8 to 2.52), and brace scores was d=0.04 (95% CI -2.13 to 1.95) which suggests minimal treatment effects for the ankle bracing conditions and the fatigue protocol. The effect size analysis for the MCT scores for the pre and post barefoot balance scores was d=-0.3 (95% CI -4.26 to 9.58), tape scores was d=-0.21 (95% CI -5.09 to 5.91), and brace scores was d=0 (95% CI -5.12 to 6.52) which also indicate a weak effect. No interaction was found between the bracing and fatigue conditions for the MCT.

CONCLUSION

Recognizing that caution should be observed in generalizing from these results, it was concluded that prophylactic devices and fatigue have no effect on static or dynamic balance. It was hypothesized that ankle braces are more effective than ankle taping on maintaining balance following lower extremity fatigue in uninjured subjects, although no significant differences were found. Additionally, it was hypothesized that ankle braces and ankle taping are more effective than barefoot on maintaining balance following lower extremity fatigue in uninjured subjects, although no significant differences were found. Also, this study resulted with no difference for the pre to post fatigue composite SOT and MCT scores. This resulted in the rejection of all research hypotheses.

DISCUSSION

Multiple investigations have found similar results to the present study. In a study similar to the present investigation, a measure of neuromuscular control called time to stabilization was used to evaluate dynamic postural stability, which is comparable to the MCT performed on the NeuroCom.[25] Two ankle braces were used, along with a controlled barefoot condition, and the balance measurement results showed no difference between the pre-fatigue and post-fatigue conditions, which were similar to the present study. Kinzey et al.[4] studied the effects of various prophylactic devices on postural control, and reported an increased average center of pressure from the use of the prophylactic devices. The results also indicated that there was no increase in proprioception from the use of prophylactic devices. Cattaneo and colleagues[22] found that static balance was improved by static and dynamic orthoses after investigating static and dynamic ankle foot orthoses to determine if they improved balance.

Muscle fatigue of the plantar flexors produced no difference for displacement of the center of pressure, and therefore the fatigue had no effect on the balance, both with and without vision.[1] In contrary, Vuillerme et al.[28] used a fatigue protocol where subjects performed toe lifts until they could no longer perform the task to fatigue the calf muscles and found that there was an eye-visual target distance in which postural control was dependent. Anaerobic and aerobic exercise affected postural control and used the Balance Error Scoring System to measure the postural control and found that there was an adverse effect for up to 13 minutes post fatigue.[20] Gribble et al.[26] studied the effect of lower extremity fatigue and found a significant difference found for knee and hip, although, the ankle fatigue did not affect the postural control according to the center of pressure excursion velocity values. Additionally, Gribble et al.[27] found that when the hip abductors and adductors were fatigued, they affected center of pressure excursion velocity more than the fatigue of the ankle inverters.

Harkins et al.[14] examined postural stability by reading sway velocity after fatigue and found a significant difference after a 30% and a 50% fatigue protocol using an isokinetic dynamometer and a NeuroCom. Another study observed the effect of muscle fatigue on postural control and discovered that calf muscle fatigue had a short lasting effect on balance.[18] Bizid et al.[19] also composed a study in which the calf muscles were fatigued with electrical stimulation and concluded that the time between the fatigue and the balance assessment might account for the lack of a significant effect. Typically, fatigue lasted anywhere from 35 to 75 seconds, depending on the percent reduction of peak torque, which is consistent with the present investigation.

Many investigations have explored the negative effect fatigue has on balance.[13,14,17-21,25,26,27] Exercise fatigue negatively affects postural stability due to a reduction in muscle spindle activity.[14] There are several studies comparing the effects that various prophylactic devices have on balance.[4,22,23] These investigative results will aid clinicians in the awareness of the affects fatigue has on balance which is essential when conducting sideline postural control exams during injury evaluation. Additionally, it may allow clinicians to select ideal prophylactic devices that are suitable for the individuals that they may work with on a daily basis.

A significant number of lower extremity injuries occur within sports participation and physical activity, making it important to understand how they can be prevented. By preventing these injuries, many physically active persons may continue their sports participation and daily activities without the interruption of injury. Fatigue of the plantar flexors and dorsiflexors of the lower extremity did not result in a difference between pre and post balance scores. There was also no difference in the effect of ankle taping and bracing on balance for the SOT and MCT assessment protocols. Although there was a decrease in the range of motion for both the tape and the brace conditions compared to the barefoot condition, there was no change in the balance scores either pre or post fatigue of the lower extremity.

In the present investigation, the exercise protocol may not have fatigued the ankle musculature to the extent of affecting stability in terms of center of gravity and neuromuscular latency. Future investigations should incorporate whole body fatigue to create more sport specific environments in the laboratory setting. There is also the possibility that the subjects may have adopted a hip strategy to compensate for the ankle fatigue and may have used this new strategy to maintain their balance after fatigue. The implementation of a hip strategy after lower extremity fatigue should be studied in further detail as well. Additionally, the individual raw scores for the SOT and MCT should be examined rather than the composite scores.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The previous study investigated the effects of prophylactic devices and fatigue on static and dynamic postural balance. There were no significant differences between the pre and post balance scores for both the SOT and the MCT in all three conditions (barefoot, tape, brace). Previous research has shown that there is a decrease in balance, and postural stability following exercise fatigue.[1,13,20] The present study shows that fatigue has no effect on balance and each research hypothesis was rejected.

Recommendations

This study investigated the effects of prophylactic devices and fatigue on static and dynamic balance. The NeuroCom Equitest Balance System was used to assess the static and dynamic balance with the composite scores for the SOT and MCT. The results of these assessment protocols indicated that there were no effects of the fatigue on balance nor of the prophylactic ankle support on balance. This may be due to the lack of sensitivity of the assessment tool, therefore, future investigations should incorporate the use of other balance assessments with greater sensitivity to the change in center of pressure or latency. Additionally, the NeuroCom used a broad age group for the composite scores (20 to 59 years) and, therefore, the subjects aged 18 and 19 were grouped into this category due to the unavailability of norms for their age group.

The original number of subjects used for this study was 30, however, only 24 subjects completed all three testing sessions. Four subjects dropped out of the study due to the lack of time available, and 2 subjects were injured between testing sessions. Therefore, these subjects were no longer qualified to participate. In the hope that future research will explore further the problem at hand, it is recommended that a larger subject pool would increase the power of the statistical influence. Also, the present study did not investigate the relationship between males and females and the differences in their balance strategies. Further research is warranted to determine if there is a difference between the balance of males and females.

The present investigation used the Biodex isokinetic dynamometer system, which has previously been shown to induce quantifiable levels of fatigue.[60] Incorporating a fatigue protocol that fatigues the whole body may introduce a different experimental result. Additionally, the present study did not consider the foot type of the subjects. Future investigations involving the foot type of the subjects, such as a supinated or pronated foot, may allow for researchers to identify common abnormalities in balance. The foot type may have an effect on the balance of the individual and therefore should be considered during future research.

This investigation was conducted on subjects with healthy ankles. Establishing the effect of balance in braced and taped ankles needs to be studied in a population of unstable ankles. Many of the subjects of the present study were inexperienced with the use of the braces and tape, therefore, future investigations should look at the effects of long term use of the braces and tape on balance after fatigue. This would allow the subjects to adapt to the new ankle appliance and the resulting post fatigue balance scores may change.

Additionally, future research should incorporate various methods of fatigue to determine if the fatigue protocol used in the investigation was not sufficient to alter the balance of the subjects in the study. Further research should also incorporate the comparison of various fatigue protocols.

APPENDIX A

Consent Form
for Participation in:
The Effect of Prophylactic Devices and Fatigue on Balance
Department of Health, Physical Education, and Recreation
Texas State University

IRB Approval #: 2009F4082

The principal investigator is Alanna Shay. The researcher can be contacted by email: as1673@txstate.edu, or phone: 512-245-9282.

Faculty Supervisor: Jack Ransone, PhD, Professor of Athletic Training. Dr. Ransone may be contacted by email: ransone@txstate.edu, or phone: 512-245-8176.

INTRODUCTION AND PURPOSE OF THE STUDY

You have been asked to participate in a research study to assess your balance after fatigue with two prophylactic measures which will include ankle taping and ankle bracing. You will be chosen based on completion of the initial pre-participation questionnaire admitting no previous injuries to the lower extremity in the past year. The investigation will help to determine if ankle bracing and ankle taping help to maintain balance after exercise of the lower extremity. Your participation is strictly voluntary and you may choose to stop any of the procedures at any time for any reason.

You will be evaluated in the Athletic Training Research Lab at Texas State University in the Jowers building, room D108. The following form includes more details regarding the research. If you have any questions or concerns about the study, please ask before you decide to participate.

PROCEDURES

Each subject will be instructed to wear athletic clothing, including a t-shirt, gym shorts, tennis shoes, and socks. Workout clothing is necessary for the completion of testing, which will be explained in detail below. The following are the procedures for the study which will take approximately 30 minutes to complete:

1. **Pre-participation information**: Before participation in the study, each subject will complete a questionnaire with 20 questions about the subject's general health and history of injuries. A certified athletic trainer will also determine if the subject has the physical capability to complete the study by measuring general joint motion and checking the alignment of the spine, arms, and legs.

2. **Control/treatment**: The subjects will be asked to either remove their shoes for a barefoot assessment or allow a certified athletic trainer to apply ankle tape or ankle braces to their ankles.

3. **NeuroCom**: The subjects will be fitted for a safety harness which is a vest with straps that attach to the top of the NeuroCom machine and will prevent the subject from falling. The NeuroCom is a machine used to measure balance. It has a balance plate approximately the size of a bathroom scale that the subject will stand on.

4. **Biodex set up**: The Biodex is an exercise machine used to measure the power of the subject's leg. The subjects will sit in the Biodex chair while the principal investigator to set up the lever arms at the appropriate area to allow the patient to point toes down as far as possible and then bring toes as far up to shin as possible.

5. **Warm up**: Prior to testing, subjects will complete a 5-minute warm up on the stationary bike, followed by 1 minute of jumping jacks, and 1 minute of jump rope.

6. **Biodex**: The subjects will complete the exercise protocol on the Biodex. Both ankles will be tested by bending the foot back and forward. The principal investigator will instruct the subject on how to use the machine to make the muscle tired.

7. **NeuroCom**: Immediately after the exercise protocol, the subjects will be asked to step on the NeuroCom plate in order to test for balance. Once testing is completed, they may remove the safety harness.

8. **Cool Down**: Once the testing is completed, the subjects will be asked to step on the treadmill for a 5 minute cool down, followed by calf stretching on a slant board.

POTENTIAL RISKS AND DISCOMFORTS

Subjects will be informed about the nature of what is involved as a participant of this study, including a description of anything they might consider to be unpleasant or a risk. The potential risks for this experiment are minimal because the subjects will be supervised by the principal investigator during the duration of the study; however, with any exercise, there are potential risks for injury. Minor discomforts may be experienced due to the exercise phase of the experiment. Warming up prior to the exercise protocol will minimize the risks.

If an emergency occurs during testing, the subjects will be instructed to exit the building immediately. If it is a medical emergency, then emergency services will be contacted.

The primary investigator is Professional Rescuer Certified and will assist with all emergency situations until EMS arrives on the scene. In the event that the participant will require medical attention, the participant will be responsible for covering all medical expenses.

POSSIBLE BENEFITS

The benefits from this investigation will provide information for the athletic and medical community. Also, the results from this investigation may help you learn about:

- Your overall balance
- Your endurance level of your lower extremity
- Body movement deficits

CONFIDENTIALITY

Each subject in this study will be issued a number to differentiate the results found between subjects and to maintain the confidentiality of the subject's information and results. Name, social security numbers, telephone numbers, and address are not required for testing; however, name and phone number are required for this form. Results from the study may be shared for future research except for the consent forms. If consent from material is needed for research purposes, then the subjects will be contacted for additional written consent for release of their information. All data from this project will be kept in the supervisor's office in a locked file cabinet to avoid loss of confidentiality. In order to maintain confidentiality, the recorded data will be kept for up to 5 years total. After this 5 year period, all information and data will be destroyed.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. You may choose to stop the exercise at any time for any reason. If you decide to participate, you may withdraw from the study at anytime without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed. If you have any other questions regarding the research, research participants' rights, and or research-related injuries to participants, please contact the IRB chair, Dr. Jon Lasser, (512)245-3413, lasser@txstate.edu or Ms. Becky Northcut, Compliance Specialist, (512)245-2102.

AUTHORIZATION

The Athletic Training Program supports the practice of protection for human subjects participating in this research and related activities. The consent form is provided so that you can decide whether you wish to participate in the present study.

"I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and know that I am free to ask questions as they may arise. I likewise understand that I can withdraw from the study at any time without being subjected to reproach."

Contact Alanna Shay, Principle Investigator, at (512)245-9282 or email at as1673@txstate.edu if you have any questions.

____________________________________ ______________________

Participant Name Printed (18 yrs or older) Phone #

____________________________________ ______________________

Signature Date

____

Principle Investigator Signature

APPENDIX B

PRE-PARTICIPATION PHYSICAL EVALUATION- MEDICAL HISTORY

Answer all questions. Explain any yes answers below.

Yes	No	General Information:
⬭	⬭	1. Have you had a medical illness or lower extremity injury within the past year?
⬭	⬭	2. Have you been hospitalized overnight in the past year for a lower extremity injury?
⬭	⬭	3. Have you had surgery in a lower extremity in the past year?
⬭	⬭	4. Are you currently taking any prescription or non-prescription (over the counter) medication pills or using an inhaler?
⬭	⬭	5. Do you have any health issues that may warrant physician approval before engaging in physical activity?
Yes	**No**	**Symptoms—Do you:**
⬭	⬭	6. Have any allergies?
⬭	⬭	7. Get dizzy after exercise?
⬭	⬭	8. Have chest pain during or after exercise?
⬭	⬭	9. Have racing of your heart or skipped heartbeats?
⬭	⬭	10. Have high blood pressure or high cholesterol?
⬭	⬭	11. Have any current skin problems (ex: itching, rashes, acne, warts, fungus, or blisters)?
⬭	⬭	12. Have you ever had a seizure? If so, when?
⬭	⬭	13. Have any problems with your eyes or vision?
⬭	⬭	14. Have any problems with hearing?
⬭	⬭	15. Have vertigo?
		16. Have any swelling in any of your lower extremities?
Yes	**No**	**Other:**
⬭	⬭	17. Have you had a severe viral infection within the last month or do you have one currently?
⬭	⬭	18. Have you ever had a head injury or concussion? If so, when?
⬭	⬭	19. Have you ever broken or fractured any bones or dislocated any joints?

Explain all yes answers:

Emergency Contact: Name_______________ Phone Number________________

I certify that all that all the information on this form is correct.

____
Date

____
Signature of Participant

____
Date

____
Signature of Primary Investigator

PRE-PARTICIPATION PHYSICAL EVALUATION- SUBJECT INFORMATION

Activity Level:

1. Are you physically active? y/n
   (Physically active means that you do at least 30 minutes of moderately intense cardio 5 days a week or doing vigorously intense cardio 20 minutes a day, 3 days a week)

   Please list the activities that you do for physical activity and include how long and for how many days per week:

APPENDIX C

ACSM GUIDELINES FOR PHYSICAL FITNESS

Guidelines for healthy adults under age 65:

Basic recommendations from ACSM:

Do moderately intense cardio 30 minutes a day, five days a week
Or
Do vigorously intense cardio 20 minutes a day, 3 days a week
And

Do eight to 10 strength-training exercises, eight to 12 repetitions of each exercise twice a week.

Moderate-intensity physical activity means working hard enough to raise your heart rate and break a sweat, yet still being able to carry on a conversation. It should be noted that to lose weight or maintain weight loss, 60 to 90 minutes of physical activity may be necessary. The 30-minute recommendation is for the average healthy adult to maintain health and reduce the risk for chronic disease.

Haskell, W., Lee, I., Pate, R., Powell, K., Blair, S., Franklin, B., Macera, C., Heath, G., Thompson, P., and Bauman, P. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med. Sci. Sports Exerc,* 39(8), 1423-1434.[63]

APPENDIX D

SIZE CHART

McDavid 195R Ultralite Ankle Guard Universal Size Guide:

Size	Men's Shoe Size	Women's Shoe Size
XS	6-7	7-8
S	8-9	9-10
M	9-11	10-12
L	11-13	12-14
XL	14 & Over	15 & Over

APPENDIX E

ANKLE TAPE METHOD

The ankle taping method will consist of 2 proximal anchors, 2 stirrup strips, c-strips from the heel to the proximal anchor strip, 1 figure 8, 2 heel locks (one medial and one lateral), and close up strips using 1.5 inch Johnson & Johnson tape with one layer of Mueller pre-wrap underneath.

APPENDIX F

BORG'S RPE SCALE	
6	Very, very light
7	
8	
9	Very light
10	
11	Fairly light
12	
13	SOMEWHAT HARD
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Borg, G. Borg's Perceived Exertion and Pain Scales. Human Kinetics. 1998. (Figure 7.3, page 49).[64]

APPENDIX G

STEP BY STEP PROCEDURES FOR DATA COLLECTION:

1. **Go over consent form and health questionnaire and sign.**
    a. Verify that the subject has not had any lower extremity injury in the past year.
    b. Notify the subject that they will be performing physical activity during the study.
    c. Answer any questions that the subject may have and sign the document.
    d. Ask the subject the following questions and document on the "subject information sheet"
        i. Issue subject # to keep track of data and keep information confidential
        ii. Height
        iii. Weight
        iv. Which leg would you kick a soccer ball with to determine leg dominance?
2. **Quick ortho screen.**
    a. Instruct the subject to remove socks and shoes
    b. Ask the subject to do a body squat
    c. Have the subject sit on the exam table and complete an assessment of ROM of plantarflexion, dorsiflexion, inversion, and eversion.
    d. Mark pass or fail on the "subject information sheet"
3. **Ask the subject if they have any questions.**
4. **Instruct subject to sit on the Biodex to allow for proper seat and attachment placement and to set the limits of the range of motion.**
    a. Attach the thigh rest under the seat and lock in place so that the leg is at a 90 degree angle.
    b. Attach the foot pedal so that it reaches the bottom of the test leg and allows for plantarflexion and dorsiflexion without loss of contact of the pedal.
    c. Enter subject information into the Biodex system and select appropriate fatigue protocol.
        i. Select Protocol: Isokinetic Bilateral: Ankle Plantarflexion/Dorsiflexion: 120/120: Alanna Shay: Thesis
    d. Set the limits of ROM for the first test leg.
5. **Apply the safety harness to the subject and set up the subject for the Neurocom.**

a. Align feet on the grid of the platform: with medial malleoli in line with the thick horizontal stripe and the lateral calcaneus in line with the S,M, or T-Line (short(30-55in), medium(56-65in), or tall(66+ in)).
b. Instruct the subject to look forward and to stand as still as possible for the remainder of the test.
c. Enter subject information into the NeuroCom computer system
    i. Select File cabinet: new patient: fill in appropriate blanks: save: assessment: SOT and MCT: Allign foot: start
d. Start the NeuroCom Pre-Fatigue test
    i. Complete the Sensory Organization Test and the Motor Control Test
e. Remove the attachments for the harness

6. Subject must put on socks and shoes and begin the warmup
a. 3 minutes on bike
b. 1 minute jumping jacks
c. 1 minute jump rope
d. Remove shoes and socks for the Biodex testing

7. Treatment
a. The subject will either be taped, braced, or asked to remain barefoot
b. An assistant (a certified ATC) to the principle investigator will be asked to apply the treatment (taping or bracing) to the subject

8. Biodex Testing
a. Instruct subject to sit in the seat while the investigator places and tightens appropriate straps
b. Make sure the subject's test leg is at 90 degrees and they are able to plantarflex/dorsiflex with their foot on the pedal so that their heel does not lift up
c. Secure all straps and hand the emergency stop handle to the subject
    i. Explain to subject: if at any point during this test you feel you need to stop the test, push this emergency stop button
d. Show the subject the RPE scale and inform them that they will be asked what their rating is periodically throughout the testing
e. Press start on the Biodex screen and ask the subject to do a couple of trial runs to get a feel of the motion they will be performing
f. Once the honk sounds, the subject is to start pumping their ankle (performing ankle plantarflexion/dorsiflexion motions repeatedly) as hard and as fast as they can until the investigator tells them to stop
g. The assistant will take over the motivating of the subject and periodically ask the subject to give their RPE from the chart that will be displayed in front of them
h. The investigator will watch the screen and note the highest torque completed by the subject and hightlight the mark on the screen
i. The 50% mark will automatically be highlighted
j. After the torque falls under 50% for 5 consecutive runs, the subject may stop

k. The test leg will then be switched and the appropriate straps and Biodex attachments will be set in place
l. Repeat 7a-7h for the new test leg
m. Immediately remove all straps and help the subject to remove themselves from the chair

9. NeuroCom Testing

a. Repeat steps 4a-4e

10. Repeat steps 3-8 with at least 24 hours between

a. Each test day will be completed with a different treatment
b. Encourage the subjects to stretch afterward and in the time between sessions do decrease their risk of DOMS.

11. Thank each subject for their participation in the thesis study

APPENDIX H

SUBJECT INFORMATION SHEET

Date: ________________

Subject #: ____________

Has subject completed the following:
- o Consent Form (signed and dated)
- o Health Quesionnaire
- o Physical Activity Form

Age: ____

If female, date of last menstrual cycle: _________

Ortho-Screen Lower Extremity: PASS or FAIL

Goniometric Measurements:

Barefoot		Tape		Brace	
Plantarflx		Plantarflx		Plantarflx	
Dorsiflx		Dorsiflx		Dorsiflx	
Inv		Inv		Inv	
Ev		Ev		Ev	

Height: _____

Weight: _____ lb

Dominant Leg: RIGHT or LEFT

Subject #: ____
(Brace/Tape/Barefoot)

NeuroCom Pre-Fatigue Scores:

- SOT

	Equilibrium			**Strategy**			**COG Alignment**					
Conditions	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1		Trial 2		Trial 3	
1												
2												
3												
4												
5												
6												

Composite Score:

- MCT

	Weight Symmetry	**Latency (msec)**		**Amplitude Scaling**		**Strength Symmetry**
Translation		**Left**	**Right**	**Left**	**Right**	
Small B						
Med B						
Large B						
Small F						
Med F						
Large F						

Composite Score:_____

Biodex Scores:

L. Ankle			#Reps:
	Away	Toward	
Peak Torque			
Total Work			
%CV			

R. Ankle			#Reps:
	Away	Toward	
Peak Torque			
Total Work			
%CV			

NeuroCom Post-Fatigue Scores:

- SOT

	Equilibrium			**Strategy**			**COG Alignment**					
Conditions	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1		Trial 2		Trial 3	
1												
2												
3												
4												
5												
6												

Composite Score:

- MCT

	Weight	**Latency (msec)**		**Amplitude Scaling**		**Strength**
Translation	**Symmetry**	**Left**	**Right**	**Left**	**Right**	**Symmetry**
Small B						
Med B						
Large B						
Small F						
Med F						
Large F						

Composite Score:_____

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