This is to certify that the
thesis entitled

The effect of ankle support on postural stability using the
BESS test

presented by

Natalie Herter

has been accepted towards fulfillment
of the requirements for the

Masters degree in Kinesiology

Jerry Corassini
Major Professor's Signature

4/17/09

Date

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.
MAY BE RECALLED with earlier due date if requested.

DATE DUE	DATE DUE	DATE DUE

THE EFFECT OF ANKLE SUPPORT ON POSTURAL STABILITY USING THE BESS TEST

By

Natalie Herter

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Kinesiology

2009

ABSTRACT

THE EFFECT OF ANKLE SUPPORT ON POSTURAL STABILITY USING THE BESS TEST

By

Natalie Herter

Purpose: To investigate the effect of wearing an ankle brace or ankle tape on postural stability as measured by the BESS test. To investigate gender differences of postural stability as measured by the BESS test.

Participants: A total of 55 subjects volunteered to participate in the study. There were 26 male subjects and 29 female subjects

Methods: The BESS test consists of six-20 seconds conditions: double leg, single-leg, and tandem (heel-to-toe) stances on a firm surface and a foam surface. All participants randomly performed all six stances with ankle tape, ankle brace and no ankle support with a five-minute rest between each condition. Descriptive, MANOVA, and pairwise comparisons were used for statistical analyses. Level of significance was set prior at $P<.05$.

Results: There were significant differences between ankle conditions. Results indicated that participants performed best with no ankle support, followed by ankle brace, and lastly, ankle tape. There were no significant differences between genders ($p= .260$).

Conclusion: This study demonstrated that ankle tape or ankle brace has an effect on an individual's postural stability as measured by the BESS test. Therefore, the BESS test should be performed in the same condition for baseline measures in which post-injury testing will most likely be conducted.

ACKNOWLEDGMENTS

To begin with, I would like to thank Mike Schroeder for helping form the initial idea of this study and starting me on the research. You made the start of this journey a lot smoother; thank you! I would also like to thank other fellow classmates for their help, support and answering those small tedious questions, especially Greg and Amanda.

I would also like to thank my committee members Dr. Tom Mackowiak, Dr. Jeff Kovan, and Dr. Tracey Covassin. To Dr. Mackowiak, thank you for being on my committee, your support, and your genuine interest in this research. To Dr. Kovan, thank you for your knowledge and support. To Dr. Covassin thank you for keeping me motivated and on-schedule through this long process and for all your hard work and effort.

I would like to thank Danielle McKenzie for her assistance in data collection. Thank you for toughing out those long days and nights without one complaint. Hopefully it helped prepare you for your thesis at least a little! Good luck! I would also like to thank Mark Kidwell for his assistance in the tedious, monotonous tasks.

Lastly, I would like to thank all of the participants who volunteered for this study.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1

Introduction

Overview of the Problem

A concussion can be a serious injury for all sports. Making a proper return to play decision can be difficult for medical personnel due to a myriad of signs and symptoms that are not always observable to sports medical personnel. The Balance Error Scoring System (BESS) test is one aspect of concussion evaluation and management. However, numerous variables may affect the results of the BESS test including ankle bracing and taping. The BESS test is commonly used to assess and evaluate impairment of balance and coordination following a concussion (Riemann & Guskiewicz, 2000). The BESS is thought to help determine postural stability in a fast and effective way. Athletes are usually administered a baseline BESS test in a quiet controlled environment. However, an athletes' post-concussion test primarily takes place on the sidelines with several extraneous variables that may affect balance. Specifically, the BESS test is done on the sidelines in competitive shoes, ankle and knee bracing, or ankle prophylactic tape, which may affect an athletes' BESS test scores. According to Onate, Beck, and Van Lunen (2007) further research needs to be done to determine the effects of ankle bracing and taping on balance as measured by the BESS. If sports medicine personnel do not have an accurate score from the BESS test, it may potentially affect their return to play decision for concussed athletes.

Along with ankle support another variable to consider is gender. Unlike ankle support it is not something that can be changed, however, it is still a variable that can affect post-injury scores if an athletes' BESS score is not compared to their baseline. Researchers have determined that males have poorer postural stability compared to females due to differences in body heights (Kinney LaPier et al., 1997). In another study by Ekhdahl et al. (1989), women were found to be more stable than men on traditional functional balance tests and a force platform test. However, most research examining gender differences and postural stability have been studied in the elderly. If gender differences in postural stability exist in young adults it should be something considered when performing a BESS test, especially if a baseline was not administered for post-concussion comparisons.

The BESS test can help determine postural stability without needing to use complex or expensive equipment. It consists of three different stances on two different surfaces. The three stances are shoulder width, tandem stance, and single-leg balance. A scoring error results for every correction made to maintain the body stance. There have been numerous studies researching the effectiveness of the BESS as well as possible variables that could affect the results of a BESS test. According to a study by Riemann and Guskiewicz (2000), they determine that the BESS test is a useful procedure to help personnel when making a return-to-play decision when comparing its results to force-platform equipment. Even though the BESS test is considered valid and reliable there are variables that could affect the results. Susco, McLeod, Gansnedert, and Shultz

(2004) discovered that fatigue up to 20 minutes can result in an athlete having an increased BESS score (decreased performance). Onate, Beck, and VanLunen (2007) discovered that an uncontrolled environment (several distractions) can also impact an athletes' BESS score. The type of athlete has also been shown to influence BESS test scores and their ability to balance (Bressel, Yonker, Kras, & Heath, 2007). There are also variables that have been known to impact the BESS test such as dehydration (Patel, Mihalik, Notebaert, Guskiewicz, & Prentice, 2007). However, to date no study has examined the BESS test and ankle support.

Even though the BESS test has not been used to study postural stability with ankle support, there have been other methods used to help determine if there is a difference with postural stability and ankle support. Kinzey, Ingersoll, and Knight (1997) looked at center of gravity (used to determine proprioception) with and without ankle bracing. The researchers did not find any conclusive evidence to support or refute the concept that ankle bracing increases proprioception. Palmeiri, Ingersoll, Cordova, and Kinzey (2002) conducted a similar study on center of gravity while wearing an ankle brace for four days. The researchers concluded there was no difference between ankle support and no ankle support. Thus, more research is needed to determine if ankle support affects postural stability.

Significance of Problem

According to Thurman, Branche, and Sniezek (1998) more that 300,000 people suffer mild traumatic brain injuries each year, most of which are sports-related concussions. Assessment and management of sports-related concussion should be a multifaceted approach that includes the BESS test. If the BESS test is not assessed properly, then it could affect when an athlete is returned to play following a concussion. If an athlete returns to play too soon and sustains a second concussion, it could result in catastrophic consequences due to second impact syndrome (Cantu & Voy, 1995). Second impact syndrome results in a rapid increase of pressure in the brain and is fatal 50% of the time (Cantu & Voy, 1995). Furthermore, if an athlete returns to play too soon and does not suffer another head injury, there can still be further neurological complications. They can have reoccurring concussion symptoms or decreased neurological function such as memory, concentration, or attention (Guskiewicz, McCrea, Marshall, Cantu, Randolph, Barr, Onate, & Kelly, 2003). Sallis and Jones (2000) stated that post-concussion syndrome also occurs in about 25% of the population that suffers from a concussion. Post-concussion syndrome is when the person exhibits persistent symptoms post injury (Sallis & Jones, 2000). On the other side, if an athlete is recorded to have a lower BESS test score because of variables (e.g. ankle support) not related to the head trauma, they might potentially lose practice and game time that could be considered valuable to the athletes, coaches, and team. Therefore determining the affect of ankle bracing and taping on the BESS test can help medical personnel make a more informed return to play decision along with other concussion assessment protocols.

When someone suffers a concussion they can have several possible signs or symptoms, such as memory loss, decrease postural stability or balance, nausea, loss of concentration, etc. depending on the area of the brain affected. The BESS test focuses on a possible decrease of postural stability and balance when someone sustains a concussion. The cerebellum is responsible for balance and coordination. In addition, there are somatosensors throughout the body that receive information from your senses, which is then processed in your brain. For balance there are the mechanoreceptors, visual receptors, and vestibular (hearing) receptors (Martini, 2004). The information received by these sensors are sent via afferent nerve pathways, processed in the central nervous system, sent back along the efferent pathways and resulting in an action (Martini, 2004). Visual and vestibular sensors would not be affected by ankle taping or bracing, but the mechanoreceptors may be affected by ankle taping or bracing. The taping and bracing can cause different signals being sent to the central nervous system due to different pressures or proprioception due to the ankle support. Therefore it is important to determine if ankle support could affect the outcome of the BESS test. In addition, knowing this information will help medical personnel make an informed return to play decision to reduce the risk of further injury to the head

Problem Statement and Research Plan

The purpose of the study is to investigate the effect of wearing an ankle brace or ankle tape on postural control as measured by the BESS test. A secondary purpose is to determine if gender differences exist on the BESS test while wearing an ankle brace or ankle tape.

Hypotheses:

1. There will be no difference on postural stability between ankle bracing, ankle taping, and no ankle support as measured by the BESS test.
2. There will be no difference between genders on postural stability between ankle bracing, ankle taping, and no ankle support as measured by the BESS test.

Definitions of Terms

Ankle Bracing- In this study we will be using a lace-up style brace. The lace-up ankle brace restricts plantarflexion. It restricts movement in both the frontal and sagital plane (Cordova, Scott, Ingersoll, & LeBlanc, 2005). The purpose of ankle bracing is to restrict movement to decrease the occurrence of ankle injuries.

Ankle Taping- In this study we will use the ankle taping technique, closed basket weave, described in Arnheim's Principles of Athletic Training (Prentice, 2003). It offers strong tape support and is most commonly used for acute ankle sprains or chronic instability (Prentice, 2003). It restricts movement to decrease the occurrence of ankle injuries.

Balance Error Scoring System (BESS) test- The Balance Error Scoring System was developed to be used as a standardized, objective assessment tool of postural control. It uses three stances (double leg, single leg, and tandem stance) on both firm and foam surfaces (Reimann and Guskiewicz, 2000).

Concussion- A concussion is a complex process affecting the brain, occurring through traumatic biomechanical factors (Aubry, Cantu, Dvorak, Graf-Baumann, Johnston, Kelly et al., 2002).

Postural Stability- Being in a straight line with symmetry throughout the body from the head to the feet (Prentice, 2003; Greenman, 2003). If someone has good postural control they should be able to keep their balance with few or no adjustments needed. The body is able to have postural control by its' orientation with respect to gravity, visual and somatosensory information (McCollum, 1996).

Chapter 2

Review of Literature

The review of literature will be divided into six major sections. First, an overview of concussion including concussion incidence, concussion injury rates, and concussion assessment and management will be discussed. Second, an overview of the ankle will include ankle anatomy, ankle injury rates and ankle sprains. Third, balance will focus on the visual system and vestibular system. The fourth section will examine the BESS scoring system. The fifth section will focus on ankle support including ankle taping and ankle bracing. Finally, this review of literature will discuss gender differences and postural stability.

Concussion Incidence and Injury Rates

According to the National Collegiate Athletic Association (NCAA) injury surveillance system, football, female soccer, and female basketball had concussions account for approximately six to eight percent of all injuries during the 2005-2006 academic year (Gessel, Fields, Collins, Dick, & Comstock, 2007). The highest incidence for all sports in both high school and collegiate was approximately 15 % in high school female soccer (Gessel, Fields, Collins, Dick, & Comstock, 2007). Football, male and female soccer, volleyball, male and female basketball, wrestling and softball for both collegiate and high school all reporting concussions (Gessel, Fields, Collins, Dick, & Comstock, 2007). Out of those nine categories, seven (all except volleyball and men's basketball) had a higher incidence rate of concussions, in high school when compared to collegiate (Gessel, Fields, Collins, Dick, & Comstock, 2007). During the 2002-2003 NCAA season, eight percent of all injuries occurring in football were concussions (McCrea, Guskiewicz, Marshall, Barr, Randolph, Cantu, et al., 2003). However, it is important to remember that, although concussions are considered common in football, they still occur in many other sports.

Overview of Concussions

The definition of concussion has continued to be a topic of controversy among sports medicine professionals (Oliaro, Anderson, & Hooker, 2001). A concussion is defined as a clinical syndrome characterized by immediate and transient posttraumatic impairment of neural functions (Prentice, 2003). Currently there is no agreement among researchers or clinicians with respect to defining a concussion, measuring severity, diagnostic measures, and return-to-play criteria. Concussions can be categorized in three different grades, with a grade 3 being the most severe. According to the American Academy of Neurology (AAN) Concussion Grading Scale, a Grade 1 or mild concussion is transient confusion, no loss of consciousness, and symptoms or abnormalities resolve in 15 minutes or less. A Grade 2 or moderate concussion consists of transient confusion, no loss of consciousness, and symptoms or mental status abnormalities lasting longer then 15 minutes. Lastly, a Grade 3 concussion is considered to be any loss of consciousness (AAN, 1997). On the other hand the Concussion in Sport Group (CISG) states how grading scales may not be appropriate for categorizing concussions. They suggest using combined methods for recovery should be used to assess severity and/or prognosis of a concussion. According to CISG a loss of consciousness is not needed to diagnose a person with a concussion. There is a list of 20 possible signs and symptoms (with a range of one to six for severity) along with neuropsychological testing to determine the severity of the concussion (Aubry, Cantu, Dvorak, et al., 2001).

Concussion Return to Play Guidelines

If a concussed athlete returns to play too soon it can result in catastrophic consequences (Guskiewicz, Bruce, Cantu, et al., 2004), therefore, sports medicine professionals need to be accurate in their management of concussed athletes. In order to properly determine the symptoms and whether or not an athlete should return to play there are several methods certified athletic trainers (ATC) could utilize. The Concussion in Sport group did not endorse any return-to-play guidelines, however, they recommended a new stepwise protocol for return-to-play (Aubry, Cantu, & Dvorak, 2001). The Vienna return-to-play guidelines were developed based on the Canadian Academy of Sports Medicine Committee guidelines published in 2000. This protocol begins with no activity or complete rest until the concussed athlete is asymptomatic. Once asymptomatic, the injured athlete would perform light aerobic exercise with no resistance training (Aubry, Cantu, & Dvorak, 2001). If the athlete continues to be asymptomatic then he or she can proceed to the next stage. The following stages (e.g., sport specific exercise, non-contact drills, etc.) must be completed without symptoms returning over a 24-hour period (Aubry, Cantu, & Dvorak, 2001). If symptoms return, then the athlete must revert back to the preceding stage until asymptomatic then begin this stepwise progression from this point forward (Aubry, Cantu, & Dvorak, 2001). Once the athlete can complete non-contact drills without experiencing symptoms he or she can begin full contact drills and return to game play with medical clearance (Aubry, Cantu, & Dvorak, 2001). The NATA position paper recommends a similar protocol for returning a concussed athlete back to participation. If the concussed athlete is asymptomatic after exertional maneuvers (biking, push-ups, jogging); the athlete can progress to sport specific skills. Upon completion of symptom-free sport-specific skills, a neuropsychological and postural-stability assessment is recommended prior to full contact participation. The NATA position paper does not recommend a time-frame (e.g., 24 hours) between each progressive step, which is a major difference from the Vienna Guidelines.

Evaluation of Concussion

The evaluation of concussions should be a multifaceted approach that includes, postural stability, mental screening, a symptom checklist and neuropsychological testing (Guskiewicz, Bruce, Cantu, Ferrara, Kelly, McCrea, Putukian, & McLeod, 2004). Concussed athletes should not be returned to play unless they are asymptomatic and their neuropsychological scores are back to baseline (Aubry, Cantu, & Dvorak, 2001).

Mental Status Screening

Concussions can be assessed using a mental status screening test. The most widely used and reliable and valid test is the Standardized Assessment of Concussion (SAC). It measures orientation, immediate memory, concentration, and delayed recall. This can be performed in five minutes and is very "on the field" friendly. It consists of being able to remember a set of words at varying times, being able to answer basic questions about date, time, location, and being able to recite the months of the year backwards.

Balance Error Scoring System (BESS)

The BESS test consists of a total of six stances, three on a firm surface and the same three stances on an unstable (medium density foam) surface. All stances are done with the person's eyes closed with their hands on their iliac crests. The stances consists of feet shoulder width apart, a tandem stance (one foot in front of the other, nondominant in the rear), and the last stance is single-leg on the person's non-dominant leg (Prentice, 2003). The participants must hold their balance as best as possible. For every error made (i.e. bending at the hip, opening their eyes, etc) a point is added. Errors possible are: lifting hands of the iliac crest, opening the eyes, stepping, stumbling, or falling, moving the hip into more than a 30 degrees of flexion or abduction, lifting the forefoot or heel, and remaining out of the testing position for more that five seconds. Each separate stance is scored individually. For each error performed by the athlete, he/she will receive one point. If a same error is performed more than once during a single stance (within the 20 seconds), he/she will receive a point for each time that error is performed. The BESS test has significant correlations with the force-platform sway measures, with inter-tester reliability coefficients from .78 to .96. The BESS is thought to be a valid and reliable measurement of postural stability without having to use complex and/or expensive equipment

(Riemann & Guskiewicz, 1999). The higher the score the worse the person performed.

Neuropsychological testing

As a result of the difficulty in detecting signs and symptoms of concussions in athletes, neuropsychological testing has become an objective method for determining subtle cognitive changes associated with concussed athletes (Barth, Alves, Ryan, et al., 1989; Collins, Grindell, Lovell, Dede, Moser, & Phalin, 1999; Erlanger, Saliba, Almquist, Webright, & Freeman, 2001). Neuropsychological testing has evolved from the traditional paper and pencil test to the computerized test. There are currently four computerized neuropsychological tests available to the consumer: Automated Neuropsychological Assessment Metrics (ANAM), Immediate Post concussion Assessment and Cognitive Testing (ImPACT), Concussion Resolution Index (CRI), and CogSport.

Barth et al. (1989) conducted the first major study using preseason baseline neurocognitive measures on 2,350 collegiate athletes from 10 NCAA Division 1A football programs. All athletes who sustained a concussion during the season were reassessed 1, 5, and 10 days post-injury. Results indicated concussed athletes returned to baseline scores within 10 days after injury.

Another study conducted by Macciocchi et al. (1996) investigated 183 collegiate football players and a matched control group. Athletes and control subjects were tested during preseason, 1, 5, 10 days, and 12 weeks post-injury. Results revealed football players who sustained a concussion had increased symptoms and decreased neurocognitive performance when compared to control subjects. At 5 days post-injury, neurocognitive levels returned to baseline on almost all players. While both studies provided valuable information regarding recovery time, they did not examine postural stability testing among concussed athletes.

Self-reporting

There are numerous assessment tools that can to be used to help determine signs and symptoms of a concussion. One of the more obvious assessment tools is the self-reported symptoms. This is where the athlete either reports "yes" or "no" on a symptom scale (similar to Likert scale) that allows the athlete to rate the severity of their concussion symptoms. Examples of concussion symptoms are: fatigue, headache, dizziness, nausea, sensitivity to light, loss of balance, difficulty sleeping, etc.

In a study by Piland et al. (2006) high school football players used the graded symptom checklist (GSC). All athletes were administered the graded symptom checklist at baseline, which revealed concussion symptoms prior to the athlete being concussed. The researchers suggest that athletes who self-report symptoms at baseline could cause potential problems when post-injury assessment is performed (Piland, Motl, Guskiewicz, McCrea, & Ferrara, 2006). Another study assessed neurocognitive decrements in concussed athletes after they were symptom free (Broglio, Macciocchi, & Ferrara, 2007). Twenty-one Division 1 athletes participated completed the ImPACT test 72 hours after a concussion, while still symptomatic and then again asymptomatic. Results revealed 81% of athletes still reporting symptoms demonstrated at least one deficit, while 38% continued to show neurocognitive impairment in at least one variable while they reported being asymptomatic. These results help support the need for other assessment tools for the evaluation and management of concussion besides just self-reporting concussion symptoms.

Management

With, that said, it is important to see what is being used as assessment tools on and off the field. A survey was sent to 2,750 certified athletic trainers and NATA members to help investigate current trends on concussion evaluation. As results, 95% used clinical examination, 85% used symptom checklists, 48% used Standardized Assessment of Concussion (SAC), 18% used neuropsychological testing, and 16% used the BESS test. Only 3% complied with the recent position statement, which advocated using symptom checklists, neuropsychological testing, and balance testing (Notebaert & Guskiewicz, 2005).

Overview of the Ankle

Ankle Injuries. Ankle sprains are the most common sport-related injuries, accounting for 15% percent of all injuries in the NCAA (Hootman, Dick, & Agel 2007). There was an estimated 326,396 ankle injuries sustained by high school athletes in the 2005-2006 academic year (Nelson, Collins, Yard, Fields, & Comstock, 2007). An ankle injury most commonly occurs by inversion and plantarflexion, resulting in the injury occurring on the outside or lateral aspect of the ankle (Garrick, 1977). Lateral ankle sprains account for 85% of all sprains (Callaghan, 1997). Lateral ankle sprains occur more frequently due to the anatomy of the lower leg. The malleoli of the tibia and fibula articulates with the talus, the malleoli help to decrease the occurrence or likelihood of displacement of the talocrural joint. However, the malleoli of the fibula extends more distal than the tibia, which is a contributor to the low amount of eversion ankle sprains. The movements that occur at this joint are plantar flexion and dorsiflexion. The gastrocnemius, soleus plantaris, peroneus longus, peroneus brevis, tibialis posterior, flexor hallucis longus, and flexor digitorum are considered plantar flexors. The tibialis anterior, extensor digitorum longus, extensor hallicus longus and peroneus tertius act as dorsiflexors. The talocrural joint is commonly referred to as the ankle joint. Inversion, eversion, pronation, and supination all occur at the subtalar joint. Inversion and adduction when combined creates supination. The muscles needed for these movements are the tibialis posterior, flexor digitorum longus, flexor hallicus longus, tibialis anterior, and extensor hallicus longus. Pronation is a combination of eversion and abduction. The muscles needed to create these movements are the peroneus longus, peroneus brevis, peroneus tertius and extensor digitorum longus. It is important to note that most of these muscles are needed for more than one movement to occur.

The main ankle lateral ligaments that help support the ankle joints are the anterior talorfibular ligament, which helps prevent anterior displacement of talus. The calcaneofibular ligament helps prevent inversion of the calcaneus, and the posterior talofibular ligament, which resists posterior displacement of talus. The deltoid ligament is made up of four strong ligaments and is on the medial aspect of the ankle. The deltoid ligament prevents abduction and eversion of the ankle joint and prevents eversion, pronation, and anterior displacement of talus. When the ankle is in dorsiflexion it is much more stable than when it is in plantarflexion. Hence the reason why there many of the ankle injuries occur while an athlete is in plantarflexion (Prentice, 2003).

Ankle Sprains

The majority of ankle injuries are lateral or inversion ankle sprains with the lateral ligament complex of the ankle being the most frequently injured single structure on the body (Garrick, 1977). The weakest and most susceptible to injury is the anteriortalofibular ligament. All ankle sprains are classified by Grade 1, Grade 2, or Grade 3, with Grade 3 being the most severe. Lateral ankle sprains are caused by inverting and planterflexing the ankle. With a Grade one inversion ankle sprain there is mild stretching of the anteriortalofibular ligament. There is mild pain and the ability to bear weight is not at all or minimally effected. There is mild point tenderness and swelling over the ligament and has no joint laxity. In a Grade two ankle sprain the person may state that they felt a pop or snap. There is moderate pain and disability and weight bearing is difficult and causes pain. There is tenderness and edema in the joint and possible ecchymosis. There could be a positive talar tilt test and anterior drawer. Long-term effects of a Grade two are possible chronic instability with a recurrence of re-injury. Lastly is a Grade three inversion ankle sprain. Many times when this occur the ankle will subluxate and then reduce itself. The person is unable to weight bear, and there is severe swelling. Hemarthrosis, ecchymosis, positive talar tilt, and a positive anterior drawer are all present (Prentice, 2003).

Medial or eversion ankle sprains are caused by eversion of the foot. Eversion ankle sprains account for about 5-10% of all ankle sprains (Prentice, 2003). Many eversion ankle sprains result in an avulsion fracture of the tibia. The last type of ankle sprain is a syndesmotic or "high" ankle sprain. This sprain occurs at the distal tibiofemoral joint and results due to increased external rotation and/or forced dorsiflexion. Seventy three percent of people who sprain their ankle will have residual symptoms, which include pain, repeated sprains, and "giving away". This can be considered chronic ankle instability (CAI). Individuals with CAI can affect static and dynamic stability (Brown & Mynark, 2007). Brown and Mynark (2007) examined 40 healthy recreationally active individuals (20 with CAI and 20 stable ankles) to determine ankle stabilization. Each participant stood on the force plate shoulder width apart and their hands on their hips. Participants performed three static stances without tibial nerve stimulation and seven stances with tibial nerve stimulation. Results found participants with CAI took longer to stabilize in the anterior-posterior direction. The authors suggest this could indication subtle central sensorimotor changes.

Balance

The ability to balance is a rather complex one that can be affected by subtle changes such as CAI and ankle injuries. The somatosensory, visual, and vestibular systems are all used when someone is maintaining their balance. In the body there are sensory receptors that monitor conditions in and outside the body (e.g. noises, lights, smells, etc). There are both somatic and visceral sensory information. These are considered to be in the afferent division of the peripheral nervous system, which sends information to the central nervous system. The sensory receptors determine our general senses, smell, sight, taste, balance and hearing. The sensory receptors take in information and are processed in the CNS. The sensory division is part of the peripheral nervous system.

There are five primary types of receptors. They are: mechanoreceptors that respond to pressure, touch, vibrations, or stretch, thermoreceptors that respond to changes in temperature, nociceptors that respond to painful stimuli, photoreceptors that respond to light, and chemoreceptors that respond to chemical stimuli (Wilmore & Costill, 2004). The information travels along the efferent pathway and results in a movement or thought. The sensory input will travel along the nerves and reach the spinal cord, where they can trigger a reflex or continue to travel up to the brain stem, cerebellum, thalamus, or the cerebral cortex. Sensory signals that help maintain postural stability will terminate at the brain stem. This is because postural stability is considered a subconscious motor reaction, but since it is more complex than a reflex it cannot be terminated at the spinal cord (Wilmore & Costill, 2004). Sensory signals specific receptors important to balance are the mechanoreceptors (specifically proprioceptors), visual, and vestibular (hearing). Proprioceptors monitor the position of the joint, tension in tendons and ligaments, and muscle contractions (Martini, 2004). If a ligament in an ankle is already stretched, it may take longer for the information to travel along the afferent pathway to the CNS, resulting in a longer reaction time for a person to reposition him or herself allowing them to maintain their balance.

Visual System

Vision is also important in maintaining balance. The information taken in by your eyes and processed helps someone decipher where they are in comparison to objects, people, etc. If someone closes their eyes or has their surroundings "swayed" they will have a more difficult time maintaining his/her balance. In a study by McCollum, Shupert, and Nashner (1996) participants stood in six different sensory environments with their eyes opened, covered, and with visual surrounding sway references (moving). Both the platform in which the participants stood and the visual surrounding could be rotated. Three times the platform was fixed and three times the platform had sway references. Performance index was used to determine amount of postural sway. Healthy subjects had the highest score (performed the worst) with the platform on sway reference and the visual surrounding on sway references. The second worse performance was the sway reference of the platform with their eyes covered. Both of these settings altered the visual sensory information.

Vestibular System

The last sensory aspect is the vestibular or hearing. There are several receptors in the ear. The receptors pertaining to the body's equilibrium will be the only ones discussed. The hair cell receptors in the semicircular ducts respond to rotational movements of the head (Martini, 2004). The hair cell receptors with the statoconia (densely packed calcium carbonate crystals) in the saccule and the utricle convey information about the position with respect to gravity as well as acceleration (Martini, 2004). Both the eyes and the ears work together. If the body is moving the eyes are constantly moving trying to fix on a point to maintain body position and orientation, therefore making the head move (Martini, 2004).

Balance Error Scoring System (BESS)

Numerous studies have examined the BESS with both concussed athletes and control subjects (Riemann & Guskiewicz, 2000; Broglio, Macciocchi, & Ferrara, 2007; Valvovich, Perrin, & Gansnedert, 2003). In a study by Bressel, Yonker, Kras, and Heath (2007), gymnasts had the best BESS test score compared to soccer and basketball athletes. They took a total of 34 female Division 1 participants; 11 soccer athletes, 11 basketball and 12 gymnasts. They performed the BESS test and the Star Excursion Balance test to assess both static and dynamic balance respectively. However, there was no significant difference in static and dynamic balance between the gymnasts and the basketball players.

According to Patel, Mihalik, Notebaert, Guskiewicz, and Prentice (2007) dehydration does not affect neurological and postural control in 24 healthy recreationally active males. All participants partook in two different sessions, separated by at least seven days (the groups were also counterbalanced). During one session the participants were euhydrated and the other session they were dehydrated. During the euhydrated session, participants did not participate in the exercise task. Both sessions consisted of the SAC, the Automated Neuropsychological Assessment Metrics, the Sensory Organization Test, BESS test and a Graded Symptom Checklist. A urine specific gravity test and body mass was used to determine hydration status. For postural control, both the NeuroCom Sensory Organization test and the BESS test showed no significant difference between the euhydtrated and dehydrated athletes. However, athletes did express difficulties with vision and balance as well as reporting feeling slowed down, fatigue, and drowsy. These symptoms may have an effect on their balance and vision. This was the first study to investigate dehydration and further studies are needed.

Along with dehydration, fatigue can also affect the BESS test (Wilkins, Valovich, Perrin, & Gansneder, 2004). In a study by Wilkins et al. (2004) 13 control participants were pre-tested, then rested 20 minutes, and then post-tested using the BESS test. Thirteen participants in the fatigue protocol were pre-tested, exerted to fatigue, and then immediately post-tested (the Borg scale was used to determine fatigue). Results found that the fatigue grouped scored significantly lower on the post-test compared to their baseline and the control group for the tandem stance and the single leg stance. However, the double-legged stance was not affected. There are also others studies that support this finding (Crowell, Guskiewicz, Prentice, & Onate, 2001). Crowell et al. (2001) found a decreased postural stability of the BESS test after male and female club-sport participants performed a fatigue protocol that consisted of squat jumps, sprints, and running (on the treadmill).

Susco, McLeod, Gansnedert, and Shultz (2004) did a similar study with 100 participants in five groups, which included a control group. The control group (group 1) was pre-tested, rested for 20 minutes, immediately post-tested, rested for another 20 minutes, and then post-tested again. Group two was pre-tested, performed the 20-minute exercise protocol, and immediately post-tested. Group three was post-tested 5 minutes following the exercise, Group 4, 10 minutes after the exercise, and Group 5 was tested 15 minutes after the exercise. All groups were post-tested a second time at 20 minutes. For example Group two was post-tested immediately after exercise and then post-tested again at 20 minutes post exercise. All groups were post-tested a total of two times. Post-test one had more errors than their pre-test and post-test two compared to all exertional groups. At 20 minutes all post-test scores were no different from their pre-test scores for all exertional groups.

Valovich, Perrin, and Gansnedert (2003) found practice effects on the BESS test when athletes performed the BESS test 5 times within 30 days, potentially contributing to testing reactivity. In this study there were a total of 32 high school athletes; there were 16 participants in the control group and 16 participants in the practice group. All participants were pre-tested with the SAC and BESS test, and re-tested on day 30. Participants that were in the practice group were re-tested on days three, five, and seven. Results found a significant improvement on days five and seven compared to baseline, but when comparing the baseline test to the 30-day test there was no significant difference. It would be possible to assume that there is a learning effect when repeatedly testing, but with significant time interference (over 20 days) the learning effect no longer exists.

Onate, Beck, and Van Lunen (2007) found that external stimuli impaired results on the BESS test. This study examined a total of 21 collegiate baseball players who performed the BESS test in a controlled locker room and an uncontrolled sideline. They were split into two groups, allowing the study to be counterbalanced. The sideline BESS test was done during live batting practice and intersquad competition, with the participants in the dugout. There were significant differences found for the single-leg stance on the foam surface. There were worse scores in the tandem leg stance on foam, and total BESS score on the field compared to the controlled setting.

Ankle support

The majority of athletes who injure their ankle will return to practice and competition with ankle taping or ankle bracing. There are several studies that have conflicting results when researching the effect of ankle support on balance and proprioception. According to Brown and Mynark (2007) there is a difference in dynamic balance in a double-leg stance comparing healthy recreationally active athletes to those with chronic ankle instability. However, this study did not examine the impact of ankle support or bracing on a person's ability to balance and whether or not it impacted postural stability.

Ankle bracing and ankle taping have both been researched to determine the effectiveness. There have been researchers stating that both are effective, especially when decreasing the reoccurrence of injuries. Out of 51,931 exposures to possible ankle injuries, there were 159 injuries and 23 re-injuries when wearing tape, and 37 injuries and one re-injury occurred when wearing an ankle brace (Hume & Gerrard, 1998). In other words, there was a rate of 9.3 injuries per 1000 exposures to injuries for a laced ankle brace compared to 6.0 injuries per 1000 exposures for ankle taping. There was not the same amount of exposure for ankle taping and ankle bracing (Hume & Gerrard, 1998). Another study demonstrated that prophylactic bracing would decrease the amount of reoccurrence in ankle injuries (Pedowitz, Reddy, Parekh, Huffman, & Sennett, 2007). However, in this study, they used their school as a control and compared it to other similar school, but did not ensure the same methods and criteria for diagnosing an ankle injury in all schools, nor did they collect data to determine how many of the experimental athletes used some kind of ankle support or if they had any other types of prevention.

Some studies state that ankle bracing is more effective in decreasing the occurrence of ankle injuries, whereas other studies will state that ankle taping is more effective (Hume & Gerrard, 1998). However, all are in agreement that both reduce the occurrence of ankle injuries. In a study done by Sharpe, Knapik, and Jones (1997), there was a 0% recurrence for athletes that were braced and a 25% reoccurrence for athletes that were taped. External ankle support provides support by resisting excess range of motion (particularly in inversion), increasing muscle activation, redistribution of loads, and a reinforcement of ligaments (Hume & Gerrard, 1998). Besides just looking at if ankle support helps prevent the occurrences it is important to examine if there are neuromuscular effects of an ankle support. Friden, Zatterstrom, Lindstrand et al. (1989), examined postural equilibrium control during a single leg stance using a stabiliometry, with a unilateral ankle sprain. When an ankle braced was used there was no significant difference in the parameters compared to the uninjured leg. Another study that also used a stabiliometry, but used taping instead of bracing on athletes with functional instability had similar results, finding that the taping did not influence their ability to balance (Tropp, Ekstmad, & Gillquist, 1985).

Although, there have been no significant differences with ankle bracing, a study by Kinzey, Ingersoll, and Knight (1997) reported that in 24 male participants with no history of ankle injuries relocated their center of pressure only when not wearing ankle braces. Participants performed a one legged modified Romberg tests with variations that altered their visual, vestibular, and proprioceptive inputs. There are also other studies with similar findings among healthy individuals. Bennel and Goldie (1994) found that there was a significant difference in postural control on healthy individuals with the use of ankle bracing or taping. These studies could suggest with an injured or functionally unstable ankle, that ankle support does not affect postural control, however, with a healthy individual it could affect ankle support. This could impact the postural control of those athletes that use ankle support as a preventative measure in a negative way. However, a study by Palmier, Ingersoll, Cordova, and Kinzey (2002) had results that contradicted this finding. They examined 28 college students without any previous ankle injury and compared their center of pressure at medial-lateral and anterior-posterior in a one-legged stance. They had a control group that did not wear the brace and an experimental group that wore a brace everyday up to four days. They found no significant difference for any day in either angle. It is important to note that is was only four days of wearing a brace, which is not a substantial amount of time.

Cordova, Scott, Ingersoll, and Leblanc (2004) discovered that ankle support (tape and two different types of bracing) decreased sprint speed by about 1% as well as a decreased vertical jump by about 1%. They used tape, lace-up brace and a semi-rigid brace. The vertical jump height was determined by hitting colored vanes and a force platform, and a stopwatch or photocell was used to determine sprint and agility testing. Each subject had a baseline and then performed the task wearing whatever ankle support was chosen for them. Results found that sprint speed, agility, and vertical jump do not affect a person's ability to balance. Papadopoulos, Nikolopoulos, Badekas, Vagenas, Papadakis, and Athanasopoulos (2007) researched EMG activity of four lower leg muscles along with a force-plate to determine if there was an effect of neuromuscular control with an ankle brace on. They had a group without a brace and then two other groups, each with a different interface pressure of the ankle brace. They had the participants stand on their dominant leg with eyes open and eyes closed. It was concluded that their ankle brace did not affect balance control strategy of the CNS. However, these studies did not use the BESS balance test.

Gender

Gender may also impact someone's ability to balance. There are very few research conducted comparing males to females and their postural stability or balance for young, healthy individuals. Most research includes the elderly population and not young adults. In those studies, there has been a general finding of elderly women have more falls and a decrease ability to balance. However, with an indication that there is a decrease ability in elderly females to balance it may or may not suggest that young female adults will have a decrease ability balance when compared to young male adults. Furthermore, there are gender differences in the performance of core stabilizing muscles (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004).

In a study done by Leetun, Ireland, Willson, Ballantyne, and Davis (2004) they looked at possible structural and kinematic differences between males and females which could implicate stability differences, and impact injury occurrences in lower body extremities. This study consisted of a total of 139 athletes from six universities, 79 were females. They tested core strength within two weeks of the athletes starting practice and followed them and the occurrence of injury for the length of one season. Core strength was tested by hip abduction, hip external rotation, posterior control via the modified Biering-Sorensen test, side bridge, and straight leg lowering. Thirty-five percent of females sustained an injury compared to 22% of men. Male athletes also demonstrated greater core stabilization ability when compared to females. Athletes who sustained an injury over the course of the season also had a tendency to have decrease core strength. Hip and trunk weakness reduces a person's ability to stabilize their hip and trunk. It's not surprising that females had a decrease in core strength. Although, this study's main purpose was to see if there was a correlation between core strength and injury, it could also implicate a possibility of gender differences in balance.

One study done that had a large age range (31-80 years old) used motion analysis for balance evaluation (Kejonen, Kauranen, Ahasan, & Vanharanta, 2002). There were a total of 100 participants. They were divided up into 10 groups by their age and gender. Every participant stood with their legs shoulder width apart with eyes open and closed. Motion analysis was used to determine maximal anterior-posterior movements and total movements. This study found no statistical difference between the groups.

Another study had an even larger sample (7,979) and were all 30 years old or older (Era, Sainio, Koskinen, Haavisto, Vaara, & Aromaa, 2006). They used both a platform and a non-instrumental field test. In the platform, participants stood normal with eyes open and closed (both for 30 s), semi-tandem (20 s) and tandem stand with eyes open (20 s). The largest findings were those amongst age groups. However, there were differences between genders. Males tended to have a greater sway reference using the force platform, but performed better with the non-instrumental field test, especially the tandem stance and their feet side by side, which females had the most difficulty. According to Era et al. separate normative values for both genders are needed.

Another study that examined sway by a force platform but added a noise variable to determine if that impacted results between genders (Polechonski & Blaszcxyk, 2006). There were a total of 40 males and 40 females with a mean age of 22 years old. All participants were asked to stand in an upright position with eyes closed and opened and then had either white noise of specific audience applause through headphones. There was silence along with three different noise volumes resulting in a total of 14 experimental trials. The results showed that women had a greater postural stability. The trials with the largest significance in favor of women were: eyes closed, white noise at 80 dB, eyes closed, applause at 60 dB, and eyes closed, applause at 100 dB. The only trial in which men had a greater postural stability was with eyes open and white noise at 100 dB. This was the youngest age group that was done out of these studies so it could indicate that females have greater postural stability at a young age, but deteriorates more and faster as they age. It also added a noise variable that other studies did not have.

Summary

The BESS test is one aspect of concussion evaluation and management. However, numerous variables can affect the results of the BESS test including ankle bracing, ankle taping, and gender. The BESS test is commonly used to assess and evaluate impairment of balance and coordination following a concussion (Riemann & Guskiewicz, 2000). Athletes are usually administered a baseline BESS test in a quiet controlled environment. However, an athletes' post-concussion test primarily takes place on the sidelines with several extraneous variables that may affect balance. Specifically, the BESS test is done on the sidelines in competitive shoes, ankle and knee bracing, or ankle prophylactic tape, which may affect an athletes' BESS test scores. Therefore, the purpose of this study is to investigate the effect of wearing an ankle brace or ankle tape on postural control as measured by the BESS test. A secondary

purpose is to determine if gender differences exist on the BESS test while wearing an ankle brace or ankle tape.

Chapter 3

Methods

Research Design

This study was a quasi-experimental counterbalance design. The independent variables were ankle group (ankle tape, ankle brace, no ankle support) and gender (male, female). The BESS test score was the dependent variable. This study had a convenient sample of recreationally active collegiate athletes. Therefore, there was no random selection, however, there was random assignment and equivalence at the start (each person was their own control).

Participants

Selection criteria. A convenient sample of 26 male and 29 female recreationally active collegiate athletes from a major mid-western university participated in this study. Participants ranged in age from 18-30 years. People with chronic ankle instability, a lower leg injury within the past six months, a head injury within the past 12 months, lower leg surgery within the past six months, Parkinson's disease, otitis media, Meniere disease, or any other visual, vestibular, or balance disorders that may affect postural stability were excluded from participation in the study.

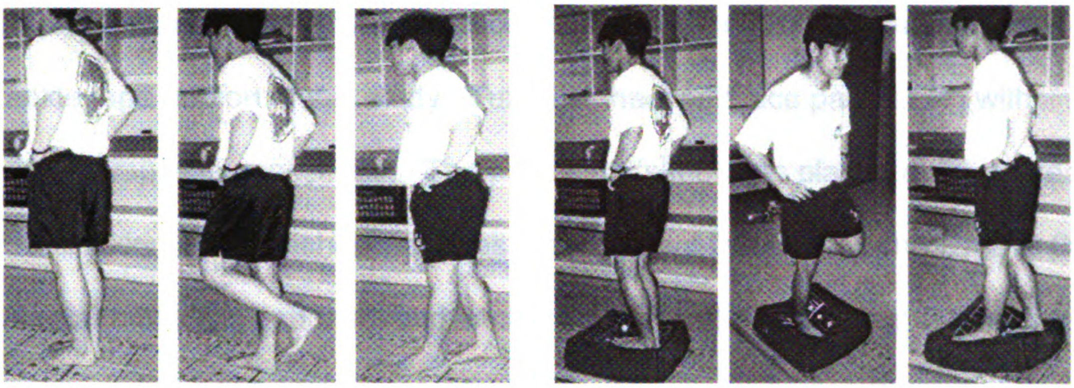
Sampling method. A convenient sample was used for this study. Participants were recruited by making announcements in a 100 level Kinesiology classroom as well as e-mails and flyers to athletic training students and other kinesiology undergraduate students.

Instrumentation

Balance Error Scoring System

The BESS test was used to determine the participant's postural stability with and without wearing an ankle brace or ankle tape on both ankles. The BESS test consists of six-20 seconds conditions: double leg, single-leg, and tandem (heel-to-toe) stances on a firm surface and a foam surface (see Figure 1). The firm surface consisted of a concrete floor and the foam surface was a 46 X 43 X 13cm^3 block of medium-density Airex (Alcan Airex, Aargau, Switzerland) foam. Single leg dominance was determined by asking the participant which leg they use to kick a soccer ball. The single-leg stance was performed on the non-dominant leg, and in the tandem stance the non-dominant leg was placed behind the dominant leg. Double-leg stance consisted of having their feet together and touching. All participants wore no shoes, but did wear cotton socks to help with consistency and decrease the possibility of any extraneous variables. Testing was performed in a controlled clinical environment, with the participant and researcher in a closed, quiet, lab room, to help minimize the possibility of distractions for the participant.

Figure1: BESS Test Demonstrating 3 hard surface and 3 foam stances (Reimann & Guskiewicz, 2000).



To score the BESS test, the participants faced forward, eyes closed, and placed their hands on their hips (iliac crests) for each stance performed. An error was recorded for every time the participant a) opened their eyes, b) stepped, stumbled, or fell out of test position, c) removed their hand(s) from their hip(s), d) moved their hip into more than 30 degrees of flexion or abduction, e) lifted their toes or heels from testing surface, or f) remained out of the test position for longer than five seconds. The higher the score received the "worse" the participant performed. Hence, a lower score is desired. The minimum test score is a 0 and the maximum test score is 10.

The BESS scoring system has been used in numerous studies and its validation and reliability has been proven in the high school, collegiate, and professional athletic settings (McCrea, Guskiewicz, Marshall, Barr, Randolph, Cantu, et al., (2003); Reimann, & Guskiewicz, (2000); Oliaro, Anderson, & Hooker, (2001); McLeod Barr, McCrea, & Guskiewicz, 2006).

Ankle Tape

A closed basket weave according to Prentice (2003) was used for the ankle tape portion of this study. Tuff-skin, heel and lace pads along with underwrap was applied first. The participant's foot was placed at 90 degrees of dorsiflexion. One anchor wrap was placed about five to six inches above the medial malleolus and a second anchor was placed directly over the styloid process of the fifth metatarsal. The first strip was applied posterior to the malleolus and attached to the anchor pulling the tape laterally. Next, the second strip (Gibney strip) started around the posterior aspect, directly under the malleolus and attached both ends to the foot anchor. The strips and Gibney strips were done alternatively with each piece of tape overlapping at least half of the preceding strip until there was three of each. For arch support two or three circular strips laterally to medially was used. Lastly, two heel locks were applied to maximize stability.

Ankle Brace

The ankle brace used was a DonJoy Stabilizing Ankle. This is a semi-rigid lace-up brace. It has removal medial and lateral plastic stays that were used. It is a non-stretch nylon with figure eight straps.

Procedures

The researcher obtained approval for human subjects from the Michigan State University Institutional Review Board. Written informed consent was received from participants prior to their voluntary participation in this study.

Assignment. After completing informed consent, participants were randomly assigned to one of three conditions. The participants were shown all three stances and told to keep their head forward, eyes closed, and hands on their hips. They were told to maintain their balance with having as little movement as possible. The participants were told to make any necessary adjustments to keep their balance and to return to the testing position as soon as possible. During all six stances of the BESS test, the researchers recorded all of the participants' errors. A stopwatch was used to keep track of the 20 seconds and any time the participant left the test position for longer than five seconds.

All participants performed all three conditions with a five-minute rest between each condition. Each participant performed all three conditions of the study, however, the sequence in which the test was performed was randomly assigned. Random assignment occurred by using a random numbers table.

Threats to Internal Validity. There were several threats to internal validity in this study. History threat could occur. Since testing occurred on separate days for each group we told participants not to discuss the study with any other participants. Maturation also could have been a threat, some participants could have became fatigued, especially their legs. Having the five minutes of rest between each test helped minimize fatigue. Instrumentation could have been a threat, due to human error. There is always some subjectivity when a person is grading. However, a strict grading sheet, the same people graded, and videotaping allowed the researchers to go back and review the tests helped minimize instrumentation being a threat to validity. There have been some studies demonstrating a possible testing reactivity (Valovich, Perrin, & Gansnedert, 2003). We only tested three times, therefore helping to decrease the threat of testing reactivity. Lastly, there may have been some "on-stage" testing effects with the participant getting nervous and wanting to perform as best they can. This was be minimized since they tried their best throughout, so there should not have been significant differences between ankle support and no ankle support. Also, during the test their eyes were closed so they did not see the researcher and were able to better focus. Group threats were unlikely since there was random assignment and each person acted as their control.

Threats to external validity. The biggest threat of external validity was the participants' reaction to experimental setting. BESS tests are not usually performed in a labratory setting. Usually they are performed on the sideline during a game or practice with external stimuli present to distract the athlete. However, in order to ensure as best as possible that the ankle bracing and ankle taping were the only variables present, it was necessary for the test to be performed in a controlled, clinical setting. The other external validity should not have been a factor due to random assignment, the participants acting as their control, and a counterbalanced research design.

Data Collection

Testing session. Participants reported to Room 38 IM Circle on their designated day of testing. Participants were told to wear shorts and a t-shirt (standard work-out clothes) and asked to remove their shoes. Participants were offered something to eat or drink prior to participation. Written consent was completed the day of testing prior to beginning. Once they began their first BESS testing, no breaks were allowed during the six stances. A five-minute break was allowed between testing periods. They were allowed to use the restroom at this time. There was a student assistant in the room to ensure that no participants discussed or practiced the tests. After their five minute rest period, participants performed the BESS test again with the ankle brace (in Group 1), ankle tape (in Group 2), or without any ankle support (in Group 3). While one participant rested, another participant was tested at this time. Once the third session of testing was complete they were done with the study.

Table 3-1: Testing Order of Participants

	Test 1	**Test 2**	**Test 3**
Group 1	No support	Bracing	Taping
Group 2	Bracing	Taping	No support
Group 3	Taping	No support	Bracing

Key Personnel. All BESS testing will be administered and graded by two researchers who were knowledgeable and experienced in BESS testing. A student assistant was in charge of the stopwatch and video camera.

Data management. All data was recorded on a grading sheet, which was kept in a folder, in a locked filing cabinet in a locked office. The data was then typed into a password-protected computer in a locked office. Informed consent documents were kept in a folder, in a locked filing cabinet, in a locked office. Access to the data and documents was limited to the researchers and the faculty advisor. All data was kept confidential and protected to help protect the privacy of the participants and sensitive information.

Data Analysis

Demographic information was summarized using descriptive data. A 2 gender x 3 group (ankle brace, ankle tape, no ankle support) x 6 BESS conditions MANOVA was conducted to determine differences on all BESS test scores. In addition, the Tukey Honestly Significant Difference post hoc analysis were performed. Data was analyzed using Statistical Package for the Social Sciences (SPSS) 16.0 software. Level of significance was set a prior to $P<.05$.

Chapter 4

Results

The primary purpose of this study was to determine if ankle support affected postural stability. A secondary purpose was to examine gender differences in postural stability. For clarity, the results section is separated into subject demographics, ICC test results, BESS test results and BESS test results for gender. BESS test results will include scores on double leg, single leg, and tandem stances on a firm and foam surface. BESS test scores will be reported for no ankle support, ankle brace, and ankle tape.

Subject Demographics

A total of 55 subjects volunteered to participate in the study. There were 26 male subjects (age = 21.64 ± 2.58 years, 70.60 ± 3.24 inches, 176.72 ± 27.49 lbs.) and 29 female subjects (21.41 ± 2.85 years, 65.14 ± 2.68 inches, 143.66 ± 21.05 lbs.). All were healthy individuals with no self-reported chronic ankle instability, a head injury within the past six months, lower leg surgery within the past six months, a lower leg injury within the past six months, Parkinson's disease, otitis media, Meniere disease, or any other visual, vestibular, or balance disorders that may affect postural stability.

Intra-Class Correlations Results

Intra-class correlations (ICC) were performed to determine measures of consistency or agreement of values within cases. Intra-class correlation was 0.979 for no ankle support, 0.948 for ankle brace, and 0.967 for ankle tape (see Table 4.1)

Table 4.1 Intra-Class Correlations for Total BESS Scores for No Ankle Support, Ankle Brace, and Ankle Tape

Condition	Intra-class correlation	95% Confidence Level Lower boundary	95% Confidence Level Upper boundary
No Ankle Support	0.979	0.965	0.988
Ankle Brace	0.948	0.912	0.970
Ankle Tape	0.967	0.945	0.981

BESS Test Scores

Participants performed six-20 seconds stances: double leg, tandem, and single leg on a firm (concrete floor) and foam (Airex) surface (see Table 4-2). All stances were performed with no ankle support, ankle brace, and ankle tape. In accounting for all the conditions, the participants performed a total of 24 stances. A MANOVA was conducted to determine BESS differences in ankle conditions and gender. Results demonstrated significant differences within the ankle condition groups ($F_{(2,52)} = 13.54$, $p = .000$) (see Tables 4-3, 4-4). Pairwise comparisons revealed significant differences between the no ankle support and ankle brace ($p =.001$). Specifically, when participants wore no ankle brace or ankle tape they had significantly less balance errors than when they were wearing an ankle brace on both ankles. Pairwise comparisons indicated significant differences between the no ankle support and ankle tape conditions ($p =.000$). Similarly, participants not wearing any ankle support had better balance compared to wearing ankle tape on both ankles. Finally, pairwise comparisons revealed significant differences between the ankle brace and ankle tape conditions. Participants had fewer scoring errors when wearing ankle braces compared to ankle tape (p= 0.04).

Table 4-2: Descriptive Statistics for Individual BESS Scores for No ankle Support, Ankle Brace, and Ankle Tape on a Firm and Foam Surface

Condition	N	Mean	Std. Deviation	Minimum	Maximum
Normal					
Firm Double	55	0.00	± 0.00	0	0
Firm Tandem	55	0.67	± 1.01	0	5
Firm Single	55	2.20	± 1.76	0	7
Normal					
Foam Double	55	0.05	± 0.30	0	2
Foam Tandem	55	3.47	± 2.10	0	10
Foam Single	55	5.56	± 1.90	0	10
Ankle Brace					
Firm Double	55	0.02	± 0.14	0	1
Firm Tandem	55	1.22	± 1.62	0	7
Firm Single	55	2.98	± 1.91	0	7
Ankle Brace					
Foam Double	55	0.05	± 0.30	0	2
Foam Tandem	55	3.44	± 2.34	0	10
Foam Single	55	6.20	± 1.60	0	9
Ankle Tape					
Firm Double	55	0.00	+ 0.00	0	0
Firm Tandem	55	1.82	+ 1.87	0	6
Firm Single	55	3.53	+ 2.45	0	10
Ankle Tape					
Foam Double	55	0.07	± 0.42	0	3
Foam Tandem	55	3.51	± 1.91	0	8
Foam Single	55	6.49	± 1.33	4	9

Table 4-3: Descriptive Statistics for Total BESS Scores for No Ankle Support, Ankle Brace, and Ankle Tape on a Firm and Foam Surface

Condition	N	Mean	Std. Deviation
Normal	55	12.00	± 5.16
Ankle Brace	55	13.95	± 4.87
Ankle Tape	55	15.44	± 5.08

Table 4-4 MANOVA Comparing all Three Ankle Condition Groups

Condition Group	Wilk's Lambda	df	F	p
Condition	.641	2	14.54	.000*

*(significant at the p = .05 level)

Table 4-5 Pairwise Comparison for all Three Ankle Condition Groups

Condition 1	Mean Difference (1-2)	Significance	95% CI Upper Bound	95% CI Lower Bound
Normal-Ankle Brace	-1.94	.001*	-0.78	-3.10
Normal – Ankle Tape	-3.44	.001*	-2.12	-4.75
Ankle Tape-Ankle Brace	1.497	.034*	2.88	.12

*(significant at the p = .05 level)

Gender and BESS Test Scores

There were no significant differences between gender for any of the ankle conditions ($F_{(1,53)}$ = 1.296, p = .260) (see Table 4-6).

Table 4-6: Descriptive Statistics for Gender BESS Scores for No ankle Support, Ankle Brace, and Ankle Tape on a Firm and Foam Surface

Condition	N	Mean	Std. Deviation
No Ankle Support			
Male	26	12.77	± 4.76
Female	29	11.24	± 5.50
Ankle Brace			
Male	26	14.64	± 4.86
Female	29	13.24	± 4.87
Ankle Tape			
Male	26	15.92	± 5.83
Female	29	14.97	± 4.36

Chapter 5

Discussion

The purpose of this study was to determine the effect of ankle support on postural ability and gender differences using the BESS test. We hypothesized that there would be no significant differences between no ankle support, ankle bracing, and ankle taping. We also hypothesized that there would be no significant difference between genders.

This section will be broken down into six subsections. These include the discussion of the BESS test scores; gender and BESS test scores, utilization and clinical significance of BESS test scores, limitations of current study, future research implications, and conclusions.

BESS Test Scores

The BESS test is a clinical evaluation tool used for the evaluation of head injuries. It consists of six-20 seconds stances (three on a firm surface and three on a foam surface). This study examined the possible affect of wearing no ankle support, ankle braces, and an ankle tape on the outcome of an individual's score as assessed by the BESS test. Our results indicated that healthy individuals scored best with no ankle support, followed by ankle brace, and ankle tape. Most of the participants stated that the ankle brace was uncomfortable, especially over the medial malleoli, and the ankle tape felt more "supportive" and "restrictive". Research has shown that both ankle tape and ankle brace restricts movement of the ankle (Hume & Gerrard, 1998).

This restriction of movement, of a healthy ankle, could be a possible reason for ankle support negatively affecting the performance of the BESS test. Hardy, Huxel, and Nesser (2008) observed possible differences in bracing and non-bracing during the Star Excursion Balance Test with healthy individuals. This test is similar to the BESS test and is human scored. Hardy et al. found no significant differences between the two groups. However, their study observed dynamic stability, whereas the BESS test determines static stability. In the BESS test knee and hip flexion results in an error, whereas in the Star Excursion in order to properly execute the exercise, knee and hip flexion must occur, which may have been a possible reason why the results were different. During the Star Excursion there could have been possible compensation in the knee or hip movements for the lack of ankle movements (not apparent), whereas the BESS test does not allow for those "compensations".

Another aspect that is thought to be a possible difference in ankle support versus no ankle support may be changes in proprioception. Proprioception is the ability to determine the position of a joint (in this case the talocrural joint) in space (Prentice, 2003). An ankle brace increases stability in an injured ankle and this increased stability is thought to be an increase in proprioception (Kinzey, Ingersoll, & Knight, 1997). Proprioceptive input is one of three primary forms of sensory input that control postural stability (Kinzey, Ingersoll, & Knight, 1997). Several studies investigated center of pressure during static balance, and, reported that healthy individuals wearing ankle support found significant differences in anteroposterior and mediolateral center of pressure (Kinzey, Ingersoll, & Knight, 1997; Papadopoulos, Nikilipoulos, Badekas, et. al., 2007). These results could help support our findings of a decrease in postural stability while wearing ankle braces, which could be explained by a possible decrease in proprioception among healthy individuals. Contrary to these findings, Papadopoulos, Nikilipoulos, and Badekas, et al. (2007) examined the electromyographic activation of muscles that evert the foot and found no significant difference between no ankle support and different pressures of ankle support.

Ankle support, specifically external support reduces joint angular displacement and velocity and emphasizes external forces that cause angular displacement (Cordova, Ingersoll, & Palmieri, 2002). With this displacement occurring, reaction time and compensation is possible and should be considered. Individuals with chronic ankle instability have a faster reaction time with perturbation while having their ankles taped; however individuals with healthy ankles do not have a faster reaction time (Cordova, Ingersoll, & Palmieri, 2002; Kernozek, Durall, Friske, Mussallem, 2008). Although, both of these reaction times occurred during perturbation, and not during static balance of healthy individuals. Therefore, there could be differences in displacement and compensation of that displacement of healthy individuals while performing static balance.

Most of these studies use technological resources for data collection. The BESS test is human scored, resulting in possible human error and the inability to detect minute differences. This could be another explanation for differences in our results and other studies. However, research has demonstrated that there is a strong correlation between the use of the BESS test and a force-platform system (Riemann & Guskiewicz, 2000). In addition, our intra-class correlations were all over 0.95. Therefore, indicating consistency among human scorers during the BESS test.

Gender and BESS test scores

In this study we compared postural stability of male and females using the BESS test. The results showed no significant differences in postural stability between males and females aged 18-30.

The majority of research on gender and balance does not observe differences in college-age individuals. The majority of research has been performed in on elderly and has generally found that females have a lower ability to balance and more occurrences of falls (Rankin, Woollacott, Sumway-Cook, & Brown, 2000). However, research indicated that there is a decreased ability in elderly females to balance, which may or may not suggest that young female adults will have a decrease ability to balance when compared to young male adults. One study that used participants with a mean age of 22 (similar to this study) found that females had better postural stability when there was a noise variable (Polechonski & Blaszcxyk, 2006). There may be a difference between genders in young adults when an attentional variable is present, however, there were no attentional variables in this study. Thus, more research is needed to support our results.

Research has showed that postural stability decreases with age (Rankin, Woollacott, Shumway-Cook & Brown, 2000; Redfern, Jennings, Martin, & Furman, 2001). Studies reported conflicting results between genders among younger participants; however, none were younger than 30 years old which was the age demographic for this study (Kejonen, Kauranen, Ahasan, & Vanharanta, 2002; Era, Sainio, Koskinen, Haavisto, Vaara, & Aromaa, 2006). This may suggest that until the affects of aging occur, there is no difference in postural stability between genders.

Utilization and Clinical Significance

The BESS test is only one of several evaluative tools used by medical personnel in diagnosing and assessing a head injury and/or concussion. For all concussion evaluation tests it is important to have baselines test scores for comparative purposes if an athlete incurs a concussion. This allows for the athletic trainer or other medical personnel to confidently identify when an athlete is no longer symptomatic and has completely returned to his/her baseline BESS test scores. This study indicates that athletes should be baseline tested in similar ankle conditions to their post-concussion tests. If an athlete wears braces or has their ankle tape for preventative reasons, has chronic ankle instability, has recently injured his or herself the baseline BESS test should be done with the ankle support, or the ankle support should be removed before performing the BESS test. In addition, if an athlete did not wear ankle support but was injured and now wears ankle support another baseline BESS test should be performed with the ankle support on for possible changes due to the ankle support and the injury.

Limitations

One limitation to this study was sample population. Healthy non-athletic individuals participated in this study. High-school age individuals were not included in this study due to the difficulties in obtaining parental consent and assent. Along with a smaller age range (18-30 yrs), no high school or NCAA athletes were participants. The participants who volunteered were all from one Division I, Mid-West university.

Along with the participants not being athletes, some of them had never worn an ankle brace or had their ankles taped. This unfamiliar feeling for some of the participants could have affected the results.

Another limitation is none of the participants wore shoes. We felt it would be best for participants to not wear shoes to limit possible variables between shoes. Not many sports consist of the athlete not wearing any type of athletic footwear. However, for research purposes we felt it was necessary to remain consistent among participants.

Future Research Considerations

Future research considerations would be to test high school or collegiate athletes with and without ankle support. Most athletes have had their ankles braced or taped at some time during their sport career; therefore, the possible unfamiliarity of ankle support most likely would not exist. Future research should also compare different sports (i.e. track versus gymnast versus basketball player, etc.) and ankle support with the BESS test.

Along with different sports, many sports may use different ankle braces. In this study we only observed the difference with one type of ankle brace (semi-rigid) and one type of ankle tape technique. Further research could observe differences between several types of braces and prophylactic ankle tape that have been in use for five, ten, or twenty minutes.

Making the study more "real-life" would be to add athletic footwear. Many sports teams have team appointed footwear. A study could be to have the athletes perform the BESS test wearing all the same footwear and then further the study by having them wear ankle support with the footwear.

Another aspect of making the study more congruent to real life is the surface in which the BESS test is taken. In this study it was performed on a concrete floor, not many sports occur on a concrete floor. The BESS test could be done on several different playing surfaces (i.e. basketball court, turf, grass, etc) to examine differences between these surfaces.

Lastly, future research could compare healthy individuals to individuals with chronic ankle instability and/or an ankle injury within the past six months. Most likely there would be a difference between the groups with no ankle support, but comparing the two groups with ankle support on both groups, to our knowledge, has not been researched.

Conclusion

To our knowledge this was the first study to observe the effects of ankle support on the BESS test, as well as compare gender differences on the BESS test. Specifically, this study examined the effect ankle support has on postural stability using the BESS test. Our results indicated that healthy individuals scored best with no ankle support, followed by ankle bracing, and ankle taping. However, there was no difference in the BESS test between genders. The results of this study could have implications for evaluation and management of concussion. The BESS test is used as an evaluative tool for individuals who have sustained a concussion. Concussions are a common occurring injury in sports. Baselines for evaluative tests of concussions include the BESS test. Therefore, it is important for the baseline BESS test to be as accurate as possible. Clinicians should consider ankle support when performing both the baseline and post-concussion BESS test. Further research should observe all possible variables that may affect a baseline BESS test, such as footwear, chronic ankle instability, and various populations.

APPENDIX A

The Effect of Ankle Support on Postural Stability using the BESS Test
Informed Consent

For questions regarding this study, Please contact:
Tracey Covassin Ph.D, ATC
Department of Kinesiology
Michigan State University
Phone: (517) 353-2010
E-mail: covassin@msu.edu

or

For questions regarding your rights as a research participant, please contact:
MSU's Human Research Protection
Michigan State University
202 Olds Hall
East Lansing, MI 48824
ucrihs@msu.edu
Phone: (517) 355-2180
Fax: (517) 432-4503

1. PURPOSE OF RESEARCH:

You are being asked to participate in a research study to determine if ankle support affects postural stability. You have been selected as a possible participant because you are recreationally active. From this study, the researchers hope to learn if ankle taping or ankle bracing affects postural stability. A secondary purpose is to examine gender differences in postural stability. Your participation in this study will take approximately one hour.

2. WHAT YOU WILL DO:

The study will use the Balance Error Scoring System (BESS) as an assessment tool for postural stability. No invasive procedures are performed. The BESS test consists of a total of six stances, three on a firm surface and the same three stances on an unstable (medium density foam) surface. All stances are done with your eyes closed with your hands on your hips and held for 20 seconds. The stances consists of feet shoulder with apart, a tandem stance (one foot in front of the other, nondominant in the rear), and the last stance is single-leg on your non-dominant leg. You must hold their balance as best as possible. For every error made (i.e. bending at the hip, opening their eyes, etc) a point is added. Errors possible are: lifting hands of the iliac crest, opening the eyes, stepping, stumbling, or falling, moving the hip into more than a 30 degree of flexion or abduction, lifting the forefoot or heel, and remaining out of the testing position for more that five seconds.
You will perform all six stances with your ankles taped, ankles braced, and with no ankle tape or ankle brace. There will be a five-minute rest period between each session (ankles taped, ankles brace, no ankle tape/brace). All stances will be video taped recorded so the research can ensure consistency with your balance errors recorded.

3. POTENTIAL BENEFITS:

You will not directly benefit from participation in this study. However, information gathered from this study may potentially determine the effectiveness of ankle support on postural stability.

4. POTENTIAL RISKS:

You are aware that your participation in the above stated study involves minimal discomfort or harm to you. Please be assured that you may choose to remove yourself from this study at any time. All scoring and recording are strictly confidential and will not be released to anyone. If you are injured during the BESS test a certified athletic trainer will be able to assist you with your injury.

5. PRIVACY AND CONFIDENTIALITY:

Participation in this study is completely voluntary. You have the right to say no. You may change your mind at any time and withdraw. Confidentiality will be protected by; (a) results will be presented in aggregate form in any presentations and publications; and (b) all data will be stored in a computer that has a password necessary to see confidential data. Your privacy will be protected to the maximum extent allowable by law. You may also discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you or your health care insurer. The results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous.

6. COSTS AND COMPENSATION FOR BEING IN THE STUDY:

Procedures being performed for research purposes only will be provided free of charge by Dr. Covassin and her research assistant. You will not receive money or any other form of compensation for participating in this study.

7. THE RIGHT TO GET HELP IF INJURED:

If you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. Financial compensation for lost wages, disability, pain or discomfort is not available. This does not mean that you are giving up any legal rights you may have. You may contact Dr. Tracey Covassin at 517-353-2010 with any questions.

8. CONTACT INFORMATION FOR QUESTIONS AND CONCERNS

If you have any questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher Dr. Tracey Covassin at 517-353-2010 or e-mail her at covassin@msu.edu (105 IM Sport Circle, Department of Kinesiology, East Lansing, MI 48824).

If you have any questions or concerns about your role and rights as a research participant, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection at 517-355-2180, Fax 571-432-4503, or e-mail irb@msu.edu or regular mail at 202 Olds Hall, MSU, East Lansing, MI 48824.

9. DOCUMENTATION OF INFORMED CONSENT.

Your signature below indicates your voluntary agreement to participate in this study.

I, ______________________________ have read and agree to participate in this study as described above.
(Please Print Your Name)

____
(Please Sign Your Name)

_____/_____/_____
(Date)

APPENDIX B

Double Leg		
Stable Surface/No Support	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Tandem		
Stable Surface/No Support	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Single-leg		
Stable Surface/No Support	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Double leg		
Unstable/No Support	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Tandem		
Unstable Surface/No Support	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Single-leg		
Unstable Surface/No Support	Tally	Total
Open eyes		
30 degrees hip flex./abd.		

Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	

Double Leg		
Stable Surface/Brace	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Tandem		
Stable Surface/Brace	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Single-leg		
Stable Surface/Brace	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Double leg		
Unstable/Brace	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Tandem		
Unstable Surface/Brace	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	

Single-leg		
Unstable Surface/Brace	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	

Double Leg		
Stable Surface/Tape	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Tandem		
Stable Surface/Tape	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Single-leg		
Stable Surface/Tape	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Double leg		
Unstable/Tape	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Tandem		
Unstable Surface/Tape	Tally	Total
Open eyes		
30 degrees hip flex./abd.		

Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	
Single-leg		
Unstable Surface/Tape	Tally	Total
Open eyes		
30 degrees hip flex./abd.		
Move forefoot or hindfoot		
Lift hands off hips		
Falls/Stumbles		
	Total	

REFERENCES

Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 1st International Symposium on Concussion in Sport, Vienna 2001. *Clin J Sport Med.* Jan 2002;12:6-11.

Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., et al. (2002) Summary and agreement statement of the first international conference on concussion in sport, Vienna 2001 [Electronic version]. *British Journal of Sports Medicine,* 36, 6-10.

Barth, J., Alves, W., Ryan, T., Macciocchi, S., Rimel, R., Jane, J., Nelson, W. Mild head injury in sports: Neuropsychological sequelae and recovery of function. In: H. Levin, H. Eisenberg, A. Benton (Eds.), *Mild Head Injury..* New York:NY Oxford University Press;1989:257-275.

Bressel, E., Yonker, J.C., Kras, J., & Heath, E.M. (2007) Comparison of static and dynamic balance in female collegiate soccer, baseball, and gymnastics athletes. [Electronic version]. *Journal of Athletic Training,* 42(1), 42-46.

Brogli, S., Macciocchi, S., Ferrara, M. (2007) Neurocognitive performance of concussed athletes when symptom free. *Journal of Athletic Training,* 42(4), 504-508

Brown, C.N., Mynark, R. (2007) Balance deficits in recreational athletes with chronic ankle instability. [Electronic version]. *Journal of Athletic Training* 42(3), 367-373.

Callaghan, M. (1997) Role of ankle taping and bracing in the athlete. *British Journal of Sports Medicine* 31, 102-108.

Canadian Academy of Sport Medicine Concussion Committee: Guidelines for assessment and management of sport-related concussion. *Clin J Sport Med.*2000;10:209-211.

Cantu, R., & Voy, R. (1995) Second impact syndrome. *The Physician and Sports Medicine, 7,* 83-84.

Collins, M., Grindell, S., Lovell, M., Dede, D., Moser, D., Phalin, B., et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA.* 1999;282(10):964-970.

Cordova, M.L., Scott, B.D., Ingersoll, C.D., & LeBlanc, M.J. (2005) Effects of ankle support on lower-extremity functional performance: A meta-analysis.[Electronic version]. *Medicine and Science in Sports and Exercise,* 37(4), 635-641.

Cordova, M.L., Ingersoll, C.D., & Palmieri, R.M. (2002). Efficacy of prophylatic ankle support: An experimental perspective. *Journal of Athletic Training.*37(4), 446-458.

Era, P., Sainio, P., Koskinen, S., Haavisto, P., Vaara, M., Aromaa, A. (2006) Postural balance in a random sample of 7,979 subjects aged 30 years and older. *Gerontology,* 52, 204-213

Erlanger, D., Saliba, E., Barth, J., Almquist, J., Webright, W., Freeman, J. Monitoring resolution of postconcussion symptoms in athletes: Preliminary results of a web-based neuropsychological test protocol. *J Athl Train.* 2001;36(3):280-287.

Friden, T., Zatterstrom, R., Lindstrand, A., et al. (1989) A stabilometric technique for evaluation of lower limb instabilities. *American Journal of Sports Medicine* 17(1), 111-119

Garrick, J.G. (1977) The frequency of injury, mechanism of injury, and epidemiology of ankle sprains. [Electronic version]. *The American Journal of Sports Medicine,* 5(6), 241-242.

Gessel, L., Fields, S., Collins, C., Dick, R., Comstock, D. (2007) Concussions among United States high school and collegiate athletes. *Journal of Athletic Training* 42(4), 475-503.

Greenman, P.E. (2003) Principles of manual medicine (3rd ed.). Philedelphia: Lippincott Williams & Williams.

Guskiewicz, K., Bruce, S., Cantu, R., Ferrara, M., Leyy, J., McCrea, M., Putukian, M., McLeod, T. (2004) National Athletic Trainer's Association position statement: Management of sport-related concussion. *Journal of Athletic Training* 39(3), 280- 297.

Guskiewicz, K, McCrea, M., Marshall, S., Cantu, R., Randolph, C., Barr, W., Onate, J., Kelly, J. (2003) Cumulative effects associated with recurrent concussion in collegiate football players *American Medical Association* 290(19), 2549-2555.

Hardy, L., Huxel, K., Brucker, J., Nesser, T. (2008) Prophylactic ankle braces and Star Excursion Balance measures in healthy volunteers. *Journal of Athletic Training* 43(4), 347-351.

Hume, P., Gerrard, D. (1998) Effectiveness of external ankle support: bracing and taping in rugby union. *Sports Medicine* 25(5), 285-312.

Kejonen, P., Kaurenen, K, Ahasan, R., Vanharanta, H. (2002) Motion analysis measurements of body movements during standing: association with age and sex. *International Journal of Rehabilitation Research*. 25(4), 297-304.

Kernozek, T., Durall, C, Friske, A., Mussallem, M. (2008) Ankle bracing, plantar-flexion level, and ankle muscle latencies during inversion stress in healthy participants [Electronic version]. *Journal of Athletic Training.* 43(1), 37-43.

Kinzey, S., Ingersoll, C., Knight, K. (1997) The effects of selected ankle appliances on postural control. *Journal of Athletic Training* 32(4), 300-303.

Leetun, D., Ireland, M., Willson, J., Ballantyne, B., Davis, I. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine and Science in Sports and Exercise.* 36(6), 926-934

Macciocchi, S., Barth, J., Alves, W., Rimel, R., Jane, J. Neuropsychological functioning and recovery after mild head injury in collegiate athletes. *Neurosurgery.*1996; 39:510-514.

Martinin, F.H. (2004) Fundamentals of Anatomy and Physiology (6th ed.) San Francisco: Benjamin Cummings.

McCollum, G., Shupert, C.L., & Nashner, L.M. (1996) Organizing sensory information for postural control in altered sensory environments. [Electronic version]. *Journal of Theoretical Biology,* 180, 257-270.

McCrea, M., Guskiewicz, K.M, Marshall, S.W., Barr, W., Randolph, C., Cantu, R.C., Onate, J.A., Yang, J., & Kelly, J.P. (2003) Acute effects and recovery time following concussion in collegiate football players. [Electronic version]. *Journal of American Medical Association,* 290(19), 2556-2563.

McLeod, T.C., Barr, W.B., McCrea, M., Guskiewicz, K.M. (2006) Psychometric and measurement properties of concussion assessment tools in youth sports. *Journal of Athletic Training,* 41(4), 339-408

Nelson, A.J., Collins, C.L., Yard, E.E., Fields, S.K., & Comstock, R.D. (2007) Ankle injuries among the United States high school sports athletes, 2005-2006. [Electronic version]. *Journal of Athletic Training,* 42(3), 381-387.

Notebaert, A., Guskiewicz, K. (2005) Current trends in athletic training practice for concussion assessment and management. *Journal of Athletic Training,* 40(4), 320-325

Oliaro, S., Anderson, S., & Hooker, D. (2001) Management of cerebral concussion in sports: The athletic trainer's perspective. [Electronic version]. *Journal of Athletic Training,* 36(3), 257-262.

Onate, J.A., Beck, B.C., & Van Lunen, B.L. (2007) On-field testing environment and Balance Error Scoring System performance during preseason screening of healthy collegiate baseball players. [Electronic version]. *Journal of Athletic Training,* 42(4), 446-451.

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

Papadopoulos, E.S., Nikolopoulos, C., Badekas, A., Vagenas, G., Papadakis, S.A., & Athanasopoulos, S. (2007) The effect of different skin-ankle brace application pressures on quiet single-limb balance and electromyographic activation onset of lower limb muscles. [Electronic version]. *BMC Musculoskeletal Disorders* 8(89).

Patel, A.V., Mihalik, J.P., Notebaert, A.J., Gusiewicz, K.M., & Prentice, W.E. (2007) Neuropsychological performance, postural stability, and symptoms after dehydration. [Electronic version]. *Journal of Athletic Training,* 42(1), 66-75.

Pedowitz, D.I., Reddy, S., Parekh, S.G., Huffman, G.R., & Sennett, B.J. (2007) Prophylactic bracing decreases ankle injuries in collegiate female volleyball players. [Electronic version]. *The American Journal of Sports Medicine,* 10(10).

Piland, S., Motl, R., Guskiewicz, K., McCrea, M., Ferrara, M. (2006) Structural validity of a self-report concussion-related symptom scale. *Medicine and Science in Sports and Exercise,* 38(1), 27-32.

Polechonski, J., Blaszczyk, J. (2006) The effect of acoustic noise on postural sway in male and female subjects. *Journal of Human Kinetics,* 15, 37-52.

Prentice, W.E. (2003) Arnheim's principles of Athletic Training: A competency-based approach (11th ed.). Boston: McGraw Hill.

Rankin, J., Woollacott, M., Shumway-Cook, A., & Brown, L. (2000) Cognitive influence on postural stability: a neuromuscular analysis in young and older adults. [Electronic version]. *The Journals of Gerontology,* 55A (3), 112-119.

Redfern, M, Jennings, R., Martin, C., & Furman, J. (2001) Attention influences sensory integration for postural control in older adults. [Electronic version]. *Journal of Gait and Posture,* 14, 211-216

Riemann, B.L., & Guskiewicz, K.M. (2000) Effects of mild head injury on postural stability as measured through clinical balance testing. [Electronic version]. *Journal of Athletic Training,* 35(1), 19-25.

Reimann, B.L., Guskiewicz, K.M., & Shields E.W. (1999) Relationship between clinical and forceplate measures of postural stability. [Electronic version]. *Journal of Sport Rehabilitation,* 8, 71-82.

Sallis, R.E., & Jones, K. (2000) Prevalence of headaches in football players. [Electronic version]. *Medicine and Science in Sports and Exercise,* 32(11), 1820-1824.

Susco, T.M., McLeod, T.C., Gansnedert, B.M., & Shultz, S.J. (2004) Balance recovers within 20 minutes after exertion as measured by the Balance Error Scoring System. [Electronic version]. *Journal of Athletic Training,* 39(3), 241-246.

Thurman, J.D., Branche, C.M, & Sniezek, J.E. (1998) The epidemiology of sports-related traumatic brain injuries in the United Stated: Recent developments.[Electronic version]. *Journal of Head Trauma Rehabilitation,* 13, 1-8.

Tropp H, Ekstrand, J., Gillquist, J. (1984) Factors affecting stabilometry recordings of single limb stance. *American Journmal of Sports Medicine*, 12(3), 185-188

Valovich, T., Perrin, D., Gansnedert, B. (2003) Repeat administration elicits a practice effect with the Balance Error Scoring System but not with the Standardized Assessment of Concussion in high school athletes. *Journal of Athletic Training*, 81(1), 51-56

Wilkins, J.C., McLeod, T.C., Perrin, D.H., and Gansneder, B.M. (2004) Performance on the Balance Error Scoring System decreases after fatigue. [Electronic version]. *Journal of Athletic Training,* 39(2), 156-161.

Wilmore, J.H., Costill, D.L. (2004) Physiology of Sport and Exercise. Hong Kong: Human Kinetics.