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The Stability of Low-Top versus High-Top Basketball Shoes

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The Stability of Low-Top versus High-Top Basketball Shoes

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Abstract

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BACKGROUND: Ankle sprains are one of the most common athletic injuries that occur in sports participation (Trevino, Davis, & Hecht, 1994). There has been numerous prevention strategies designed to decrease the occurrence of ankle sprains (Hume & Gerrard, 1998). **OBJECTIVE:** To evaluate the stability of collegiate level basketball players wearing low-top and high-top basketball shoes. The researcher's hypothesis is that the high-tops will provide significantly greater stability than the low-tops. **METHODS:** Eleven intercollegiate basketball players from the University of Central Oklahoma served as subjects. **MEASUREMENT:** Average left-right excursion was recorded using the *F-Scan* Foot Pressure Mapping System (Tekscan, Boston, MA) as subjects performed three layups in low-top and high-top basketball shoes. The data will be inputted into PAWS version 18 for data analysis. The data were analyzed using a dependent t-test, alpha level of p=0.05. **RESULTS:** High-top shoes showed significantly greater stability than low-top shoes (left: t = -2.785, p = 0.019, right: t = -2.256, p = 0.048). **CONCLUSIONS:** The high-top shoes showed significantly greater stability than low-top shoes, as a result depending on the situation, high-top shoes may help prevent ankle sprains.

Chapter One: Introduction

Background

Ankle sprains are one of the most common athletic injuries that occur to athletes throughout their competitive careers. This is in part due to the high demands sports participation places on the body, and most notably the lower extremity that absorbs these forces. There has been numerous prevention strategies designed to decrease the occurrence of ankle sprains. These methods include taping, bracing, height of footwear, and proprioception and balance training (Thacker et al., 1999; Hume & Gerrard, 1998; Ashton-Miller, Ottaviani, Hutchinson, & Wojtys, 1996).

Ankle sprains are an occurrence in everyday activity, which is accentuated by participation in sports. Waterman, Owens, Davey, Zacchilli, and Belmont (2010) studied the epidemiology of ankle sprains in the United States via occurrences reported in emergency rooms. Over the course of this study, approximately 3,140,132 ankle sprains occurred in a population of 1,461,379,599 individuals. Almost half of the ankle sprains (49.3%) that occurred were due to participation in athletic activity. The highest percentage of ankle sprains was observed in basketball (41.1%), football (9.3%), and soccer (7.9%). This large incidence of ankle sprains, especially in athletic activity, signifies a growing need to develop preventative and protective strategies to combat this problem.

This high incidence of ankle sprains adds greatly to the health care costs. Soboroff, Pappius, and Komaroff (1984) performed a study to analyze the cost of ankle sprains on the health care system. They found that the cost of treating ankle injuries ranged from $318 to $914 per sprain. When estimating the number of sprains that occur each year, this results in an annual cost in the United States of $2 billion. This figure provides a glimpse into the significant problems associated with this condition. Some of these costs could be minimized with the advancements in prevention mechanisms, such as: taping and bracing, proprioception and balance training, and the height of footwear.

Basketball appears to have a greater risk for acquiring an ankle sprain compared to other sports. This can be a result of cutting manoeuvres, changing direction, landing in an unbalanced position or another athlete's foot. Trevino, Davis, and Hecht (1994) reported that up to 45% of sports related injuries are due to ankle sprains observed in high risk sports such as basketball. The occurrence of an initial ankle sprain leads to an increased risk for subsequent sprains. This recurrence rate was evident in a study by Smith and Reischl (1986) who found 70% of the players had a history of an ankle sprain. Of those who had already experienced an ankle sprain 80% had sustained multiple sprains. Approximately 50% of the athletes had lingering symptoms from their previous injuries, and that 15% of the injured athletes felt that these symptoms negatively affected their playing performance (Smith & Reischl, 1986). This study emphasizes the potential seriousness of ankle sprains on performance and causing long term side effects.

Due to the large incidence in ankle sprains and the consequences involved whilst treating the injury, such as time lost practicing and competing in sports; prevention of these injuries is essential as the symptoms have long term effects. Yeung, Chan, So, and Yuan (1994) reported that the long term side effects associated with ankle injuries "may result in the player experiencing pain, sense of instability, crepitus (grating, crackling or popping sounds and sensations experienced under the skin and joints), and weakness" (p. 114). Struijs and Kerkhoffs (2002) also found consequences included "mechanical instability, intermittent swelling and stiffness, and accumulation of cartilage damage leading to degenerative changes" (p. 945). The need for prevention strategies and adequate and proper treatment of these injuries is essential to minimize complications and their long term residual symptoms.

Purpose

The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes in Division II Collegiate basketball athletes at the University of Central Oklahoma (UCO). This was accomplished by measuring the average left-right excursion from the center of pressure (CoP), using the Tekscan® F-scan in-shoe pressure analysis (Boston, MA). Left-right excursion is used as a measure of sway in the horizontal direction. Karlsson and Frykberg (2000) found that velocity of sway is a measure of the body's sway, which occurs predominantly in the horizontal plane, and pertains to the postural stability of the body. Even though taping and bracing techniques have been developed, many athletes do not tolerate or prefer to use these preventative methods. Beriau, Cox, and Manning (1994) found that the factors that affect an individual's decision to wear a supportive device are based on "perceived comfort, support, and performance restriction" (p. 228). Previous studies have investigated the effect of shoe height on the prevention of ankle sprains mainly using an ankle inversion platform (Ashton-Miller et al., 1996; Ottaviani et al., 1995; Ricard, Schulties, & Saret, 2000). Ricard et al. (2000) performed a study with subjects wearing high-top and low-top shoes to see if shoe height affected the rate and amount of inversion allowed. They reported that high-top shoes were superior to low-top shoes in significantly reducing ankle inversion (Ricard et al. 2000).

Many researchers have focused on the inversion moment and the ability of high-top basketball shoes to limit the amount of inversion allowed compared to low-top shoes (Ottaviani et al., 1995; Ricard et al., 2000). Ottaviani et al. (1995) studied the effects of the height of basketball shoes on their ability to reduce and resist the maximal inversion and eversion moment at the ankle in the frontal plane. When the foot was placed in 0° of ankle plantarflexion it was found that the three quarter-top basketball shoe was significantly (p =

0.05) better at resisting the inversion moment by 29.4%. This was also the case at 16° of ankle plantarflexion, inversion was resisted significantly ($p = 0.05$) by 20.4%. These results show that shoe height has a significant effect on resisting an inversion action, similar to the mechanism causing an ankle sprain (Ottaviani et al., 1995). If high-top shoes are effective at limiting inversion this may eliminate the need for bracing or taping.

However, not all research agrees with these findings. There has been conflicting reports in the literature in regards to the effectiveness and increased stability of high-top basketball shoes. Garrick and Requa (1973) found high-top shoes to provide greater protection than low-top shoes in preventing ankle sprains. However, Rovere, Clarke, Yates, and Burley (1988) recorded significant ($p = 0.05$) findings for protective qualities of low-top shoes. Also, Barrett et al. (1993) found no differences when comparing low-top and high-top shoes. This study is very relevant and applicable to many sports, specifically those requiring a high degree of cutting, jumping, maneuvering and changing direction. Shoe stability is important to consider with the attempt to reduce the incidence of ankle sprains. This could have a profound influence on shoe design and manufacturing.

Stability can be measured in terms of magnitude of excursion from the center of pressure (CoP). Postural stability has been analyzed by many researchers who have used a force plate to measure the time-varying coordinates of the CoP (Benvenuti et al., 1999; Goldie, Bach, & Evans, 1989; McKeon, & Hertel, 2008). These values are often recorded as the statistical measures of sway, which include the standard deviation, path length or mean velocity of the CoP (Goldie, Bach, & Evans, 1989). The reasoning behind using CoP as a measure of postural control is that CoP excursions are computed from ground reaction forces (Hertel, Gay, & Denegar, 2002). These excursions provide useful information regarding postural control during quiet standing due to the effort of the muscles of the ankle contracting to control a stable posture and react to changes in the ground forces. A high magnitude or velocity of CoP excursions has been related to impaired postural control (Hertel et al., 2002). Force plate analysis can be used to provide a quantitative measure of stability. McKeon, and Hertel (2008) used force plate analysis to determine postural control and found that it to be a better predictor at identifying deficits in stability that are closely related with an increased risk of suffering an acute ankle sprain, rather than those leading to chronic ankle instability (CAI). There is limited research on pressure plate data regarding stability. However, the use of a pressure plate allows for data to be recorded from dynamic movements and a greater number of variables may be recorded.

Significance

The significance of this study was to reduce the incidence of ankle sprains, not just in college players but also elite athletes and recreational basketball players, by determining if there is a difference in stability between high-top and low-top basketball shoes. The relevance of shoes may decrease the chance of injury occurring which in turn can decrease the time lost practicing and competing, the long term degenerative effects, and overall health care costs.

Hypothesis

The researcher hypothesized that high-top shoes will prove to be more stable than low-top shoes. This will be shown by a lower average left-right excursion in high-top shoes compared to low-top shoes. The null hypothesis statement was that there will be no difference in stability between low-top and high-top basketball shoes.

Delimitations

Male and female Division II Collegiate basketball athletes at the University of Central Oklahoma (UCO) were recruited for this study. Individuals were excluded if they did not meet the inclusion criteria which include being a current member of the men's or women's basketball team. Therefore, the researcher has delimited the population to include only this segmented athletic population.

Subjects brought their own low-top and high-top basketball shoes to the testing session. This decreased internal validity but increased external validity. Internal validity is decreased as each subject's shoes will differ from each other, adding a greater variety. External validity was increased as the results are more generalizable to the population.

Limitations

The limitations with this study were the sample size. Subjects brought their own high-top and low-top shoes, this variability decreased internal validity but increased external validity. This study was carried out in a basketball gym individually, without any interference from other players and therefore did not include all the dynamics of an actual basketball game situation.

Operational definitions

- Ankle injury- "acute trauma to the ankle ligaments that resulted in an athlete's inability to participate in basketball one day after the injury" (Sitler et al., 1994, p. 454).
- Foot dominance- "limb preferred to execute a manipulative or mobilizing action while the other non-dominant foot provides stabilizing support" (Gabbard & Hart, 1996, p. 289).
- Left-right excursion- the displacement from the CoP. These CoP excursions are calculated from the ground reaction forces (Hertel et al., 2002).
- Postural sway- average left-right excursion.

Conclusion

The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes in Division II Collegiate basketball athletes at UCO, by measuring the average left-right excursion. The significance of this study was to reduce the incidence of ankle sprains, in basketball players. By decreasing the chance of injury occurring this in turn can decrease the time lost practicing and competing due to injury, the long term degenerative effects, and overall health care costs. The height of shoes may act as an alternate or additional preventative method to taping or bracing.

Literature Review

Ankle sprains are a common occurrence in everyday activities and even more predominant in sports, especially those involving jumping, cutting, and rapid changes in direction. The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes in Division II Collegiate basketball athletes. This was be accomplished by using average left-right excursion as a measurement of stability. The relevancy of this proposed study was to find an effective preventative method to ankle sprains and alternative to ankle taping or bracing. There are a number of factors, internal and external, that must be considered regarding an ankle injury.

Anatomy

The ankle is a complex structure which is composed of three joints; the talocrural joint, the subtalar joint, and the distal tibiofibular syndesmosis. Each of these joints has their own role on structure and function (Hertel, 2002). These three joints work in harmony to allow movement to occur at the rearfoot. The stability of the ankle joints are influenced by "the congruity of the articular surfaces when the joints are loaded, the static ligamentous restraints, and the musculotendinous units, which allow for dynamic stabilization of the joints" (Hertel, 2002, p. 365).

The articulations between the dome of the talus, the medial malleolus, tibial plafond, and the lateral malleolus all interact to form the talocrural joint. Torque is transmitted from the lower leg (internal and external rotation) to the foot (pronation and supination) during weight bearing, due to the shape of the talocrural joint, thereby, allowing efficient and effective biomechanics to occur (Hertel, 2002). Stormont, Morrey, An, and Cass (1985) reported that when the ankle complex is in its closed packed position, the articular surfaces provide the majority of stabilization against excessive talar rotation and translation; however, the presence of the ligaments adds to talocrural joint support and stability against unwarranted motion.

Ligamentous support surrounds the joint medially and laterally for increased protection. This comes from a joint capsule and several ligaments, including the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL), and deltoid ligament. The lateral ligamentous support is provided by the ATFL, PTFL, and CFL, whereas medially the deltoid ligament offers support (Hertel, 2002). Even though there is only one ligament medially it has two separate layers and is structurally stronger than the lateral ligaments combined (Bonnel, Toullec, Mabit, & Tourné, 2010). The superficial layer originates from the superior portion of the medial malleolus and then spreads distally following its fibers. The deep layer is comprised of bundles of fibers originating diagonally from the medial malleolus and inserts on the talus (Bonnel et al., 2010).

The function of the ligaments surrounding the ankle is to restrict excessive range of motion at the ankle to prevent injury. As described by Hertel (2002) the function of the ATFL is to prevent dislocation of the talus anteriorly from the mortise and provide a restraint against excessive inversion and internal rotation of the talus on the tibia. The ATFL is strained as the foot moves in the following directions: dorsiflexion to plantarflexion and eversion to inversion The further the foot moves into these positions the greater the strain placed on the ATFL and increases the chance of injury (Renstrom et al., 1988). Supination is restricted by the CFL for both the talocrural and subtalar joints (Hertel, 2002). When the talocrural joint is loaded, the PTFL acts to restrain inversion and internal rotation motions (Stormont et al., 1985).

The talus and calcaneus are responsible for forming the subtalar joint and it also transfers torque between the lower leg (internal and external rotation) and the foot (pronation and supination) similar to the talocrural joint (Hertel, 2002). The subtalar joint is actually composed by two articulations: the inferior posterior facet of the talus and the superior posterior facet of the calcaneus form the posterior joint, and the anterior subtalar joint is created by the head of the talus, the anterior-superior facets, the sustentaculum tali of the calcaneus, and the concave proximal surface of the tarsal navicular (Rockar, 1995). This articulation is similar to a ball-and-socket joint, due to the nature of the surfaces, and allows greater movement to occur than other joints. In this dynamic, the talar head acts as the ball and the calcaneal and navicular surfaces constitute the socket (Perry, 1983).

The distal articulation between the tibia and fibula is the third joint of the ankle, which to some is not considered a true joint. This joint is a syndesmosis which means it only allows a small amount of movement between the two bones. However, this small amount of motion, known as accessory gliding, is essential for normal mechanics to occur in the ankle (Hertel, 2002). Stabilization of this joint is provided by a thick interosseous membrane between the two bones and the distal anterior and posterior inferior tibiofibular ligaments. This joint provides a structural advantage to the taolcrural joint. This joint is injured when a high ankle sprain occurs and results in damage to the anterior inferior tibiofibular ligament (Miller, Shelton, Barrett, Savoie, & Dukes, 1995).

Range of Motion

The range of motion (ROM) allowed at the ankle occurs in all three planes of motion simultaneously. The ROM available is responsible for a variety of movements seen in basketball, such as running, jumping, landing, and cutting. According to Huson (1987), the motion allowed at the rearfoot occurs in all three cardinal planes: sagittal-plane motion (plantarflexion-dorsiflexion), frontal-plane motion (inversion-eversion), and transverse-plane motion (internal rotation-external rotation). In the majority of activities the foot moves in the diagonal plane, which includes two or more planes of motion simultaneously. This is seen as the rearfoot moves as a unit about an oblique axis of rotation. This joint rearfoot motion is best known as pronation and supination (Hertel, 2002). In the open kinetic chain (distal segment is mobile or not fixed), pronation is a result of dorsiflexion, eversion, and external rotation, while supination is a combination of plantarflexion, inversion, and internal rotation (Rockar, 1995). In the closed kinetic chain (distal segment is not mobile or is fixed), pronation is a mixture of plantarflexion, eversion, and external rotation, while supination requires dorsiflexion, inversion, and internal rotation (Rockar, 1995). As a result prevention measures are most commonly aimed at preventing lateral ankle sprains by limiting range of motion in inversion and plantarflexion.

Dynamic Stability

Stability is an important factor to be considered regarding lower extremity injuries. When activated, musculotendinous units generate stiffness within, this leads to dynamic protection and greater stability of the joints (Hertel, 2002). Muscles function concentrically and eccentrically, and it is their eccentric function that is more important at providing dynamic stability to the joints that the muscles cross. The peroneal longus and brevis muscles, found on the lateral aspect of the lower leg, are vital for producing supination and assisting in protection against lateral ankle sprains (Ashton-Miller, Ottaviani, Hutchinson, & Wojtys, 1996). Along with the peroneals, the muscles of the anterior compartment of the lower leg (anterior tibialis, extensor digitorum longus, extensor digitorum brevis, and peroneus tertius) may use their eccentric function to assist in the dynamic stability of the lateral ankle. The theory behind this is that the muscles may be able to slow plantarflexion as the foot supinates and prevent injury to the lateral ligaments that occur as a result of an inversion moment (Sinkjaer, Toft, Andreassen, Hornemann, 1988).

Dynamic stability is influenced by many factors, especially anatomical features. Hertel (2002) explained that many articular nerve fibers end in mechanoreceptors in the capsule and ligaments of joints. These endings are stimulated by the static position and motion of the joint in which they lie, and it has been shown that the central effects of such stimulation include alterations in the activity of neighbouring muscles (Hertel, 2002). In general, these receptors subserve reflexes, with the probable effect to stabilize the joints in the face of passive displacements by provoking appropriate muscular activity. In particular, the mechanoreceptors in the human foot and ankle may control reflexive contractions of the calf muscles which must occur to maintain stablility of the foot on uneven ground (Freeman, Dean, Hanham, 1965). It is thought; 1) the afferent nerve fibres in the capsule and ligaments of the foot and ankle subserve reflexes which help to stabilise the foot during gait, and 2) when the joints of the foot or ankle sustain a sprain, partial deafferentation of the injured joints occurs, so that 3) reflex stabilization of the foot is negatively affected and the foot tends to “give way” (Freeman et al., 1965).

Hertel (2002) explains where the neural influence originates to supply the ankle and foot. The ankle complex receives motor and sensory nervous stimulation from the lumbar and sacral plexes located in the spinal cord. The motor supply to the muscles is received from the tibial, deep peroneal, and superficial peroneal nerves. The sensory supply originates from three mixed nerves and two sensory nerves: the sural and saphenous nerves.

Dynamic stability is not just limited to the foot and ankle complex. It is also affected by extraneous variables, hip and trunk motions, joint angles, joint ROM, muscle strength and endurance, and compensatory motions (Guskiewicz & Perrin, 1996).

Proprioception

Proprioception is the perception of your body in space and can be measured statically and dynamically. Jerosch and Prymka (1996) explained that some proprioception is achieved by nerve impulses being sent to the spinal cord instead of the brain and therefore acting as a faster reaction, or reflex, to external stimuli. It has been shown that proprioception decreases after injury to the ankle joint (Jerosch & Prymka, 1996). In a study of peroneal reaction time, Konradsen and Ravn (1990) found that persons with functionally unstable ankles have a slower reaction time compared to those that served as controls indicating deficits in performance.

Jerosch and Prymka (1996) defined static proprioception as position sense and is the conscious knowledge of the position of different parts of the body in relation to one another. Dynamic proprioception is the sense of the rate of movement within the joint (Jerosch & Prymka, 1996).

In a study by Benvenuti et al. (1999), they found a combination of direct body measurements and force plate data were effective in showing disequilibrium and underlying impairments in proprioception. Therefore, in order to obtain a complete measure of proprioception, a combination of static and dynamic measurements must be taken. The static measurements of proprioception would include the repositioning of the ankle by the subject. Force plate data would be a dynamic interpretation of proprioception, as the subject has to adjust their body to maintain a position on the plate.

Injury

Ankle sprains are often seen in sports that require frequent changes in the direction, rapid acceleration and deceleration, many of such maneuvers can be found in basketball.

Hootman, Dick, and Agel (2007) reported that ankle sprains are the most common injury in college athletics. This fact was further substantiated by the National Collegiate Athletic Association Injury Surveillance Survey (NCAAISS) which revealed that 15% of reported injuries were due to ankle sprains. The majority of these injuries occur to the lateral aspect of the joint with an inversion mechanism of injury (Andrews, Harrelson, & Wilk, 2004). A lateral ankle sprain is the result of an acute injury to the lateral ligaments of the ankle.

Lateral ankle sprains often result from landing with the foot in a plantarflexed and inverted position. Hockenbury and Sammarco (2001) suggested that ankle sprains may result from “running on uneven terrain, stepping on another athlete's foot during play, or landing from a jump in an unbalanced position” (p. 118). When the foot is in a relaxed state in an open packed position, the ankle is plantarflexed and inverted. If the foot unexpectedly contacts the ground or another object by the foot in a relaxed state, the risk for lateral ligament injury is increased (Hockenbury & Sammarco, 2001). The mechanism of injury may occur from plantarflexion-inversion, plantarflexion-inversion and rotation, or specifically inversion.

Due to the number of mechanisms that cause lateral ankle sprains to occur, Ng and De (2007) reported that up to 85% of all sprains involve the lateral aspect of the ankle. Initial damage is to the ATFL because the direction of force and further stress affects the CF and PTFL. The ATFL is three times more likely to be involved than the CFL, as it is weaker than the CFL and due to the fact that the ankle is typically plantarflexed and inverted (Ng & De, 2007).

A grading system has been devised based on the extent of damage to the lateral ligamentous structures. DeFranco, Carl, and Bach (2008) explain that grade I results in the ligaments remaining intact, grade II is when a partial tear of the ligament is involved and a grade III sprain is equivalent to a full tear of the ligament. Furthermore, it is believed that lateral ankle ligament injury results in mechanical instability, due to ligamentous deafferentation. (Myers, Riemann, Hwang, Fu, & Lephart, 2003).

After suffering an initial ankle sprain, the chance of subsequent sprains is significantly increased, this may lead to chronic ankle instability (CAI). Wikstrom, Tillman, & Borsa (2005) reported that CAI is often associated with a number of symptoms. The most common symptoms appear to be “pain during activity, recurrent swelling, a feeling of giving way, and repetitive injury” (Wikstrom et al., 2005, p. 169). CAI has also been categorized as mechanical or functional. Mechanical instability results when the ROM of the ankle exceeds that of the physiological limitations allowed. Functional instability is more of subjective description. The individual experiences a feeling of “giving way” during activity after an initial or recurrent sprain. The available ROM may not be exceeded but the motion occurs involuntarily (DeFranco, Carl, & Bach, 2008).

Incidence

Many authors have investigated the incidence of ankle sprains via different methods, most commonly via surveys or experimental methods. Smith and Reischl (1986) studied the occurrence of lateral ankle sprains in young male athletes. They conducted a survey of 84 varsity basketball players. The results showed that 70% of individuals had a history of ankle sprain, and of those 80% suffered multiple sprains. In 32% of cases, the athlete missed more than two weeks of play, however, 55% did not seek medical attention for their injury. Residual symptoms were noticed in approximately 50% of the athletes, and of those 15% of subjects felt their recurring symptoms put them at a disadvantage physically. This study indicates the possible complications and impact on performance of an ankle sprain in young athletes.

There are numerous studies that support this high rate of incidence. McKay, Goldie, Payne, and Oakes (2001) surveyed 10,393 basketball participants. Ankle injuries occurred at a rate of 3.85 per 1,000 participants; 45.9% of these injuries resulted in at least one week or more of competition being lost and 45% of these occurred from landing. More than half (56.8%) of those suffering ankle injuries did not acquire medical treatment. From this study, the apparent risk factors for ankle sprains were: a history of ankle injuries, make it five times more likely to reinjure the ankle (odds ratio (OR) 4.94, 95% confidence interval (CI) 1.95 to 12.48); shoes with air cells in the heel had a higher rate of sprains than shoes without air cells (OR 4.34, 95% CI 1.51 to 12.40); subjects who did not perform any stretching before the game were at a greater risk of suffering an ankle injury than those who did (OR 2.62, 95% CI 1.01 to 6.34).

The incidence of ankle sprains in the United States is a large problem affecting the whole population. Waterman, Owens, Davey, Zacchilli, and Belmont (2010), investigated the occurrence rates of ankle sprains in the United States via those reported in emergency rooms. They hypothesized that ankle sprains were related to sex, race, age, and involvement in athletics. The data collected by the National Electronic Injury Surveillance System (NEISS) was utilized to determine the incidence of ankle sprain injuries throughout 2002 to 2006. During this time, 3,140,132 ankle sprains were recorded at emergency rooms among an at-risk population. The greatest incidences of ankle sprain were found in individuals between the ages of 15 and 19 years old. Athletic activity was the cause of almost half of all ankle sprains (49.3%). The sports that acquired the highest incidence were basketball (41.1%), football (9.3%), and soccer (7.9%) (Waterman et al., 2010). This large incidence of ankle sprains, especially in athletic activity, signifies a growing need to develop preventative and protective strategies to combat this problem.

Trevino, Davis, and Hecht (1994) found that up to 45% of ankle sprains resulted from sports related injuries. The occurrence of an initial ankle sprain leads to an increased risk for subsequent sprains. This was shown by Leanderson, Nemeth, and Eriksson (1993) who performed a study to determine the frequency of ankle sprains in basketball players. Data was collected via a survey sent out to 102 basketball players in a second division league in Sweden. The results showed that 92% of those who played had suffered an ankle sprain, and multiple sprains on an ankle had occurred in 83% of these individuals. Over the past two seasons, 78% of the players suffered an ankle injury. The frequency rate was 5.5 ankle injuries per 1000 activity hours. Out of all the players, 22% used some form of prophylactic device for supportive purposes (Leanderson et al., 1993). Due to the high incidence of ankle sprains observed in basketball and the consequences resulting from them, prevention is essential to decrease the recurrence rate and minimize the long term effects.

The long term side effects of ankle sprains have been extensively studied. Yeung, Chan, So, and Yuan (1994) reported that ankle injuries may cause an individual to experience "disability and residual symptoms, the most common being pain, sense of instability, crepitus (grating, crackling or popping sounds and sensations experienced under the skin and joints), and weakness" (p. 115). Struijs and Kerkhoffs (2002) also found consequences included mechanical instability related to CAI, intermittent swelling and stiffness after activity, and cartilage damage leading to degenerative changes.

The recurrent effects associated with ankle sprains add to the health care costs. In a cost analysis study, Soboroff, Pappius, and Komaroff (1984) found that when medical treatment was sought, the cost ranged from $318 to $914 per sprain, with an annual cost in the United States of approximately $2 billion. This large sum reflects the problem of the incidence of ankle sprains. Some of these costs could be minimized with the advancements in prevention mechanisms, such as taping and bracing, proprioception and balance training, and the height of footwear have all been used as methods employed to limit the occurrence of ankle sprains.

Risk Factors

There are numerous risk factors, intrinsic and extrinsic, that have been related to an increased threat of suffering an ankle injury. Intrinsic factors occur within the body whereas; extrinsic factors are anything outside the body that may influence an ankle sprain. The main intrinsic risk factors predisposing individuals to ankle sprains include; functional and/or mechanical instability, CAI, pathological laxity, arthrokinematic impairments, synovial and degenerative changes, impaired proprioception and sensation, impaired postural control, and strength deficits, poor conditioning. The extrinsic factors that may result in ankle injury include footwear, uneven surfaces, and landing on another player’s foot.

The functional or chronic disability associated with multiple ankle sprains can be the result of a variety of abnormalities and usually is derived from previous sprains. Andrews and Wilk (2004) reported these changes may include anterior, posterior, or varus instability of the talus in the ankle mortise, instability of or an adhesion formation in the subtalar joint, inferior tibiofibular diastasis, peroneal muscle weakness, and motor incoordination as a result of articular deafferentation. Freeman et al. (1965) explained this deafferentation occurs after an injury to either the foot and/or ankle causing partial deafferentation to the area damaged. When this happens the afferent nerve fibers can no longer provide sufficient feedback, which limits the ability of the foot to provide reflex stabilization and the foot tends to “give way”. Individuals have little control over these abnormalities, except peroneal weakness which can be improved through rehabilitation and strengthening.

It has been suggested that a protective reflex mechanism exists to protect the ankle from excessive inversion. Hume and Gerrard (1998) stated that the central and peripheral nervous systems play a major role in the function of a joint. One of these protective mechanism is the stretch reflex which acts to prevent excessive ROM. Reactive preactivation of muscles (coactivation) surrounding a joint increases stiffness and has the potential to protect the ankle. When a sudden unexpected inversion moment takes place the strength of the ligaments and the anatomical alignment are the main structures that act to prevent excessive inversion before the muscle reflex can be activated. However, these structures are at an increased risk for injury (Hume & Gerrard, 1998).

Instability is one factor that can predispose an individual to injury. Hume and Gerrard (1998) reported that the stability can be affected by structural and functional components of the body. The articulating surfaces, ligaments and muscles crossing the joints determine the positioning and control of the joint movement. Due to the design of the structural anatomy of the ankle complex, it is predisposed to an inversion sprain injury. The stability of a joint and its resistance to injury depends on the "anatomical arrangement of the bones (shape of the joint and the axes/planes of motion), the origin and insertion of the muscles and ligaments, the muscles' angle of pull on the bone at a certain moment in the ROM, the viscoelastic properties of the ligaments, the structural response of the connective tissues and nerves, and level of proprioception and strength" (Hume & Gerrard, 1998, p. 286). These factors affect and can limit the ROM of a joint, and are the determining factors whether an ankle sprain will occur or not (Hume & Gerrard, 1998).

Baumhauer, Alosa, Renström, Trevino, and Beynnon (1995) examined injury risk factors to determine if individuals were at an increased risk for an inversion ankle sprain due to any abnormalities. A total of 145 college aged athletes were evaluated before the athletic season. During testing, athletes were measured for generalized joint laxity, anatomic foot and ankle alignment, ankle ligament stability, and isokinetic strength. Throughout the season these athletes were observed and during this time 15 athletes suffered an inversion ankle injury. The results analyzed within-group (uninjured versus injured groups) and within-subject (injured versus uninjured ankles) data. The researchers found no significant differences between the injured (N = 15) and uninjured (N = 130) groups in any of the parameters measured. The athletes who suffered an ankle sprain had lower strength ratios of dorsi- to plantarflexion (0.373 in the injured group, 0.348 in the uninjured group), and higher ratios of eversion to inversion strength (1.0 in the injured group, 0.8 in the uninjured group). The greater ratio seen in eversion to inversion resulted from the injury mechanism. Peak torque about the ankle was not significant between uninjured and injured subjects. However, when comparing within subjects, an increased plantarflexion strength was noticed in the injured ankle (mean = 72.20, SD = 23.33 ft lbs) compared with the uninjured ankle (mean = 68.33, SD = 19.26 ft lbs). The main finding was the significant difference in eversion-to-inversion strength ratio for the injured group compared with the uninjured group. The plantarflexion strength and the ratio of dorsiflexion to plantar flexion strength were significantly different, within subjects, for the injured ankle compared with the opposite uninjured ankle. The findings indicated that the eversion to inversion strength imbalance was related to a higher incidence of inversion sprains. Also, those who demonstrated greater plantarflexion strength than dorsiflexion and a smaller dorsiflexion-to-plantarflexion ratio had a greater likelihood of experiencing a sprain (Baumhauer et al., 1995). The ability to work and strengthen muscle imbalances can be a preventative measure to decrease the incidence of sprains occurring.

There a numerous contributors thought to cause CAI. Some of these factors include neural (proprioception, reflexes, muscular reaction time), muscular (strength, power, and endurance), and mechanical mechanisms (ligamentous laxity) (Mattacola & Dwyer, 2002). A weakening or increased laxity of the ligaments, or weakness in the associated muscles, and a

ROM beyond the normal physiological limits of a joint defines instability (Prentice, 2011). These can result in proprioceptive deficits that occur following a lateral ankle sprain. Restoring proprioception following an injury is necessary to reduce the likelihood of further injury to the joint. When these deficits occur it is necessary to restore the foot and ankle to normal function. This can be achieved through proprioceptive training and rehabilitation techniques to increase and regain protection from injury and restore optimal functional (Laskowski, Newcomer-Aney, & Smith, 1997).

Verhagen et al. (2004) introduced a proprioceptive balance board program to determine its effectiveness to prevent ankle sprains in volleyball players via a prospective controlled study. There were 116 male and female volleyball teams that participated throughout the 2001–2002 season. Teams were randomly assigned based on four geographical regions. The teams were assigned to either the intervention group (n = 641 players) or the control group (n = 486 players). The intervention group followed a specific balance board training program; the control group did not participate in balance board training and only followed their normal training routine. The exposure for each player and their injuries were recorded by the team's coach on a weekly basis. There was significantly less ankle sprains in the intervention group compared to the control group (risk difference = 0.4/1000 playing hours; 95% CI). However, the results were only significant for athletes who had a history of ankle sprains. The results from this study show that the use of proprioceptive balance board training can be an effective tool against the recurrence of sprains (Verhagen et al., 2004).

Hertel (2002) explained that after a sprain, depending on the severity, laxity of the involved ligaments often results, leading to mechanically instability. This mainly occurs when the ankle is placed in a position that makes it susceptible to injury (Hertel, 2002). Hypomobility may also be thought of as a mechanical insufficiency. The inability to fully dorsiflex at the talocrural joint results in the foot being unable to reach its closed packed position and leaves the joint vulnerable to inversion injuries (Hertel, 2002).

The extrinsic factors for ankle injury which have been examined via prospective studies are: use of orthotics, shoe type, player position, training errors, equipment, and length and intensity of activity (Barker, Beynnon, & Renström, 1997). The landing position of the foot can greatly impact whether a lateral ankle sprain will result or not. Wright, Neptune, van den Bogert, and Nigg, (2000), examined the effect of differences in foot positioning at touchdown that a simulated lateral ankle sprains. Analysis was performed using a mathematical model and perturbated simulations. The results indicated that a greater angle of foot supination caused a slight increase in the occurrence of sprains, but a smaller angle in the initial supination resulted in a slight decrease in sprains. It was also found that a decrease in ankle sprains resulted from individuals with a greater supination torque, as this corresponded to a greater dorsiflexion angle. This placed the foot in a closed packed position and assisted in resisting an inversion moment. The conclusions gathered from this study propose that increased supination and plantarflexion at touchdown may place the foot at an increased risk for injury, due to the foot being in a more open packed position and the ground reaction force moment arm about the subtalar joint being greater (Wright et al., 2000).

The level of competition has been proposed as a risk factor for ankle sprains. A comprehensive study was carried out by Hosea, Carey, and Harrer (2000) on high school and collegiate basketball players to investigate if the level of competition influenced the occurrence of ankle sprains. There was 11,780 male and female basketball athletes involved in the study. The results revealed that collegiate level activity provided more than a twofold increased incidence of ankle injury (thought to be due to higher intensity and skill level) compared with high school. Therefore, as skill level and presumably intensity level increases the risk of spraining an ankle also increases.

In a review of the literature, Beynnon, Murphy, and Alosa (2002) examined the intrinsic and extrinsic factors known to be associated with ankle sprains. Throughout the vast number of studies that have been carried out on the ankle, the most common intrinsic risk factors found are: previous sprain; sex; height and weight; limb dominance; anatomic foot type and size, generalized joint laxity, anatomic alignment, ankle-joint laxity, ROM of the ankle-foot complex, muscle strength, muscle reaction time, and postural sway. It can be seen there are many factors that result in an ankle injury. This is partially a result of the partial deafferentation that results and negatively affects stabilization. As height and weight of an individual increases, this directly and proportionately increases the inversion torque on the ankle that must be resisted to prevent an ankle injury when it is in a vulnerable position. This puts greater strain on the ligaments and muscles. Limb dominance has been implicated as a risk factor for lower extremity stress as researchers have found the majority of athletes place a greater demand on their dominant limb (Beynnon et al., 2002; Gabbard & Hart, 1996). This is usually the limb preferred by athletes for kicking, pushing off, jumping, and landing. Therefore, they place greater reliance on the dominant limb, which as a result has to withstand greater forces about the knee and ankle. This is evident during high-demand activities that require lots of jumping, turning, and twisting (Beynnon et al., 2002).

Beynnon et al. (2002) examined the extrinsic risk factors thought to be related to ankle injuries. These include bracing and taping, shoe type, the duration and intensity of competition, and player position. The advancement in technology and great variety of athletic shoes available makes it more difficult to find a shoe that will provide support, however this is based on the design characteristics specific to that shoe. These characteristics may either reduce the risk of injury by providing increased proprioceptive input, or increase the risk of injury by restricting ankle ROM, abnormal foot-shoe and shoe-surface traction, or increase the inversion moment arm about the ankle. All of these design characteristics are important factors in the care of athletes to prevent injury. However, when considering the incidence and risk factors associated with ankle sprains it is difficult to come up one specific method of prevention due to the number of factors reported in the literature.

Injury Prevention

Prevention of lateral ankle sprains is essential to avoiding CAI, degenerative consequences, decrease the time lost practicing and competing due to injury, and overall health care costs. Hertel (2002) explains the ability to prevent ankle sprains must take into consideration the pathologic laxity, arthrokinematic changes, and other mechanical deficits that have resulted in mechanical instability and also address the proprioceptive and neuromuscular losses seen with functional instability. Rehabilitation programs have been developed to target these specific areas; proprioceptive, neuromuscular control, and balance training specifically have been significant in reducing the risk of recurrent ankle sprains (Hertel, 2002).

Specific equipment has been designed for the prevention of ankle sprains, most commonly bracing and taping procedures, which have been extensively researched (Hume & Gerrard, 1998; Ashton-Miller et al., 1996; Garrick, & Requa, 1973). The goal of taping and bracing are to restrict the ROM at the joint. Hume and Gerrard (1998) describe that there are many characteristics of materials and designing of equipment that are aimed at reducing unnecessary ROM. This can be achieved through external mechanical restrictions (design characteristics and material stiffness) or by activation of sensory receptors due to changes in pressure caused by the equipment, which in turn causes a change in the muscle activation patterns. Muscular contraction is theorized to increase joint stiffness thereby increasing stability. Studies have shown conflicting reports on bracing, taping and, bracing versus taping.

In a study by Garrick and Requa (1973), they found that taping can cause a reduction in ankle injury. Garrick and Requa (1973) conducted a prospective, randomized case-control study over the course of two basketball seasons (1972-1973). They had 2,562 intramural university basketball players serve as subjects. Baseline data were collected during the first year and players who agreed to participate during the second year were randomly assigned to one of four conditions. These conditions were based on different external supportive devices. The four conditions studied were tape, no-tape, with low-top, or with high-top shoes. During the season a total of 66 ankle and knee sprains were reported. Throughout the season 1,163 of the subjects (45.4%) had their ankles taped while playing. The results showed a significant decrease, $p = 0.025$, in ankle injuries in those who had increased external support. The most injuries were observed in the low-top shoe no-tape group and the least for the high-top shoe taped group. It is difficult to determine which condition had more of an effect, being taped or shoe height. Some common issues were discovered; players who had a history of ankle sprain were more than twice as likely to be re-injured (27.7 injuries per 1000 playing hours for injured players and 13.9 for previously noninjured players). For all subjects, the taped injury rate was lower than the no-tape injury rate regardless of ankle sprain history. The knowledge gained from this study shows ankle taping and possibly shoe height to be an effective preventative method against ankle sprains (Garrick & Requa, 1973).

Sitler et al. (1994) performed a study to determine whether a semirigid ankle stabilizer was effective in reducing the occurrence and severity of acute sprains. The subjects used in this study were US Military Academy cadets, who played intramural basketball ($n = 1,601$).

The cadets were divided into two groups; experimental group (assigned brace) and control group (no brace). All other variables were controlled statistically or experimentally, including athletic shoe, playing surface, athlete exposure, and ankle injury history. Ankle injury was defined as “acute trauma to the ankle ligaments that resulted in an athlete’s inability to participate in basketball one day after the injury” (Sitler et al., 1994, p. 454). Over two seasons a total of 13,430 athlete exposures were experienced. The use of a brace did significantly decrease the frequency of ankle injuries. They also found that over the course of the season the cadets’ attitude toward wearing a semirigid ankle stabilizer improved.

A study by Sharpe, Knapik, and Jones (1997) was conducted on female soccer players who already had a previous history of ankle sprains. This study implied that prophylactic ankle bracing was an effective strategy to protect the ankle. The researchers obtained data from the medical records of university soccer players over five years to identify individuals with a previous history of ankle sprains (38 players; 56 previously injured ankles). Those who had a positive history were randomly assigned one of four interventions: a canvas laced ankle brace (n = 19); taping (n = 12); a combination of taping and ankle bracing (n = 8); or no external support (n = 17). The braced group had the least recurrence frequency (0%) compared to that of the taped (25%), taped and braced (25%) and no support (35%) groups (Sharpe et al., 1997). This study lead the researchers to conclude that bracing was significantly more effective at providing a restraint to ankle sprains than taping.

However, not all studies have matched this finding. Mickel et al. (2006) stated that prophylactic ankle taping is still considered to be the main method of ankle injury prevention, especially as it has been used at all levels of competitive football. Bracing has been compared as an alternate to taping. The authors in this study analyzed the incidence of ankle sprains of 83 high school football players during a single season, wearing either a brace or tape on both ankles. Over the season, six ankle sprains occurred, three in each treatment group. Therefore, there was no significant difference in the incidence of ankle sprains between wearing a brace or tape. No control was included in this study. As a result of neither condition having a mechanical advantage against ankle sprains, the cost effectiveness was considered. The average time to tape an athlete was 67 seconds per ankle, and this accumulated to 97 minutes per ankle for an entire season, whereas bracing does not require any time from athletic trainer to apply. Over the course of a season a commercially available brace is less expensive than the cost required taping each ankle. When analyzed based on cost and time alone, a commercial brace is more efficient and beneficial than taping (Mickel et al., 2006). High top shoes may eliminate this extra cost and time by providing mechanical stability.

The decision on whether to tape or wear an external supportive device is based on the preference and comfort of an athlete. The major influence on an athlete's decision to choose an external supportive device depends on how performance may be impacted as a result (Verbrugge, 1996). The consensus among many athletes is that bracing negatively impacts performance, regardless of its ability to prevent injury or not (Pienkowski, McMorrow, Shapiro, Caborn, & Stayton, 1995. Pienkowski et al. (1995) designed a study to evaluate the impact of three different brace designs (Universal, Kallassy, and Air-Stirrup ankle training brace) on athletic performance in four basketball-related activities to investigate if a specific brace may be superior to another. Twelve high school basketball players performed each activity; vertical jumping, standing long jumping, cone running, and 18.3-meter shuttle running at two test times (initially and after one week of acclimation). All subjects performed the activities with no brace and with each brace condition. No significant effects on athletic performance were found wearing any brace condition. From this, it can be observed that prophylactic ankle bracing does not inhibit or hinder athletic performance in any way

(Pienkowski et al., 1995). This knowledge is important but ultimately it all comes down to the athlete's preference and tolerance of bracing and/or taping.

Footwear

External support has been designed to limit the amount of inversion available. High-top shoes have been designed as an alternative to bracing or taping, and to provide greater mechanical stability than low-top shoes. Hughes and Stetts (1983) stated that the function of any external ankle support is to restrict the amount of ankle inversion to avoid a sprain. It is thought that if active inversion ROM is restricted then the extreme inversion that causes an ankle sprain will also be prevented. The external ankle supports are designed to provide increased stability at the joint by reinforcing the ligaments and limiting inversion, which is the cause of most ankle injuries. There is a lack of research comparing high-top and low-top basketball shoes exclusively.

This idea of using shoes as a method of external support has been a point of mutual agreement by some researchers. Robinson, Frederick, and Cooper (1986) stated that shoes have been used as an alternative means for external ankle support. Robinson et al. (1986) reported that shoe design characteristics and changes over time are necessary for allowing an optimal ROM and restriction, whilst allowing for peak performance and protection. These design changes have been observed via an increase in resistance of the shoe upper by adding stiffeners to the lateral sides of high-top basketball shoes. The idea behind this is to limit the amount of inversion and eversion ROM allowed. This has been tested using an Inman device which has shown decreased ROM of the allowed at ankle and a subsequent decrease in performance times when six athletes were put through an obstacle course; three with previously injured ankles (Robinson et al., 1986).

Advancement of shoe technology and design, has allowed the comparison of high-top shoes and low-top shoes in their ability to limit inversion and in theory, reduce the incidence of ankle sprains. Shapiro, Kabo, Mitchell, Loren, and Tsenter (1994) performed a study to analyze the effects of a variety of eight different braces and tape, with low-top and high-top shoes, on their ability to resist a mechanically applied inversion moment. This study was conducted on five cadaveric ankles placed in neutral 30° of plantarflexion. High-top shoes showed a significantly greater ($p = 0.05$) ability to resist the passive inversion moment better than low-top shoes in all braced and taped conditions. The braces were all able to resist inversion to a better degree than tape (Shapiro et al., 1994). The main concern with this study is how reliable are cadaveric subjects as opposed to living subjects.

Not all studies have shown high-top basketball shoes to be superior in preventing ankle sprains than low-top basketball shoes. Barrett et al. (1993) used a prospective, randomized experimental design on the comparison of shoe height. There were 622 intramural college basketball players who were assigned to one of the experimental groups. This was done by random stratification based on whether they had suffered an ankle sprain previously. The subjects were assigned to wear either high-top, high-top with inflatable air chambers, or low-top basketball shoes for the duration of the season. Subjects were only allowed to wear their assigned shoe during competition. The intramural season only took place over two months, within this time 15 ankle injuries occurred during 39,302 minutes of player-time: seven in high-top shoes, four in low-top shoes, and four in high-top shoes with inflatable air chambers. This resulted in an injury rate of (injuries per player-minute), 4.80×10^{-4} in high-top shoes, 4.06×10^{-4} in low-top shoes, and 2.69×10^{-4} in high-top shoes with inflatable air chambers. The results showed no significant difference between the three groups, which confirmed the null hypothesis that there was no relationship between shoe height and ankle sprain incidence (Barrett et al., 1993). Although no significant differences were found more ankle sprains occurred while wearing high-top shoes. This study only took place over a short duration and relied upon individuals to report an ankle sprain.

Ricard, Schulties, and Saret (2000) designed a study to determine if the rate and magnitude of ankle inversion was affected by shoe height, high- and low-tops. Twenty male subjects with no history of lower extremity injury within the previous six months were recruited. Subjects stood on an inversion platform that unexpectedly inverted the right ankle 35°. Subjects were filmed at 60 Hz using video motion analysis techniques Each subject completed five trials of sudden inversion for both shoe heights. A 2 x 5 factorial repeated measures analysis of variance was used to determine if significant differences in the magnitude of inversion, average rate of inversion, and maximum rate of inversion occurred between different footwear. The findings revealed that high-top shoes reduced the amount of inversion by 4.5°, the maximum rate of inversion by 100.1 °/s, and the average rate of inversion by 73.0°/s. High-tops shoes significantly decreased ($p = 0.001$) the magnitude and rate of ankle inversion. This could be beneficial for shoe manufacturers when developing high-top shoes with increased support to be more effective in reducing the amount and rate of inversion and thereby decreasing the incidence of sprains occurring. This reduction in the amount and rate of inversion may allow the body's protective mechanisms time to respond to the inversion moment act accordingly to avoid damage (Ricard et al., 2000).

Ottaviani, Ashton-Miller, Kothari, and Wojtys (1995) also found similar results. Ottaviani et al. (1995) performed a study that included an eversion moment along with the inversion moment to determine if the height of a basketball shoe affects the ability to actively oppose the force. Twenty healthy, young adult men with no recent ankle injuries were recruited for this study. A specially designed testing apparatus was used to test the functional strength of each ankle under weight bearing conditions at 0°, 16°, and 32° of ankle plantarflexion. Subjects were tested in both low-top and three-quarter top basketball shoes. The results found no significant differences at any angle of plantarflexion in the eversion moment by both shoe heights. However, significant differences were found for tests at 0° and 16° of ankle plantarflexion which revealed that the three quarter-top basketball shoe increased the maximal resistance to an inversion moment by 29.4% and 20.4% respectively. Athletic shoe height may be able to mechanically resist an inversion moment of the foot in certain positions (Ottaviani et al., 1995).

It is apparent from the research that there mixed findings on the ability of high-top shoes to reduce the incidence of ankle sprains. Many studies have focused on the ability to resist the inversion moment and not investigated the stability of the shoe, which can be assessed through the use of a force plate.

Force Plate

The ankle plays an important role in stability and overall balance of the body. This can be measured as postural stability using a force plate. Karlsson and Frykberg (2000) defined “postural stability and balance as the ability to return the body close to the equilibrium point when exposed to a perturbation” (p. 365). The human body, when standing upright is constantly in motion and therefore, needs an internal mechanism to maintain control. This control system is known as the balance or the postural control system. Assessment of the postural control system can reveal many findings about balance, motion, and weakness. It has been observed that body sway takes place mainly in the horizontal plane (Karlsson & Frykberg, 2000). Important information about postural stability can be achieved through analysis of sway. Body sway has been quantified through measurements of CoP and horizontal force displacement.

Force plate analysis has been used to determine susceptibility to injury. McGuine, Greene, Best, and Leverson (2000) conducted a study to determine if assessment of a single leg stance could indicate if an athlete was at-risk for suffering an ankle sprain. This test was conducted during the preseason of high school basketball players. Five different high schools participated in this study and data were collected for a total of 210 (119 male and 91 female) subjects, for the 1997-1998 and 1998-1999 basketball seasons. These individuals had not incurred an ankle or knee injury in the past 12 months. Balance was measured from postural sway scores, which were collected as the subject maintained a single leg stance tasks with eyes open and closed, while standing on a NeuroCom New Balance Master version 6.0 (NeuroCom International, Clackamas, OR, U.S.A.). Subjects performed three trials while holding the stance for ten seconds, with eyes open and closed for both legs. The relationship between scores was carried out using a logistic regression analysis to determine if gender, dominant leg, and balance scores were related to ankle sprain injuries. Postural sway was defined as the average degrees of sway per second (°S/S) for the 12 trials producing a compilation (COMP) score. Subjects who had previously sustained ankle sprains had a higher preseason COMP score ($m = 2.01 \pm 0.32$), while athletes who had not sustained ankle injuries had a lower score (1.74 ± 0.31).The higher the postural sway score the greater the risk an athlete had for suffering an ankle injury ($p = 0.001$). This was confirmed as subjects who displayed poor balance, shown as high sway scores, had nearly seven times as many ankle sprains as subjects who had good balance, shown as low sway scores ($p = 0.0002.$). This preseason measurement proved to be a good predictor of ankle sprain susceptibility (McGuine et al., 2000).

There have been more studies evaluating static balance via a force plate compared to studies using a pressure plate. Force plates provide useful information on the vertical and shear components of the ground reaction force, but little information can be collected in regards to how the plantar surface of the foot is loaded when in contact with the supporting surface (Orlin & McPoil, 2000).

Pressure Plate

Pressure sensors have been developed to measure the pressure distribution between two contact objects (Luo et al., 1998). The advantages of the pressure plate are that it allows for greater external validity and dynamic responses.

A study performed by Hrysomallis, McLaughlin, and Coodman (2006), assessed the direct relationship between static and dynamic balance of athletes. This was achieved by performing a static balance task on a firm surface and a dynamic balance task via a stepping task on an unstable surface. A total of 37 Australian male professional footballers took part in the study. The ability to maintain a single leg stance whilst standing on a force platform was used to assess static balance. Dynamic balance was assessed by stepping and maintaining a single leg stance whilst standing on a balance mat placed on top of a force platform. The tests were performed three times each and an average was taken. The measurements recorded included CoP and the maximum excursion in the medial–lateral. The results showed that the dynamic stability test resulted in a significantly greater ($p = 0.05$) amount of maximum center of pressure excursion (53%) than static stability. The CoP excursion tests for the right leg and the average of both was significant but the correlations were low. The values between the left leg showed no significant correlation. The results of this study indicated that performance in the static balance test was not correlated to the performance in the dynamic balance test. Therefore, static balance results should not be used to infer or predict performance in dynamic balance tests (Hrysomallis et al., 2006). In the sports setting, if possible, dynamic balance should be assessed rather than static balance due to the dynamic nature of the activity. Hrysomallis et al., (2006) also concluded that the maximum medial-lateral excursion was a reliable measure and a greater excursion value may also be related to loss of balance and injury potential. Dynamic tasks, such as basketball, pose greater demands for the balance and proprioception control system. This is a result of greater torques and destabilization placed on the body, requiring compensation and subsequently changes in CoP.

There have not been any studies that have evaluated the effects of high-top and low-top basketball shoes on stability via left-right excursion using a pressure plate. This study tested high-top and low-top shoes dynamically and via pressure plate analysis.

Conclusion

The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes in Division II Collegiate basketball athletes at UCO, by measuring the average left-right excursion, by pressure plate analysis. There appears to be a gap in the literature evaluating the stability of high-top and low-top shoes via pressure sensors analysis. Also, the use of Division II athletes is limited in the literature.

Methods

The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes in Division II Collegiate basketball athletes. This was achieved through foot pressure analysis when performing a layup. The significance of this study was and is to reduce the incidence of ankle sprains, in college, elite, and recreational basketball players. Additionally, to decrease the time lost to injury, decrease health care costs, and provide evidence of shoe stability to shoe designers.

Participants

An application for approval from the Institutional Review Board (IRB) was filled out and approved (Appendix A). The sample size for this study was based on research by Ricard, Schulties, and Saret (2000) that examined the amount of inversion allowed by low-top and high-top shoes ($d = 1.8$). Therefore, using this estimated effect size ($d = 1.8$), a statistical power of 0.80, and $p = 0.05$, required a sample size of 9 participants. Recruitment of participants was conducted via word of mouth in Hamilton Field House at the University of Central Oklahoma (UCO). A sample size of 11 (eight male, three female) Division II collegiate basketball players agreed to participate (mean age = 21.18, mean height = 184.73 cm, mean weight = 85.11 kg). Individuals had to sign an informed consent form (Appendix B) which described the procedures and risks that will occur during testing. Furthermore, participants had to fill out a Physical Activity Readiness Questionnaire (Par-Q) (Appendix C) and a questionnaire to determine their eligibility for participation (Appendix D).

Inclusion Criteria

Division II male and female basketball players from the University of Central Oklahoma (UCO) were eligible to participate.

Exclusion Criteria

Subjects were excluded if they demonstrated a prior history of lower extremity injury within the last three months as the proprioceptive component of injury may have had an effect on the variable of interest. Subjects who have had a previous fracture or surgery of either ankle were excluded. Subjects could not have been engaged in a lower extremity rehabilitation regimen during the study because it could have caused them to fatigue faster. Subjects with a history of concussion within one month of the day they were to be tested or were symptomatic without a physician's clearance were excluded as this may affect the subject's ability to balance. Inclusion and exclusion criteria were assessed using a questionnaire (Appendix D).

Procedure

Subjects were screened using a questionnaire (Appendix D) to help eliminate any possible injury prone participants. Subjects performed a full court layup with in-shoe plantar pressure sensors (Tekscan, Boston, MA). The Tekscan is a wireless system that measured foot pressure during movement. Each subject went through a step calibration procedure prior to testing to calibrate the equipment for each individual. Three practice trials were given to allow participants to familiarize themselves with the equipment and procedure. Subjects performed a full court layup and performed the task as they naturally would. Data was analyzed from the first step and ended on landing from the layup. The test was performed a total of six times; three trials in high-top basketball shoes and three in low-top basketball shoes. The order of shoe testing was randomized for each individual. Subjects performed the layups from their self-selected dominant side. The average left-right excursion, in centimeters (cm), was the measurement that was recorded for each trial. Furthermore, a combined average (an average of the averages per shoe type) for high-top shoes and low-top shoes was recorded. There was a one minute break between each trial to prevent fatigue, and five minutes between conditions to allow time to change shoes and align the in-shoe sensors in the other shoe condition. The session lasted approximately 30 minutes in Hamilton Field House at UCO. Subjects brought their own low-top and high-top basketball shoes. This decreased the internal validity but increased the external validity. Internal validity is decreased as each subject's shoes were different from each other, adding a greater variety. External validity was increased as the results will be more generalizable to the population, not everyone wears the same shoe. If any injury were to occur, participants would have been told to seek medical attention from their personal physician.

Instrumentation

The *F-Scan* Foot Pressure Mapping System (Tekscan, Boston, MA) was used to assess the average left-right excursion of the foot whilst performing a layup. LeClair and Riach (1996) studied the repeatability of force plate postural stability measurements. LeClair and Riach (1996) found all parameters to be reliable measures. CoP measures (specifically sway) were found to increase with a longer test duration while simultaneously ground reaction forces and velocity decreased slightly. It can be indicated from the results that measures of CoP excursion and ground reaction forces provide clinical information related to mechanical and sensory conditions connected to postural deficiencies or abnormalities. LeClair and Riach (1996) also found that for the test to provide reliable and valid results only one trial is required to obtain accurate postural sway, CoP, force, and velocity values.

The instrument was calibrated for each subject via a step calibration procedure. Luo et al., (1998) recommended that in actual testing situations, individual sensors should be calibrated prior to use. Orlin and McPoil, (2000) found that for higher speed activities, sampling frequencies of 200 Hertz (Hz) or greater are required. The number of samples measured by each sensor per second is the sampling frequency. The data logger sampling system collected data at 750 Hertz in this study.

Statistical Analysis

The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes. The dependent variable was the average left-right excursion. The independent variable was the type of shoe: low-top and high-top basketball shoes. The PASW version 18 system was used to analyze all collected data. The statistical analysis was performed using a dependent *t* test. To decrease the chance of committing a type II error, the alpha was set at 0.05 as the criteria for significant differences in stability between shoe types. The null hypothesis was that there would be no difference in stability between low-top and high-top basketball shoes. The researcher’s hypothesis was that high-top basketball shoes would be more stable than low-top basketball shoes.

Results

The purpose of this study was to evaluate the stability of low-top and high-top basketball shoes. Descriptive statistics were calculated for each foot in high-top and low-top basketball shoes and can be found in Table 1. The values for both feet in high-top shoes were slightly kurtotic but were included as the amount of variation of foot movement is different for each person.

The mean for left high-top shoes was 3.020 ± 0.956 cm and the mean for right high-top shoes was 2.854 ± 0.908 cm. The mean for left low-top shoes was 3.366 ± 1.120 cm and for right low-top shoes was 3.359 ± 1.433 cm. In general, high-top shoes had a lower average left-right excursion than low-top shoes.

Dependent t-tests were used to compare the means of two related groups, as the same subjects were tested more than once. Dependent t-tests were calculated to check for significance differences in average left-right excursion between shoe types (Table 2). Significant differences were found between shoe types in both right and left feet. The difference between left high-top and left low-top shoes was $t = -2.785$, $p = 0.019$, and the difference between right high-top and right low-top shoes was $t = -2.256$, $p = 0.048$. This means there was less average left-right excursion in high-top shoes compared to low-top shoes. There were no significant differences within shoes (left high-top vs right high-top and left low-top vs right low-top). There was a small effect size between shoe types (left: t^2= 0.437, right: t^2= 0.337). As a result the null hypothesis can be rejected. High-top shoes are significantly more stable than low-top basketball shoes.

Discussion

The stability of high-top and low-top basketball shoes was evaluated from the average left-right excursion using the *F-Scan* Foot Pressure Mapping System (Tekscan, Boston, MA). The results show that high-top shoes are significantly more stable compared to low-top basketball shoes. The *F-Scan* provides a reliable and valid measurement of average left-right excursion. Hrysomallis et al., (2006) stated that the maximum medial-lateral excursion was a reliable measure and the greater the excursion value may be related to a greater loss of balance and increased injury potential.

The results of this study are similar to other studies that have found a significant difference between high-top and low-top shoes (Garrick & Requa, 1973; Ottaviani et al., 1995; Ricard et al., 2000). Ricard et al., (2000) examined the effect of shoe height on the magnitude of ankle inversion in 20 subjects. The platform unexpectedly inverted the ankle to 35º. The results showed that high-top shoes reduced inversion by 4.5º and significantly decreased ($p = 0.001$) the magnitude and rate of ankle inversion compared to low-top shoes. However, the external validity question still exists as to how these findings would carry over to a basketball game.

The factors that influence ankle sprains include “the magnitude of the force, the rate of application, the point of application, the direction of the force application, the state of the tissues (bone, ligament, tendon, and muscles), preactivation of muscles, and the design of the shoe” (Ricard et al., 2000, p. 42). Therefore, being able to prevent ankle sprains requires intrinsic and extrinsic components. The design of high-top shoes can act as an extrinsic factor for ankle sprain prevention. However, the shoes will not be able to completely prevent ankle injuries, but they may be able to lessen the severity of them. In order to do this, Ricard et al., (2000) suggested that “altering the torsional stiffness of the shoe upper or midsole geometry”

(p. 42) could enhance the shoe's ability to protect from extreme inversion moments. This suggestion is a result of the biomechanical factors of the ankle and the ability of the ankle to resist the load placed on it.

Strengths

The main strength of this study was the dynamic nature of the testing protocol. This increased external validity and made it more realistic to an actual basketball game compared to static tests that other researchers have used in their studies (Ricard et al., 2000; Robinson et al., 1986; Shapiro et al., 1994). Static balance results should not be used to infer or predict performance in dynamic balance tests (Hrysomallis et al., 2006). In the sports setting, if possible, dynamic balance should be assessed rather than static balance due to the dynamic nature of the activity.

There was good compliance from the participants. The fact that there was only one testing session that did not take a long time to complete helped. Participants were able to schedule a time that was convenient for them, which helped with compliance issues. There was no drop out as all participants were physically capable of completing each trial. Also, the testing was relevant to the subjects and they were interested to know the results from the study, as it may influence their future decisions on the type of shoe worn.

Another strength of this study was the ability to generalize the results to a greater population. A layup is the same manoeuvre performed at all levels of basketball, although each person will perform it slightly differently. The results provide information to those looking to purchase basketball shoes and may influence their decision.

Limitations

There were a number of limitations to this study. The first was that the sample size was small. This was a result of only recruiting from the men's and women's intercollegiate basketball teams at UCO. Also, performing the study after the completion of the season reduced the sample size further as potential participants were lost due to injury and the seniors were no longer available. The sample size could have been increased if the criteria had been open to a wider population; however, this was a convenient sample that was easily accessible.

The second limitation was that the testing was not done in a game setting. There were no outside influences or factors to interfere with the subject performing the layups. In a game setting there would be other team members and opponents contesting the layups. Therefore, the amount of carry-over from the findings of this study to a game is not certain.

Limitations with the equipment also occurred. The alignment of the sensors in the shoe may not have been placed flatly or may have shifted when performing the layups. Also, wearing the equipment and cables from the waist to the shoes may have caused the participants to adjust the way they performed the layup, resulting in them performing unnaturally.

Another limitation is that subjects brought their own high-top and low-top basketball shoes. This variable could not be controlled for and decreased internal validity but increased external validity.

Future directions

There are numerous future studies that can be dynamically performed to reduce the incidence of ankle sprains. There are many other variables associated with ankle sprains that can be examined such as; the effects of taping and bracing, manual therapy adjustments to the foot, ankle, knee, and hip, different settings and manoeuvres. The effectiveness of ankle rehab programs could also be evaluated. Verhagen et al. (2004) introduced a proprioceptive balance board program to determine its effectiveness to prevent ankle sprains in volleyball. The Tekscan software allows for more relevant dynamic testing rather than static tests.

Practical Applications

High-top basketball shoes may be more beneficial than low-top shoes in preventing ankle sprains, due to the greater stability provided. Shoe designers and manufacturers can use this knowledge to develop a shoe with the optimal characteristics to protect the ankle from sprains while simultaneously not restricting performance. Thacker et al., (1999) stated that the variation in the design of footwear for basketball has led to many recommendations. These include increased ankle collar height, maintenance of flexibility in the sagittal plane at both the ankle and metatarsophalangeal joints, use of external support straps or stays to strengthen upper shoes, and independently tied internal boots to increase both stability and proprioception (Thacker et al., 1999).

The primary goal of external support is to decrease the risk of injury and time lost due to injury. DeFranco et al., (2008) stated that prevention may be possible through the use of strengthening and balance programs, and wearing external ankle supports for those who participate in high-risk sports. In order for the shoe to provide external support, the mechanical support should exceed the strength of the ligament (Hume & Gerrard, 1998). Prevention is key but minimizing the risks is also important.

Conclusions

It can be concluded that high-top basketball shoes provide significantly greater stability than low-top basketball shoes. This knowledge is useful for individuals purchasing basketball shoes who are trying to reduce the likelihood of suffering an ankle sprains. With the increasing diversity of shoes, some common characteristics should be included in all shoes to disperse the forces on the structures of the ankle. It is necessary that some type of external support can bypass the force, such as taping, bracing, or wearing high-top shoes, or a combination of these, to decrease the potential for injury (Ricard et al., 2000). It is important to educate individuals about the benefits of ankle rehabilitation and other preventative measures to prevent ankle sprains from occurring initially (McKay et al., 2001).

References

Andrews, J. R., Harrelson, G. L., & Wilk, K. E. (2004). *Physical rehabilitation of the injured athlete* (3th ed.). Philadelphia, PA: Elsevier, Saunders.

Ashton-Miller, J. A., Ottaviani, R. A., Hutchinson, C., & Wojtys, E. M. (1996). What best protects the inverted weightbearing ankle against further inversion? Evertor muscle strength compares favourably with shoe height, athletic tape, and three orthoses. *American Journal of Sports Medicine, 24*(6), 800-809. doi: 10.1177/036354659602400616

Barker, H. B., Beynnon, B. D., & Renström, P. A. F. H. (1997). Ankle injury risk factors in sports. *Sports Medicine, 23*(2), 69-74. doi: 10.2165/00007256-199723020-00001

Barrett, J. R., Tanji, J. L., Drake, C., Fuller, D., Kawasaki, R. R., & Fenton, R. M. (1993). High- versus low-top shoes for the prevention of ankle sprains in basketball players: a prospective randomized study. *American Journal of Sports Medicine, 21*(4), 582-585. doi: 10.1177/036354659302100416

Baumhauer, J. F., Alosa, D.M., Renström, P. A. F. H., Trevino, S., & Beynnon, B. (1995). A prospective study of ankle injury risk factors. *American Journal of Sports Medicine, 23*(5), 564-570. doi: 10.1177/036354659502300508

Benvenuti, F., Mecacci, R., Gineprari, I., Bandinelli, S., Benvenuti, E., Ferrucci, L., Baroni, A., Rabuffetti, M., Hallett, M., Dambrosia, J. D., & Stanhope, S. J. (1999). Kinematic characteristics of standing disequilibrium: reliability and validity of a posturographic protocol. *Archives of Physical Medicine and Rehabilitation, 80*(3), 278-287. Retrieved from http://www.archives-pmr.org/

Beriau, M. R., Cox, W. B., & Manning, J. (1994). Effects of ankle braces upon agility course performance in high school athletes. *Journal of Athletic Training*, *29*(3), 224-230. Retrieved from http//:journalofathletictraining.org/

Beynnon, B. D., Murphy, D. F., & Alosa, D. M. (2002). Predictive factors for lateral ankle sprains: a literature review. *Journal of Athletic Training*, *37*(4), 376-380. Retrieved from http://journalofathletictraining.org

Bonnel, F., Toullec, E., Mabit, C., & Tourné, Y. (2010). Chronic ankle instability: biomechanics and pathomechanics of ligaments injury and associated lesions. *Orthopaedics and Traumatology: Surgery and Research, 96*(4), 424-432. doi: 10.1016/j.otsr.2010.04.003

Day, B. L., Steiger, M. J., Thompson, P. D., & Marsden, C. D. (1993). Effect of vision and stance width on human body motion when standing: implications for afferent control of lateral sway. *Journal of Physiology, 469,* 479-499. Retrieved from http://jp.physoc.org/

DeFranco, M. J., Carl, R., Bach, B. R. (2008). Differentiating low and high ankle sprains. *Journal* of *Musculoskeletal Medicine, 25*, 438-443. Retrieved from http://www.musculoskeletalnetwork.com/

Freeman,M. A. R., Dean, M. R. E., Hanham, I. W. F. (1965) The etiology and prevention of functional instability of the foot. *Journal of Bone and Joint Surgery, 47*(4), 678-685. Retrieved from http://jbjs.org/

Gabbard, C., & Hart, S. (1996). A question of foot dominance. *Journal of General Physiology*, *123*(4), 289-296. doi: 10.1080/00221309.1996.9921281

Garrick, J. G., & Requa, R. Q. (1973). Role of external support in the prevention of ankle sprains. *Medicine and Science in Sports*, *5*(3), 200-203. Retrieved from http://www.acsm.org/access-public-information/acsm-journals/medicine-science-in-sports-exercise

Goldie, P. A., Bach, T. M., & Evans, O. M. (1989). Force platform measures for evaluating postural control: reliability and validity. *Archives of Physical Medicine and Rehabilitation, 70*, 510-517. Retrieved from http*://www.archives-pmr.org/*

Guskiewicz, K. M., & Perrin, D. H. (1996). Research and clinical applications of assessing balance. *Journal of Sport Rehabilitation, 5*, 45-63. Retrieved from http://journals.humankinetics.com/jsr

Hertel, J. (2002). Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *Journal of Athletic Training, 37*(4), 364-375. Retrieved from http://journalofathletictraining.org/

Hertel, J., Gay, M. R., & Denegar, C. R. (2002). Differences in postural control during single-leg stance among healthy individuals with different foot types. *Journal of Athletic Training*, *37*(2), 129-132. Retrieved from http://journalofathletictraining.org/

Hewett, T. E., Stroupe, A. L., Nance, T. A., & Noyes, F. R. (1996). Plyometric training in female athletes. Decreased impact forces and increased hamstring torques. *American Journal of Sports Medicine*, *24*, 765–773. doi: 10.1177/036354659602400611

Hockenbury, R. T., & Sammarco, G. J. (2001). Evaluation and treatment of ankle sprains. *The Physician and Sports Medicine*, *29*(2), 117-126. Retrieved from http://physsportsmed.org/

Hootman, J. M., Dick, R., & Agel, T. (2007). Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *Journal of Athletic Training, 42*(2), 311-319. Retrieved from http://journalofathletictraining.org/

Hrysomallis, C., McLaughlin, P., & Coodman, C. (2006). Relationship between static and dynamic balance tests among elite Australian footballers. *Journal of Science and Medicine in Sport, 9*(4), 288-291. doi: 10.1016/j.jsams.2006.05.021

Hughes, L. H., & Stetts, D. M. (1983). A comparison of ankle taping and a semirigid support. *Physician and Sports Medicine, 11*(4), 99-103. Retrieved from http://*physsportsmed.org/*

Hume, P. A., & Gerrard, D. F. (1998). Effectiveness of external ankle support. Bracing and taping in rugby union. *Sports Medicine, 25*(5), 285-312. doi: 10.2165/00007256-199825050-00001

Huson, A. (1987). Joints and movements of the foot: terminology and concepts. *Acta Morphologica Neerlando-Scandinavica, 25,* 117-130.

Jerosch, J., & Prymka, M. (1996). Proprioception and joint stability. *Knee Surgery, Sports Traumatology, Arthroscopy, 4*(3), 171-179. Retrieved from http://www.kssta.org/

Karlsson, A., & Frykberg, G. (2000). Correlations between force plate measures for assessment of balance. *Clinical Biomechanics, 15*, 365-369. doi: 10.1016/S0268-0033(99)00096-0

Konradsen, L., & Ravn, J. B. (1990). Ankle instability caused by prolonged peroneal reaction time. *Acta Orthopaedica, 61*(5), 338-390. Retrieved from http://www.actaorthop.org/

Laskowski, E.R., Newcomer-Aney, K., & Smith, J. (1997). Refining rehabilitation with proprioception training: expediting return to play. *The Physician and Sports Medicine, 25*(10). Retrieved from http://physsportsmed.org/

Leanderson, J., Nemeth, G., & Eriksson, E. (1993). Ankle injuries in basketball players. *Knee Surgery, Sports Traumatology, Arthroscopy, 1*(3-4), 200-202. doi: 10.1007/BF01560206

Le Clair, K., & Riach, C. L. (1996). Postural stability measures: what to measure and for how long? *Clinical Biomechanics, 11*(3), 176-178. Retrieved from http://www.clinbiomech.com/

Luo, Z. P., Berglund, L. J., & An, K. N. (1998). Validation of f-scan pressure sensor system: a technical note. *Journal of Rehabilitation Research and Development, 35*(2), 186-191. Retrieved from http://www.rehab.research.va.gov/jrrd/

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

McGuine, T., Greene, J. J., Best, T., & Leverson, G. (2000). Balance as a predictor of ankle injuries in high school basketball players. *Clinical Investigations, 10*(4), 239-244. Retrieved from http://www.future-science.com/loi/cli

McKay, G. D., Goldie, P. A., Payne, W. R., & Oakes, B. W. (2001). Ankle injuries in basketball: injury rate and risk. *British Journal of Sports Medicine, 35,* 103-108. doi: 10.1136/bjsm.35.2.103

McKeon, P. O., & Hertel, J. (2008). Systematic review of postural control and lateral ankle instability, part I: can deficits be detected with instrumented testing? *Journal of Athletic Training, 43*(3), 293-304. Retrieved from http://journalofathletictraining.org/

Mickel, T. J., Bottoni, C. R., Tsuji, G, Chang, K., Baum, L., & Tokushige, K. A. S. (2006). Prophylactic bracing versus taping for the prevention of ankle sprains in high school athletes: a prospective, randomized trial. *The Journal of Foot and Ankle Surgery, 45*(6), 360-365. doi: 10.1053/j.jfas.2006.09.005

Miller, C. D., Shelton, W. R., Barrett, G. R., Savoie, F. H., & Dukes, A. D. (1995). Deltoid and syndesmosis ligament injury of the ankle without fracture. *American Journal of Sports Medicine, 23*(6), 746-750. doi: 10.1177/036354659502300618

Myers, J. B., Riemann, B. L., Hwang, J., Fu, F. H., & Lephart, S. M. (2003). Effect of peripheral afferent alteration of the lateral ankle ligaments on dynamic stability. *American Journal of Sports Medicine, 31*(4), 498-506. doi: 10.1177/03635465103331310498

Ng, Z. D., & De, S. D. (2007). Modified Brostrom-Evans-Gould technique for recurrent lateral ankle ligament instabiliy. *Journal of Orthopaedic Surgery, 15*(3), 306-310. Retrieved from http://www.josonline.org/

Orlin, M. N., & McPoil, T. G. (2000). Plantar pressure assessment. *Physical Therapy, 80*(4), 399-409. Retrieved from http://ptjournal.apta.org/

Ottaviani, R. A., Ashton-Miller, J. A., Kothari, S. U., & Wojtys, E. M. (1995). Basketball shoe height and the maximal muscular resistance to applied ankle inversion and eversion moments. *American Journal of Sports Medicine, 23*(4), 418-423. doi: 10.1177/036354659502300408

Perry, J. (1983). Anatomy and biomechanics of the hindfoot. *Clinical Orthopaedics and Related Research, 177*, 9-15. Retrieved from http://www.clinorthop.org/

Pienkowski, D., McMorrow, M., Shapiro, R., Caborn, D. M. N., & Stayton, J. (1995). The effect of ankle stabilizers on athletic performance: a randomized prospective study. *American Journal of Sports Medicine, 23*(6), 757-762. doi: 10.1177/036354659502300621

Prentice, W. E. (2011). *Rehabilitation techniques for sports medicine and athletic training* (5th ed.). New York, NY: McGraw-Hill.

Renstrom, P., Wertz, M., Incavo, S., Pope, M., Ostgaard, H. C., Arms, S., & Haugh, L. (1988). Strain in the lateral ligaments of the ankle. *Foot and Ankle International, 9*(2), 59-63. doi: 10.1177/107110078800900201

Ricard, M. D., Schulties, S. S., & Saret, J. J. (2000). Effects of high-top and low-top shoes on ankle inversion. *Journal of Athletic Training, 35*(1), 38-43. Retrieved from http://www.journalofathletictraining.org/

Robinson, J. R., Frederick, E. C., & Cooper, L. B. (1986). Systematic stabilization and the effect on performance. *Medicine and Science in Sports, 18*(6), 625-628.

Rockar Jr, P. A. (1995). The subtalar joint: anatomy and joint motion. *Journal of Orthopaedic and Sports Physical Therapy, 21*(6), 361-372. Retrieved from http://jospt.org/

Rovere, G. D., Clarke, T.S., Yates, C. S., & Burley, K. (1988). Retrospective comparison of taping and ankle stabilizers in preventing ankle injuries. *American Journal of Sports Medicine, 16*(3), 228-233. doi: 10.1177/036354658801600305

Shapiro, M. S., Kabo, J. M., Mitchell, P. W., Loren, G., & Tsenter, M. (1994). Ankle sprain prophylaxis: an analysis of the stabilizing effects of braces and tape. *American Journal of Sports Medicine, 22*(1), 78-82. doi: 10.1177/036354659402200114

Sharpe, S. R., Knapik, J., & Jones, B. (1997). Ankle braces effectively reduce recurrence of ankle sprains in female soccer players. *Journal of Athletic Training*, *32*(1), 21-24. Retrieved from http://journalofathletictraining.org/

Sinkjaer, T., Toft, E., Andreassen, S., & Hornemann, B. C. (1988). Muscle stiffness in human ankle dorsiflexors: intrinsic and reflex components. *Journal of Neurophysiology, 60,* 1110-1121. Retrieved from http://jn.physiology.org/

Sitler, M., Ryan, J., Wheeler, B., McBride, J., Arciero, R., Anderson, J., & Horodyski, M. (1994). The efficacy of a semirigid ankle stabilizer to reduce acute ankle injuries in basketball. A randomized clinical study at West Point. *American Journal of Sports Medicine*, *22*(4), 454-461. doi: 10.1177/0363546559402200404

Smith, R. W., & Reischl, S. F. (1986). Treatment of ankle sprains in young athletes. *American Journal of Sports Medicine*, *14*(6), 465-471. doi: 10.1177/036354658601400606

Soboroff, S. H., Pappius, E. M., & Komaroff, A. L. (1984). Benefits, risks, and costs of alternative approaches to the evaluation and treatment of severe ankle sprains. *Clinical Orthopaedics and Related Research, 183*, 160-168. Retrieved from http://www.clinorthop.org/

Stormont, D. M., Morrey, B. F., An, K., & Cass, J. R. (1985). Stability of the loaded ankle: relation between articular restraint and primary and secondary static restraints.

American Journal of Sports Medicine, 13, 295-300. doi: 10.1177/036354658501300502

Struijs, P., & Kerkhoffs, G. (2002). Ankle sprain. *Clinical Evidence, 7,* 945–953. Retrieved from http://clinicalevidence.bmj.com/

Takala, E. P., Korhonen, I., & Viikara-Juntura, E. (1997). Postural sway and stepping response among working population: reproducibility, long-term stability, and associations with symptoms of the low back. *Clinical Biomechanics, 12*(7/8), 429-437. doi: 10.1016/S0268-0033(97)00033-8

Thacker, S.B., Stroup, D. F., Branche, C. M., Gilchrist, J., Goodman, R. A., & Weitman, E. A. (1999), The prevention of ankle sprains in sports: a systematic review of the literature. *American Journal of Sports Medicine, 27*(6), 753-760. Retrieved from http://ajs.sagepub.com

Trevino, S. G., Davis, P., & Hecht, P.J. (1994). Management of acute and chronic lateral ligament injuries of the ankle. *Orthopedic Clinics of North America, 25*, 1–16. Retrieved from http://www.orthopedic.theclinics.com/

Verbrugge, J. D. (1996). The effects of semirigid Air-Stirrup bracing vs. adhesive ankle taping on motor performance. *Journal of Orthopaedic and Sports Physical Therapy, 23*(5), 320-325. Retrieved from http://www.jospt.org/

Verhagen, E., van der Beek, A., Twisk, J., Bouter, L., Bahr, R., & van Mechelen, W. (2004). The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. *American Journal of Sports Medicine, 32*(6), 1385-1393. doi: 10.1177/0363546503262177

Wang, H. K., Chen, C. H., Shiang, T. Y., Jan, M. H., & Lin, K. H. (2006). Risk factor analysis of high school basketball-player ankle injuries: a prospective controlled cohort study evaluating postural sway, ankle strength, and flexibility. *Archives of Physical Medicine and Rehabilitation, 87*(6), 821-825. doi: 10.1016/j.apmr.2006.02.024

Waterman, B. R., Owens, B. D., Davey, S., Zacchilli, M. A., & Belmont, P. J. (2010). The epidemiology of ankle sprains in the United States. *The Journal of Bone and Joint Surgery, 92*(13), 2279-2284. doi: 10.2106/JBJS.I.01537

Wikstrom, E. A., Tillman, M. D., & Borsa P. A. (2005). Detection of dynamic stability deficits in subjects with functional ankle instability. *Medicine and Science in Sports and Exercise, 37*(2), 169-175. doi: 10.1249/01.MSS.0000149887.84238.6C

Wright, I. C., Neptune, R. R., van den Bogert, A. J., & Nigg, B. M. (2000). The influence on foot positioning on ankle sprains. *Journal of Biomechanics, 33,* 513-519. Retrieved from http://www.jbiomech.com/

Yeung, M. S., Chan, K. M., So, C. H., & Yuan, W. Y. (1994). An epidemiological survey on ankle sprain. *British Journal of Sports Medicine, 28*, 112-116. doi: 10.1136/bjsm.28.2.112

Tables

Table 1

Descriptive Statistics of Average Left-Right Excursion in High-Top and Low-Top Basketball Shoes.

		N	M (SD)	S	K
High-Tops	Left	11	3.020 (0.956)	-0.108	-1.279
	Right	11	2.854 (0.908)	-0.421	-1.298
Low-Tops	Left	11	3.366 (1.120)	-0.521	-0.476
	Right	11	3.359 (1.433)	-0.773	0.569

Note. S= skewness. K= kurtosis

Table 2

Dependent Samples T-Test for the Left-Right Excursion of Low-Top and High-Top Basketball Shoes.

	t	t^2	df	Significance
HTL - LTL	-2.785	0.437	10	0.019*
HTR - LTR	-2.256	0.337	10	0.048*
HTL - HTR	1.255	0.136	10	0.238
LTL - LTR	0.048	0.000230	10	0.963

Note. HTL= High-Top Left Shoe. HTR= High-Top Right Shoe. LTL= Low-Top Left Shoe. LTR= Low-Top Right Shoe.

APPENDIX A

Institutional Review Board

APPENDIX B

Informed Consent

Informed Consent

Title: The Stability of Low-Top versus High-Top Basketball Shoes

Principal Investigator: Ruth Gillespie

It is imperative that you read, understand, and sign this informed consent form prior to participation in this study. The intent of this document is to inform you of the purpose, procedures, potential benefits, risks, and discomforts of participating in this study. Additionally, participation in this study is of a voluntary nature and it is your right to withdraw from the experiment at any time and for any reason without penalty. Finally, there is no certainty as to what the outcome of the study will be; however your score will remain confidential and data will be destroyed at the end of the study.

Purpose: The purpose of this study is to evaluate the stability of low-top and high-top basketball shoes in Division II Collegiate basketball athletes at the University of Central Oklahoma (UCO), by measuring the average left-right shift in weight. The pressure device will fit right into your shoe.

Subjects: Subjects will be volunteers from the University of Central Oklahoma men's and women's basketball teams. All subjects must be cleared for participation as determined by the Physical Activity Readiness Questionnaire (PAR-Q) and, if needed, a physician's clearance (indicated in the PAR-Q). Additionally, if subjects report a lower extremity injury within the last three months, or a history of concussion within one month, this will disqualify them from the study.

Group: All the subjects will perform six layups; three in low-top and three in high-top basketball shoes. A pressure sensor will be placed in subjects shoes which will measure how much you shift your weight from right to left. .

Testing Procedures:

- All subjects will perform a basketball layup at Hamilton Field House, at the University of Central Oklahoma.
- Subjects will perform a layup with in-shoe plantar pressure sensors, using the *F-Scan* Foot Pressure Mapping System (Tekscan, Boston, MA). This is a wireless system that will measure foot pressure during movement placed in the shoe.
- Subjects will bring their own shoes.
- Three practice trials will be given to allow participants to familiarize themselves with the procedure.
- A total of six layups will be performed; three in low-top and three in high-top basketball shoes. The order of shoe testing will be randomized for each individual.
- Subjects will perform a full court layup and perform the task as they naturally would.
- There will be a one minute break between each trial to prevent fatigue, and five minutes between conditions.

- The average left-right shift in weight, in centimeters (cm), is the measurement that will be recorded for each trial and an average for high-top shoes and low-top shoes will be recorded.
- Testing will last approximately 30 minutes.

Warm-ups: Prior to testing subjects will perform three layups with the pressure sensors in their shoes to become accustomed to the testing procedure.

Benefits: Participation in this study contributes to further understanding of the affect shoes play in stability. This new knowledge could not only apply to basketball, but also to other sports. There is no direct benefit to the subject.

Risks: Subjects will be exposed to whatever minimal risks that may occur in a layup without a defender (anyone contesting or interfering with the movement). The risk will be minimized by performing the layup uncontested and having an athletic trainer present. Although risks are unlikely, you should seek medical attention from your personal physician if needed. Additionally, a Physical Activity Readiness Questionnaire (PAR-Q) to detect if they need medical clearance prior to testing.

Privacy and Confidentiality: Each subject's data will not be shared with coaches, except as group means. Only the Principal Investigator (Ruth Gillespie) and Co-Principal Investigator (Dr House) will have access to the data. No names will be associated with the measures and the data will be destroyed at the end of the study.

Questions: If you have any questions regarding your participation in this study you may contact Ruth Gillespie (Principle investigator) at (4631) 561-8394 before and/or after signing the consent form.
If you have any additional questions regarding your rights you can contact IRB member Dr. Jill Devenport at (405) 974-5497, irb@uco.edu. I ____________________understand and agree to the above and affirm that I am at least 18years old. (Print Name) (age)

Participant's Signature Date	Researcher's Signature Date

Contact Information

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Appendix C

Physical Activity Readiness Questionnaire

Appendix D

Questionnaire

UCO Survey Questionnaire

Name: ______________________________ Age: ________

Height:____________ Weight: ___________

Shoe Size:_________

1. Which is your dominant leg? Right Left
2. How many years have you played basketball for?
3. What position do you play?
4. Have you injured your lower leg in the past three months that caused you to miss participation for one week or more?
5. Are you currently engaged in lower extremity rehabilitation?
6. Have you ever fractured or had surgery on either ankle? Yes No
7. Do you have chronic ankle instability? Yes No
8. Have you been diagnosed with a concussion in the past month? Yes No

Appendix E

Thesis Summary Document

Thesis Summary Document

Ankle sprains are one of the most common athletic injuries that occur in sports participation (Trevino, Davis, & Hecht, 1994). There has been numerous prevention strategies designed to decrease the occurrence of ankle sprains (Hume & Gerrard, 1998).

Basketball appears to have a greater risk for acquiring an ankle sprain compared to other sports. Trevino, Davis, and Hecht (1994) reported that up to 45% of sports related injuries are due to ankle sprains observed in high risk sports such as basketball. Many researchers have focused on the inversion moment and the ability of high-top basketball shoes to limit the amount of inversion allowed compared to low-top shoes (Ottaviani et al., 1995; Ricard et al., 2000). Ricard et al. (2000) performed a study with subjects wearing high-top and low-top shoes to see if shoe height affected the rate and amount of inversion allowed. They reported that high-top shoes were superior to low-top shoes in significantly reducing ankle inversion (Ricard et al. 2000).

The purpose of this study was to evaluate the stability of collegiate level basketball players wearing low-top and high-top basketball shoes. The researcher's hypothesis is that the high-tops will provide significantly greater stability than the low-tops.

Eleven intercollegiate basketball players from the University of Central Oklahoma served as subjects. Average left-right excursion was recorded using the *F-Scan* Foot Pressure Mapping System (Tekscan, Boston, MA) as subjects performed three layups in low-top and high-top basketball shoes. The data were analyzed using a dependent t-test, alpha level of p=0.05.

Significant differences were found between shoe types in both right and left feet. The difference between left high-top and left low-top shoes was $t = -2.785$, $p = 0.019$, and the difference between right high-top and right low-top shoes was $t = -2.256$, $p = 0.048$. This means there was less average left-right excursion in high-top shoes compared to low-top shoes. There were no significant differences within shoes (left high-top vs right high-top and left low-top vs right low-top).

The high-top shoes showed significantly greater stability than low-top shoes, as a result depending on the situation, high-top shoes may help prevent ankle sprains.

There are numerous future studies that can be dynamically performed to reduce the incidence of ankle sprains. There are many other variables associated with ankle sprains that can be examined such as; the effects of taping and bracing, manual therapy adjustments to the foot, ankle, knee, and hip, different settings and manoeuvres. The Tekscan software allows for more relevant dynamic testing rather than static tests.