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A COMPARISON OF CLEATED FOOTWEAR CONDITIONS AND THE EFFECTS ON GROUND REACTION FORCES DURING THE PHASES OF A SIDE-CUT TASK

By

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Abstract

Zachary Bridges: A COMPARISON OF CLEATED FOOTWEAR CONDITIONS AND THE EFFECTS ON GROUND REACTION FORCES DURING THE PHASES OF A SIDE-CUT TASK (Under the Direction of Dr. John Garner)

Within sports and athletics, one area of interest is finding methods to increase the performance of athletes while simultaneously minimizing their risk for injury. In two of today's most popular sports (soccer and American football), cleated footwear is common equipment used to increase performance during sport-specific tasks. The interaction between cleated footwear and sport-specific tasks is one area of interest researchers are beginning to investigate and analyze the concerns of performance and safety. Therefore, the purpose of this study was to determine the effects of American football cleats, soccer cleats, and running shoes have on ground reaction forces (GRF's) in the y and z directions for the braking and propulsion phases of a side-cut task (SCT). Twelve male recreationally and collegiately trained American football and/or soccer players (Age: 21.82 ± 1.47 years; Height: 180.63 ± 4.73 cm; Mass: 87.77 ± 14.83 kg) participated in this study. Participants conducted three SCT trails for each footwear condition (football cleat, soccer cleat, and running shoes), for a total of nine SCT trials. GRF's produced during the SCT trials were measured and recorded using a 0.4m x 0.4m AMTI OR6-6 (AMTI, Watertown, MA) force plate. Results showed no significant differences ($p > .05$) between footwear conditions and the variables of interest in the y and z direction during the braking or propulsion phases of the SCT. For athletes and coaches, this indicates neither football nor soccer cleats provided a greater advantage in the performance of a SCT during its braking and propulsion phases.

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CHAPTER 1

INTRODUCTION

In the world of athletics, coaches, athletes, parents, and equipment manufacturers are striving to find the ideal balance between sport performance and injury prevention. From extrinsic factors such as field conditions and equipment, to intrinsic factors such as positions within a sport and joint mobility, professionals are attempting to both reduce injury risks while simultaneously maximizing performance (Iacovelli et al. 2013). With approximately 265 million players participating around the world, soccer is acknowledged as the most popular sport from a global perspective (DeBiasio et al. 2013). Injuries to the foot are among the most common injuries in soccer, accounting for about 5% of all soccer injuries worldwide (DeBiasio et al. 2013). With over one million estimated high school players in the United States alone, American football (hereafter referred to as football) has the greatest lower-extremity injury rate of any sport (Iacovelli et al. 2013; Lambson et al. 1996). Among those athletes, knee injuries are the most common, with injuries to the anterior cruciate ligament (ACL) being the most prevalent (Lambson et al. 1996). Considering the popularity of these sports and their connection to injury, there is a need for further research into the relationship between injury and performance. Two common threads between both sports include footwear and sport specific movements such as a side-cut task (SCT).

Footwear has been determined to be an extrinsic factor associated with lower-extremity injuries in sports such as football and soccer (Debiasio et al. 2013; Iacovelli et al. 2013). Various types of footwear have been associated with injuries to the foot, ankle, and knee (DeBiasio et al. 2013; Lambson et al. 1996; Sinclair et al. 2014), while different footwear conditions have also been shown to alter lower-extremity mechanics, force production, and loading at both the ankle and knee during running (Fredericks et al. 2015; Sinclair et al. 2015). In soccer and football, cleated footwear is the preferred footwear condition as it facilitates quicker changes in direction and speed due to increased cleat-surface contact, and provides stability to the foot and ankle (Hilgers, 2011). Concerning the relationship between cleated footwear and playing surface, different cleat arrangements have shown to react uniquely with various types of playing surfaces (Galbusera et al. 2013; Livesat et al. 2006). When it comes to loading at the joints, different forms of cleated footwear have shown to cause loading and kinematic differences at the foot, ankle, and knee between configurations (DeBiasio et al. 2013; Gehring 2007; Sinclair et al. 2014).

Similar to footwear, sport-specific tasks such as the SCT have also been identified as a factor associated with lower-extremity injuries (Vanrenterghem et al. 2012; Wannop et al 2014). The SCT is a quick change in direction while running, often with an approximate 45^0 change in direction (Havens & Sigward 2015; Vanrenterghem et al. 2012). Within the SCT, two primary phases exist that help facilitate the change in direction: the braking and propulsion phases. The braking phase is the first major phase and is defined as the instance the dominant foot contacts the ground to the maximum ground reaction force (GRF). In simple, the purpose of this phase is to decrease the athlete’s velocity and prepare for the change in direction. The second major phase is the propulsion phase and occurs from the maximum braking GRF until the last instance of toe-off. The purpose of this phase is to accelerate the individual in their new intended direction. From a performance enhancement standpoint, it is speculated that a large peak propulsion force is desired to accelerate the individual in the new direction. Concerning injury risk, a smaller peak braking force is desired to reduce the chance of injury to connective tissue in the knees, ankles, and feet. Together, the braking and propulsion phases facilitate the quick changes in direction provided by the SCT.

As advantageous as the SCT is in athletics, it does not come without the risk for injury. At the ankle, this maneuver has been associated with injuries such as sprains due to excessive inversion, plantarflexion, and loading across portions of the foot (Wannop et al. 2014; Havens and Sigward 2015). Concerning the knee, the SCT has long been associated with ACL injuries (Vanrenterghem et al. 2012). Often, knee injuries from SCT are due to excessive abduction, extension, and rotational torques, and limited knee extension (Havens and Sigward 2015; McGovern et al. 2015). A number of extrinsic factors have also shown to have effects on SCT, such as footwear type, playing surface, and sport-specific demands such as carrying a ball. All have been shown to have effects on lower-extremity mechanics during a SCT (Queen et al. 2008; Livesay et al. 2006; Fedie et al. 2010). Given the SCT role in athletics, and its relation to lower-extremity injury, the need for further research into this maneuver as an identified performance and injury factor would be beneficial. Therefore, the purpose of this study was to determine the effects of football cleats, soccer cleats, and running shoes have on GRF's in the y and z directions for the braking and propulsion phases of a SCT.

Hypotheses:

Ground Reaction Force (Y):

H_{01}: There will be no significant difference in GRFs in the y-direction among footwear conditions during a SCT.

H_{A1}: There will be a significant difference in GRFs in the y-direction among footwear conditions during a SCT.

Concerning GRF's in the y-direction, the football cleat is anticipated to exhibit the greatest values based on existing literature. Different forms of cleated footwear have shown to produce different initial GRF's along the y-direction during a turn task (Gehring 2007). Also, the soccer cleats have less mass due to less material to support the lower extremity and absorb forces when compared to the football cleats. Footwear with less support has shown to negatively affect specific lower extremity kinematics, as well as force production during initiating a task (Fredericks et al. 2015; Vieira et al 2015).

Ground Reaction Force (Z):

H_{01}: There will be no significant difference in GRFs in the x-direction among footwear conditions during a SCT.

H_{A1}: There will be a significant difference in GRFs in the x-direction among footwear conditions during a SCT.

Based on the existing literature, the football cleated footwear will likely have the greatest GRF's in the z-direction. When compared to traditional footwear, cleated footwear exhibits greater plantar loading across the midfoot and forefoot regions, leading to greater plantarflexion and extension moments during a jump-landing task (Butler et al. 2014; DeBiasio et al. 2013). Different forms of cleated footwear have also been shown to have an effect on GRF's along the z-direction (Gehring 2007). Given the lighter weight and less material of the soccer cleats, which has been shown to negatively affect specific lower extremity kinematics, as well as force production during initiating a task, it is expected the football cleats will result in greater GRF's in the z-direction (Fredericks et al. 2015; Vieira et al 2015).

Definitions:

Ground Reaction Force (GRF) - Force exerted by the ground with a body in contact with it along the x, y, or z axes (For the purposes of this study and given the lab used, the "x" axis refers to the anterior/posterior axis, the "y" refers to the medial/lateral axis, and the "z" refers to the superior/inferior axis).

Rate of Force Development (RFD) - A change in force over a given time

Side-Cut Task (SCT) - A quick change in direction while running, often with an approximate 45^0 change in direction (Havens & Sigward 2015; Vanrenterghem et al. 2012)

Braking Phase – The instance the dominant foot contacts the ground to the maximum GRF.

Propulsion Phase – Occurs from the maximum braking GRF until the last instance of toe-off.

Chapter II

Review of Literature

a. Footwear

Lower extremity injuries, especially those to the foot, ankle, and knee, are some of the most common injuries in sports (Villwock et al. 2009). A number of intrinsic and extrinsic factors have been shown to contribute to lower extremity injuries in sports such as age, joint flexibility, stiffness, field conditions, footwear, and sport-specific tasks (DeBasio et al. 2013; Iacovelli et al. 2012). In existing literature, different types of footwear have been shown to create different force productions on various playing surfaces and during different sporting tasks (Queen et al, 2008). Sport-specific tasks, specifically the SCT, has been shown to contribute to lower extremity injuries (Sankey, 2015). By examining these factors and their relation to injury, researchers can work to improve injury rates by understanding variables such as the effects of footwear, playing surfaces, footwear-surface relationship, plantar loading, knee loading, power production with tasks, rotational mechanics, and task mechanics.

Before looking into the number of factors surrounding footwear and lower extremity injuries, it is necessary to examine how different forms of footwear, or lack thereof, affects athletic tasks. One method to see the effects of footwear is to examine lower extremity biomechanical differences during an athletic task while wearing different forms of footwear. For instance, ankle and knee kinematics during running are different between barefoot, minimalist (mimics barefoot running), and traditional (standard running shoes) footwear conditions (Fredericks et al. 2015). Concerning foot strike pattern, non-rearfoot strikes (an initial foot strike on an area of the foot other than the rearfoot and heel) increase while running in traditional, minimalist, and barefoot footwear conditions. The increase in non-rearfoot strikes during running leads to a greater risk for ankle injuries (Fredericks et al. 2015). Likewise, changing from traditional to minimalist or barefoot footwear conditions can lead to increased ankle plantarflexion during running. At the knee, changing footwear conditions from traditional to barefoot conditions can lead to increased knee flexion, which may lead to a reduction in some patellofemoral pain (Sinclair et al. 2015).

Cleated footwear has commonly been used in various sporting activities that take place on natural and artificial playing surfaces and require quick changes in direction or dynamic agility. During a sporting task, cleated footwear serves a number of important purposes concerning performance and injury prevention, including increased cleat-surface contact for cutting tasks and changes of direction and speed, while providing stability to the foot and ankle (Hilgers, 2011). To enhance the performance aspect of cleated footwear, a number of cleat designs have been created for different field surfaces such as firm natural, soft natural, and artificial playing surfaces (Queen, 2008). A number of stability variations also exist, such as flexible midfoot, which may present a greater injury risk due to torsion of the midfoot, a flexible forefoot, which allows flexibility in the forefoot and stability in the midfoot, and added midfoot stiffening components, which helps increase kicking power and reduce injury risk to the midfoot (Hilgers, 2011). Issues surrounding cleated footwear and non-contact injuries have risen concerning some of the changes in cleat design, such as moving from stud shaped spikes to blade shaped spikes. A possible connection between bladed cleats and increased pressure distribution along the lateral foot was found to potentially lead to a higher risk of injury (Bentley, 2010).

Considering the purpose of cleated footwear, and the potential connection to injuries, cleat-surface interface warrants investigation.

Cleated footwear displays a complex and important relationship with playing surfaces. Various cleat configurations have been designed for specific playing surfaces, but not without consideration to possible risks. In a study by Galbusera et al. (2013), rotational forces between two forms of studded cleats, one form of bladed cleats, and two types of playing surfaces were analyzed. Results showed that there were no significant differences in rotational forces between cleat models, however, there was a decrease in rotational forces on natural turf between the various footwear (Galbusera et al, 2013). In a similar study by Livesay et al. (2006), the authors found natural grass playing surfaces exhibit the lowest torques with shoe types, and the highest torques between cleat-field turf and turf shoe-Astroturf interactions. The turf shoe-Astroturf interactions also exhibited a significantly higher rotational stiffness compared to the other combinations (Livesay et al. 2006). These interactions between footwear and playing surface also affect lower-extremity injury risk. Torg and Quedenfeld (1971) noted that the size, shape, and arrangements of cleats, coupled with the resulting interaction with the playing surface, correlated with lower extremity injuries among a sample population of football players. In order to fully understand the relationship between footwear and its effects on lower extremity kinetics and kinematics, a “ground-up” approach needs to be taken by first examining the effects cleated footwear has on initial force production during sports tasks.

Footwear not only has an effect on lower extremity mechanics when considering playing surface, but also on the mechanics of an athlete’s movement by altering initial force production during sports tasks. Differences in footwear have been shown to have differing effects on loads across portions of the lower extremity (Sinclair et al. 2015). Concerning force production and kinematics, as well as barefoot and traditional footwear, the rectus femoris, vastus medialis, and vastus lateralis displayed greater peak forces in the traditional footwear when compared to barefoot conditions during a running task (Sinclair et al. 2015). Forces in the gastrocnemius have shown significantly larger values in barefoot conditions than in traditional footwear, while forces in the tibialis anterior displayed higher values in traditional footwear than with barefoot conditions (Sinclair et al. 2015). At the hip, traditional footwear has demonstrated increases flexion (41.92° hip flexion) during running than when compared with barefoot conditions (37.21° hip flexion). On the other hand, knee flexion has demonstrated greater flexion angles (35.66° knee flexion) in barefoot conditions, while the ankle has shown greater degrees of plantar flexion in traditional footwear (Sinclair et al. 2015). Concerning force production during gait initiation, traditional footwear has displayed smaller medial/lateral center of pressure paths during the first two phases of a gait initiation (anticipatory postural adjustment and swing-foot unloading phase) when compared with barefoot conditions (Vieira et al 2015). Footwear does have an effect on force production and kinematics during tasks, so now the need exists to examine the specific effects footwear has on loading in the individual joints of the lower extremity.

Considering foot injuries are one of the most common injuries experienced by athletes worldwide, with stress fractures being the most prevalent, the effects of plantar loading bears a need for investigation (DeBasio et al. 2013). A number of factors have been shown to affect plantar load distributions, including shoe type and athletic tasks (DeBasio et al, 2013). Repetitive plantar loading in certain forms of footwear, such as blade-cleated footwear, turf-cleated footwear, and even running shoes, have been linked to some lower extremity injuries (Debasio et al. 2013). During a jump-landing task, blade-cleated footwear exhibited greater maximum forces (% body weight) across the lateral midfoot, medial forefoot, and lateral forefoot, while running shoes exhibited greater maximum force across the rearfoot and hallux regions (DeBiasio et al. 2013). Considering force-time interval, bladed cleats exhibited more force per time (Ns) in the lateral midfoot, medial forefoot, middle forefoot, lateral forefoot, and lesser toes (toes 2-5) regions, while running shoes displayed higher numbers across the rearfoot and hallux regions (DeBiasio et al. 2013). Similarly, during a SCT, four forms of cleated footwear (bladed, firm ground, hard ground, and turf) displayed differences in plantar loading. Firm ground cleated footwear exhibited greatest maximum force across the medial and middle forefoot, while hard ground cleated footwear showed the greatest maximum force in the lateral forefoot area (Queen et al. 2008). Seeing that footwear does have an effect on plantar loading, the need now exists to progress up the lower extremity and examine the relationship between ankle loading and footwear.

The negative effects of footwear on lower extremity kinematics also remains true at the ankle, since increased frontal and transverse plane joint actions have also been linked to a number of lower extremity injuries (Sinclair et al. 2014). When comparing the effects of barefoot, minimalist, and traditional footwear on ankle kinematics during running, a number of differences should be considered. First, there is a much greater eversion/tibial internal rotation ratio at the tibiocalcaneal joint of the ankle in the barefoot condition when compared to the traditional footwear (Sinclair et al. 2014). A similar significant eversion/tibial internal rotation ratio was also found in the minimalist footwear condition when compared to the traditional footwear (Sinclair et al. 2014). Analyzing the eversion/tibial internal rotation ratio is important in determining areas of the lower extremity susceptible to injury (Sinclair et al. 2014). Concerning a comparison between traditional and cleated footwear, differences also exist in the effects of ankle loading and mechanics. Among traditional running shoes, turf shoes, and bladed cleats, the bladed cleat footwear has been shown to create the highest peak ankle dorsiflexion angle and peak plantarflexion moments of the three forms of footwear during a landing task (Butler et al. 2014). The increased angles and moments lead for a higher potential for injury as the joint must compensate for the increased forces and range of motion (Butler et al. 2014). As this has shown, footwear does have an effect on ankle loading and kinematics, and leaves the need for investigation of footwear effects further up the lower extremity.

At the knee joint, non-contact injuries commonly occur due to an overload of force on specific ligaments (Gehring 2007). With that in mind, it is necessary to examine factors associated with knee loading and injury at the knee, such as changing direction, foot fixation and cleat-surface interaction. Foot fixation and an increased cleat-surface torsion are common factors in ankle and knee injuries, making it important to examine the relationship between footwear and the loads placed upon the knee (Lambson et al, 1996). High-traction shoes, which have a large amount of tread on the sole, have been associated with increased loading at the knee up to 20% when compared with low-traction shoes (Wannop 2010). Concerning different forms of cleated footwear and their effect on knee loads, different cleat arrangement variations have shown to exhibit different effects on the knee joint. During an 180^{o} turn task experiment, bladed cleats displayed higher initial GRFs in both the vertical and anterior-posterior directions when compared with studded cleats. However, it should be noted these higher GRFs did not directly transfer to knee joint moments (Gehring 2007). In a similar study, four styles of cleated footwear were compared in relation to their connection with ACL knee injuries. Edge, pivot disk, screw-in, and flat cleats were tested for torsional resistance and referenced to the number of documented ACL tears among a high-school football population while wearing the different forms of cleats. It was found that edge cleats provided higher torsional resistance and also a higher number of ACL incidences (Lambson et al., 1996).

It has been shown that injuries to the lower extremity are often due to a number of intrinsic and extrinsic factors, while footwear is a commonly accepted extrinsic factor in lower extremity injuries (Debasio et al 2013; Kinchington et al. 2011). Concerning injuries to the foot, blade-cleated and firm-ground cleated footwear have been associated with increased stress on certain areas of the foot. (Debasio et al. 2013; Queen et al. 2008). At the ankle, barefoot, minimalist, and blade-cleated footwear have all demonstrated factors leading to an increased risk for injury (Sinclair et al. 2014; Butler et al. 2014). Similarly, high-traction shoes, bladed cleats, and edge cleats have all exhibited factors that increase the risk for injury at the knee (Gehring 2007; Lambson et al., 1996; Wannop 2010). If factors such as individual lower extremity kinematics, as well as footwear traction and cushioning, were taken into account when designing footwear for a specific sport or task, the chance for injury could potentially be lowered (Kinchington et al. 2011). With all of this in mind, footwear does in fact warrant further investigation when considering athletic tasks and lower extremity injury.

b. Side-Cut Task

In the world of athletics, a common movement required for participation is the SCT, which is described as a sudden change in direction while running (Havens & Sigward, 2015). While the side-cut is performed at numerous cutting angles across different sports and between athletes, a standard cutting angle of 45^{o} is utilized for research purposes (Vanrenterghem et al. 2012). However, this maneuver has been associated with lower extremity injury to the ankle and knee (Vanrenterghem et al. 2012; Wannop et al 2014). The first 25% of the contact phase involves a large negative acceleration to facilitate the change in direction, often resulting in increased ankle and knee loads (Havens & Sigward 2015; Vanrenterghem et al. 2012). When these increased loads and angles exceed the body's ability to withstand them, injury can occur.

Side-cut tasks have been associated with injury in lower extremity joints such as the ankle and knee (Vanrenterghem et al. 2012; Wannop et al 2014). During a SCT, the ankle absorbing the loads from the movement often experiences inversion, plantarflexion, and loading across the medial foot and forefoot (Havens & Sigward 2015; Wannop et al. 2014). The SCT has several effects on the mechanics and loading at the ankle depending on certain variables, such as the cutting angle of the task (i.e. 45^{o} and 90^{o} SCT). At initial contact, a 90^{o} SCT has been shown to display greater ankle plantarflexion angles (Havens & Sigward, 2015). During the negative acceleration phase of a 90^{o} side-cut, the ankle has been shown to exhibit greater overall changes in angle during planting, as well as a lowered ability to absorb forces in the sagittal plane when compared to a 45^{o} side-cut. (Havens & Sigward, 2015). All of these factors are associated with an increased reliance on the knee during the contact and negative acceleration phases of a 90^{o} side-cut than when compared with a 45° side-step cut (Havens & Sigward, 2015). In regards to the ankle, a slight banking angle may reduce ankle inversion during cutting may reduce the risk for injury. Implementing a 10°-20° banking angle to the ankle during a side-cut, such as through inserts in footwear, has been shown to reduce ankle inversion and joint loading during the cut (Wannop et al 2014). These reductions may lead to less stress on the ankle during cutting (Wannop et al 2014).

SCT have often been associated with injuries at the knee, especially to the anterior cruciate ligament (ACL) (Vanrenterghem et al. 2012). During the negative acceleration phase, the knee often experiences increased abduction, extensor torques, limited knee flexion, and increased rotational torques, increasing stress on the ACL (Havens & Sigward 2015; McGovern et al. 2015). A number of differences exists between a 45° and 90° cut. In a 90° side-cut, the knee has been shown to experience less flexion at initial contact when compared to a 45° side-cut and a greater change in angle and greater extensor moments during a 90° side-cut than in a 45° cut (Havens & Sigward 2015). Also, increased power absorption at the knee is experienced during a 90° side-cut (Havens & Sigward 2015). Running speed prior to the task also has an effect on the knee. As running speed increases, the stress on the knee also increases. At a running speed of 3 m/s, knee valgus loads have been reported at 0.15 Nm/kg, while a running speed of 5 m/s has reported knee valgus loads of 1.14 Nm/kg (Vanrenterghem et al. 2012). Increased running speeds have also been shown to lead to increased knee angles (Vanrenterghem et al 2012). These factors, especially the knee valgus loads, can play a role in injury to the knee (Vanrenterghem et al. 2012). Not only does the SCT affect lower extremity joint mechanics and loads, it can also be affected by different environmental factors.

One of the most obvious relationships between environmental factors and SCT, is the relationships between cleat type and field surface. During a side-cut, firm ground cleated footwear has been shown to exhibit greater maximum force across the medial and middle forefoot, while hard ground cleated footwear has shown a greater maximum force in the lateral forefoot area (Queen et al. 2008). These greater maximum forces may play a role in injuries to different areas of the foot (Queen et al. 2008). Various field conditions have also shown to have different influences on torque between different cleat types (Livesay et al. 2006). Comparing four types of artificial playing surfaces with two forms of footwear, a standard grass soccer cleat with 12 large cleats and 2 small cleats exhibited the greatest peak torque with FieldTurf, while turf cleats exhibited the greatest peak torque with Astroturf (Livesay et al. 2006). Grass field conditions displayed the lowest peak torques between shoe conditions (Livesay et al. 2006). These increased torques may play a role in lower extremity injuries such as ACL tears (Livesay et al. 2006).

Sport-specific demands have been demonstrated to affect lower extremity mechanics while performing athletic tasks such as side-cuts (Fedie et al. 2010). In other words, recreating more realistic game-like conditions during testing has been shown to have significant effects on task performance and its relation to injury. For example, holding a football or lacrosse stick while performing a side-cut has shown to alter knee mechanics by significantly increasing peak external knee valgus when compared to performing a side-cut alone (Chaudhari et al. 2005). Similarly, holding a football in the same arm as the planting foot during a SCT has also shown significant increases in external knee valgus when compared to a side-cut alone (Chaudhari et al 2005). The increase in valgus moments places greater strain on the ACL and leads to a greater risk for injury (Chaudhari et al. 2005). Another sport-specific demand shown to influence lower extremity mechanics is the duration of the sport itself (McGovern et al. 2015). As the duration of a sport increases, side-cuts have been shown to demonstrate a greater risk for injury due to a number of factors such as decreased neuromuscular response and control (McGovern et al. 2015). When comparing prolonged to non-prolonged activities, athletes have performed side-step cuts during prolonged activity with decreased hip and knee extension (McGovern et al. 2015). The decreased extension leads to a more upright posture during the cut and places greater stress on the knee, increasing the risk for injury (McGovern et al 2015).

Athletic tasks such as the SCT have long been associated with injuries in the lower extremity, especially to the ankle and knee (Vanrenterghem et al. 2012; Wannop et al 2014). When performing a side-cut, the main mechanism for injury is typically the large negative acceleration in the early stage of the task (Havens & Sigward 2015; Vanrenterghem et al. 2012). At the ankle, excessive inversion, plantarflexion, and loading across the medial foot and forefoot can occur in injuries such as ankle sprains or injury to the lateral ligaments of the ankle (Havens & Sigward 2015; Wannop et al. 2014). The knee undergoes excessive abduction, extensor torques, limited knee flexion, and increased rotational torques potentially leading to injuries. (Havens & Sigward 2015; McGovern et al. 2015). In general, the more upright an athlete performs a side-cut, the greater risk the athlete has for injury to the lower extremity due to increased hip and knee extension which places greater burdens on the joints (McGovern et al. 2015). Also, as the running speed prior to the cut increases, so does the chance for injury (Vanrenterghem et al. 2012). Cleat type, playing surface, and sport-specific demands have also been connected to injury risk (Fedie et al. 2010; Livesay et al. 2006; Queen et al. 2008).

Given the existing literature on footwear and the SCT, the need still exists for further research into the unique relationship between the two factors. Existing literature on footwear type has shown its connection to factors such as shoe-surface interface, power production, plantar loading, ankle loading, knee loading, lower extremity mechanics, and overall lower extremity injury. Likewise, existing literature on SCT has shown its connection to ankle and knee loading and mechanics, as wells as its relation to environmental factors and lower extremity injury. Given all of this information, the need becomes clear to further investigate the specific relationship between footwear and SCT. Therefore, the purpose of this study was to determine the effects football cleats, soccer cleats, and running shoes have on GRF's in the y and z directions for the braking and propulsion phases of a SCT.

CHAPTER III

METHODS

a) Participants:

Twelve male participants ranging from 18-30 years of age were recruited for this study. Data from only eleven individuals was used for analysis due to complications with the twelfth set of data. To be considered for this experiment, participants were required to: a) participate in either collegiate or recreational football or soccer while wearing cleated footwear for at least 1 hr./wk. during the past year, b) participants could not have any history of lower body musculoskeletal injuries within the last 6 months, and c) no surgically repaired musculoskeletal injury within the last 3 years. Bulletin boards, class announcements, and word-of-mouth were used to recruit participants for this study. Upon arrival to the lab, and before participation, all volunteers signed an IRB approved consent form and completed a physical activity readiness questionnaire (PAR-Q). Mean participant anthropometric measurements are listed below in Table 1.

Table 1: Anthropometric Measurements (Mean ± SD)

Age (years)	21.82 ±1.47
Height (cm)	180.63 ±4.73
Body mass (kg)	87.77 ±14.83

b) Equipment

1. Footwear

A counterbalanced crossover design ensured all three forms of footwear [Nike Dart Running Shoes (Figure 1), Nike Tiempo Rio II FG Soccer Cleat (Figure 2), and Nike Alpha Strike 2 TD Football Cleat (Figure 3)] varied between subjects and were worn during separate trials of the SCT. The effects of tennis shoes, football cleats, and soccer cleats on force production were examined. All footwear will be pre-laced by researchers and properly fitted.

Figure 1: Nike Dart Running Shoes

Weight: .289 kg
Figure 2: Nike Tiempo Rio II FG Soccer Cleat


Weight: .213 kg

Spike Lengths: 2.4 cm (heel) / 2 cm (medial/lateral forefoot) / 1.7 cm (mid-forefoot)

Figure 3: Nike Alpha Strike 2 TD Football Cleat

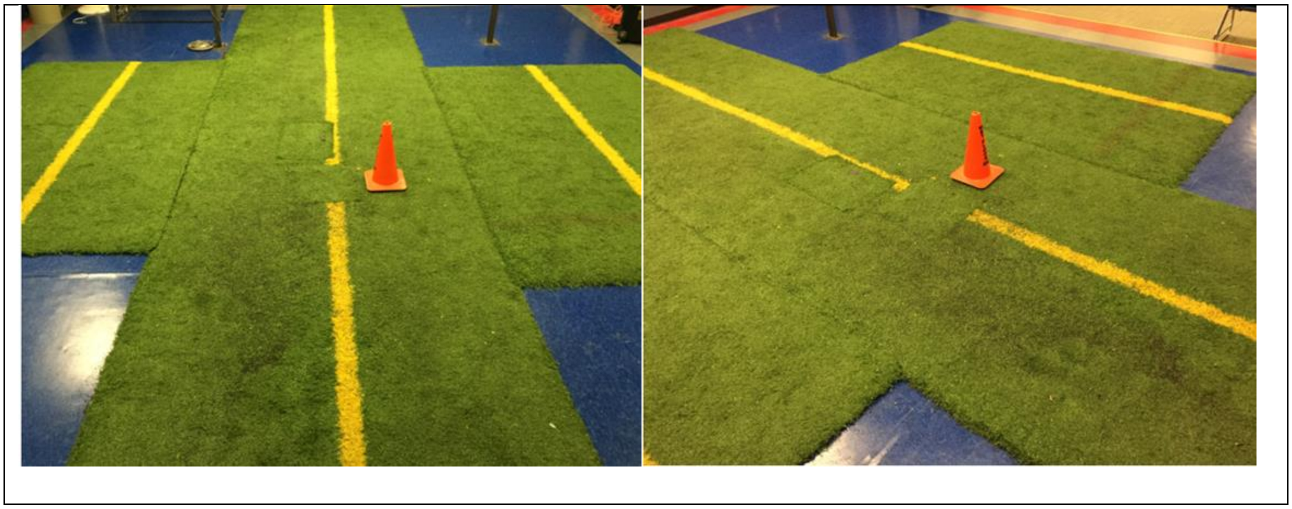
Weight: .318 kg

Spike Lengths: 2.1 cm (heel) / 2.1 cm (medial/lateral forefoot) / 1.6 cm (mid-forefoot, toe)

2. Force Plate

The SCT portion of the experiment utilized a 0.4m x 0.4m AMTI OR6-6 (AMTI, Watertown, MA) force plate (Figure 4) to record GRF’s. The force plate was placed beneath the ground and was covered with artificial field turf, secured to the floor to ensure participant safety. By planting the proper foot on the force platform during the side-cut, the GRF produced were recorded. Forces in the y (F_y), and z (F_z) direction were recorded and analyzed. F_z was a vertical force produced by the GRF, while Fx and Fy were shear forces along the anterior/posterior and medial/lateral axis, respectively.

Figure 4: Force Plate



c) Experimental Procedures:

For each participant, testing was conducted in the Applied Biomechanics Lab (ABL) at the University of Mississippi and required a one-time, 3-hour visit. After completing a consent form and Physical Activity Readiness Questionnaire (PAR-Q), each participant's age and anthropometric data (i.e. lower limb lengths and widths) were recorded for use in statistical analysis. To conduct the trials and standardize variables among participants, all were provided with a clean, compression shirt, shorts, and standard compression socks. Finally, participants were properly fitted with all three types of footwear to wear during the study.

Before initiating trials, participants performed a standard dynamic warmup consisting of 25 jumping jacks, 10 bodyweight squats, 10 walking knee hugs, 10 walking lunges (each leg), 10 straight-leg marches, and 10 push-ups. Participants were then provided with verbal instructions, as well as a physical demonstration, for the SCT and were allowed unlimited trial runs prior to starting. For the SCT, participants were given a

5-yard sprint start to simulate typical conditions experienced while performing sport-specific tasks. Running toward the force plates, participants were instructed to cut either to the left or right, planting the opposite foot on the force plate. For instance, if instructed to cut right, the left foot would plant on the force plate. Each participant conducted six total SCT, three on each foot. After completion of the trials, participants were given 10 minutes of rest in a seated position with their socks on and shoes off in order to washout the effects of the previous condition before changing into the next type of footwear. Participants performed a new set of SCT while wearing the new footwear. All details concerning the SCT remained the same between footwear groups: 5-yard start, plant and cut in opposite direction, six total trials (three per foot).

d) Statistical Analysis

A 1x3 [condition (SCT) x footwear (R,S,F)] repeated measures analysis of variance (RMANOVA) was utilized to analyze the variables of interest. An a priori analysis using data from the male subjects in Butler et al. (2014) estimated 12 participants were needed based off the following input parameters: ß=.20, α=.05, effect size =.38, and non-sphericity correction of 1.0 while including 9 different measures of 3 groups with an estimated correlation of 0.3 across the measurements. All analyses were conducted using SPSS 21 software with an alpha level set at 0.05.

Chapter IV

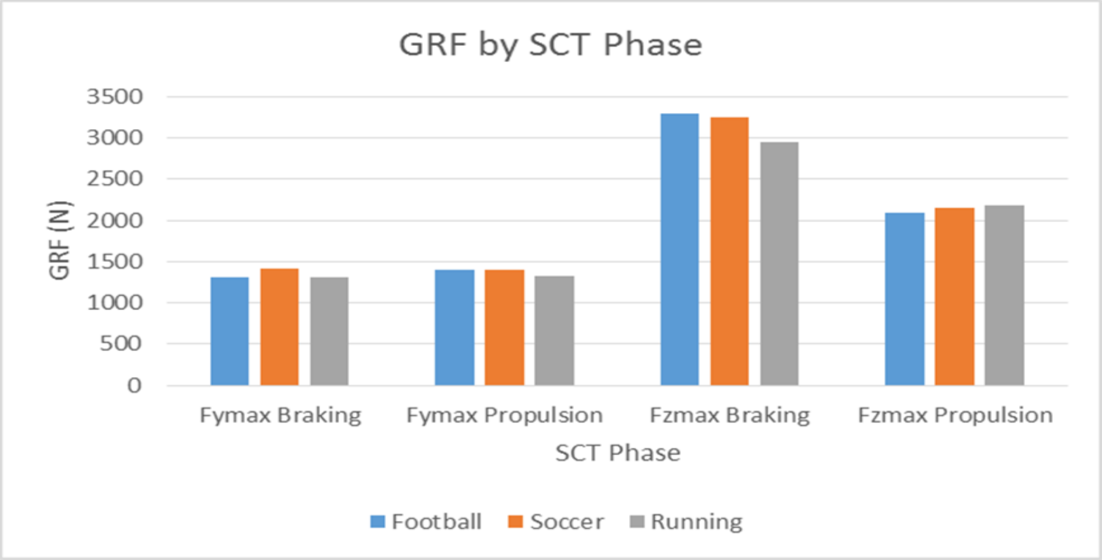
Results

A 1x3 [condition (SCT) x footwear (Running, Soccer, Football)] repeated measures analysis of variance (RMANOVA) showed there was no significance between footwear conditions and the variables of interest ($p>0.05$) during the braking and propulsion phase of the SCT (Table 2, Figure 5).

Table 2: Fy & Fz GRF for Braking and Propulsion Phases by Footwear Conditions

Footwear Conditions	**Fy max Braking (N) (Mean ± SD)**	**Fy max Propulsion (N) (Mean ± SD)**	**Fz max Braking (N) (Mean ± SD)**	**Fz max Propulsion (N) (Mean ± SD)**
Football	1316.92 ±226.14	1398.92 ±70.79	3302.56 ±720.3	2095.68 ±373.76
Soccer	1419.33 ±86.8	1393.22 ±113.34	3258.16 ±671.62	2144.99 ±330.06
Running	1305.32 ±276.59	1330.58 ±156.03	2947.46 ±953.9	2189.59 ±674.53

Figure 5: GRF by SCT Phase



Chapter V

Discussion

The purpose of this study was to determine the effects football cleats, soccer cleats, and running shoes have on GRF's in the y and z directions for the braking and propulsion phases of a SCT. It attempted to identify any differences among the footwear conditions during the braking and propulsion phases of a SCT as it relates to the optimal balance between sports performance and injury prevention. Results showed there was no significance among any of the variables of interest in each footwear condition ($p>0.05$).

Our research design is supported by much of the existing literature on the topics of footwear and the SCT when the designs of each study are considered. A number of factors have been associated with having an effect on lower extremity loading and mechanics during an athletic task, including the cutting angle of the task, the running and approach speed of the participant prior to initiating the task, footwear design and cleat arrangements, and even foot-surface interface (Bentley et al. 2010; Havens & Sigward 2015; Hilgers & Walther, 2011; Kent et al. 2015; Vanrenterghem et al 2012). Given these possible variables expressed in the existing literature as having an effect on the interaction of footwear and athletic task, the results seen in our research study concerning the cleated footwear and the SCT are justifiable.

In the existing literature, cutting angle of the SCT has been shown to have an effect on loading and lower extremity joint kinematics (Havens & Sigward 2015; Vanrenterghem et al. 2012). In the study by Havens and Sigward (2015), the authors controlled for cutting angle by marking angles on the ground with tape and reported differences in joint kinematics and loading for a 90^{o} and 45^{o} cutting angle. To get these significant differences, though, the authors had to control for the cutting angle of the SCT. In our study, participants were instructed to run, plant, and cut. No controls were made to regulate cutting angle between trials or between participants in order to mimic game-like conditions and create the least restrictive environment possible. During competition, SCT are performed at a variety of angles, not a limited number of controlled angles. By not controlling the cutting angle, we did not see any significant differences between footwear conditions.

In addition, running speed has also been shown to have an effect on lower extremity joint angles and loading, especially as speed increases (Vanrenterghem et al. 2012). By monitoring the running speed upon approach to the SCT to assure it was within ± 5% of a required speed, Vanrenterghem et al (2012) were able to demonstrate a change in lower extremity joint angles and loading. To get these significant differences, the authors had to control for the variable of approach speed. In the present study, running speed upon approach to the SCT was not controlled. Participants were instructed to begin in a sprint-start position, and approach the SCT as if it were game-like conditions. By not controlling for the approach speed, we created a more realistic condition and did not find any significant differences.

When considering the differences in the forms of cleated footwear, several of the existing literature authors have found significant differences between conditions, such as in the studies by Queen et al (2007), Bentley et al (2010), and Gehring et al (2007). In these studies where the authors found significant differences, it is important to note the footwear conditions used were distinctly different. In the present study, the footwear conditions used had very minimal differences. Slight differences existed on the top of the footwear and in the studs, but overall, the only major differences were the sports each was advertised for use. With the fact the footwear used in the present study had minimal differences compared to existing studies where footwear conditions were distinctly different, the present study plausibly saw no significant differences between conditions.

Footwear, shoe design, and cleat arrangements have been shown to affect loading and force distribution during an athletic task across the lower extremity (Bentley et al. 2010; Hilgers & Walther 2011; Queen et al 2008). For instance, a number of different shoe stability variations exist that produce a variety of loading patterns across the foot, such as flexible midfoot, flexible forefoot, and added midfoot stiffening components (Hilgers & Walther 2011). Hilgers and Walther (2011) reported how flexible midfoot footwear may present a greater injury risk due to torsion of the midfoot, while footwear with added midfoot stiffening components may help increase kicking power and reduce injury risk to the midfoot. Similarly, different cleat types and arrangements have also proved to have varying effects on the lower extremity during athletic tasks. In a study by Bentley et al. (2010), the authors displayed an increased pressure distribution along the lateral foot during a running and cutting task in bladed cleats as opposed to studded cleats, potentially leading to a higher risk of injury. For our research purposes, the design and cleat configuration of the footwear conditions was not taken into consideration concerning its connection to the forces displayed during a SCT. The present study took two forms of cleated footwear, each marketed for their respective sport that are popular among NCAA Division I athletes, and compared the differences during a SCT as it relates to the GRF’s produced during the braking and propulsions phases of the task.

Different cleat styles and configuration have been shown to interact in unique ways with various playing surfaces in the area of rotational torques. In a study by Kent et al. (2015), the authors demonstrated that different cleated footwear conditions resulted in different rotational torques between natural and artificial turf playing surfaces. A mechanical apparatus applied loaded game-like forces and rotations to the footwear conditions on the two playing surfaces and recorded various torques and forces related to the shoe-playing surface interaction (Kent et al. 2015). Concerning the artificial playing surface compared to the natural playing surface, the artificial turf displayed forces and torques that exceeded the limits of the testing machine (Kent et al. 2015). In a similar study, Torg et al (1974) found that on artificial turf, soccer style cleats with ½ inch studs and a 3/8 inch diameter produced a release coefficient of .41 ±.03, while soccer style cleats with ½ in studs and ½ inch diameters produced a release coefficient of .29 ± .03 on artificial turf. The release coefficient for the first cleat condition was deemed “probably not safe”, while the second cleat condition was deemed “safe” (Torg et al. 1974). Our study did not account for the footwear-playing surface interaction and the possible effects on the force readings.

Several limitations existed within our study that may have affected the outcome of our results. Given the existing literature on the topics discussed above, it could be noted our study did not control for the cutting angle of the SCT or the approach speed prior to the SCT. If either of these controls would have been implemented, it may have affected the nature of our results. Additionally, our study only considered two forms of cleated footwear, both made by the same manufacturing company and marketed for their respective sports. Had we compared a greater sample size of footwear, possibly with different shoe designs, stability variations, and numbers and arrangements of cleats and studs, we may have been able to determine a difference between footwear conditions. A final possible consideration to note in our study was the skill level of our participants. All participants had the requirement of having participated in either football or soccer for at least 1hr/week during the past year, making them either recreationally or collegiately trained. Our study did not separate participants based on skill level. Had we separated these populations and conducted separate studies, we may have seen a difference in results.

From the results of our study, it can be concluded there is no difference among the footwear conditions tested and the GRF's along the y and z directions during the braking and propulsion phases of a SCT. Considering the existing literature, results from our study, and the limitations discussed above, further research into this area of study is still needed to better find the balance between improving athletic performance and reducing injury risks. A number of further controls and methods should be considered in moving forward with research on this topic. Future studies should possibly take into account and control for the cutting angle of the SCT, the approach speed prior to the task, the configuration of the footwear and the cleat design, as well as possibly the interaction between the footwear and the playing surface. Additionally, a possible larger sample size of footwear conditions, along with a relatively uniform skill level of participants should be taken into consideration.

Conclusion

One of the major focusses concerning athletic equipment is the balance between increasing performance and decreasing injury risks. The purpose of this study was to determine the effects football cleats, soccer cleats, and running shoes have on GRF’s in the y and z directions for the braking and propulsion phases of a SCT. We found that during the braking and propulsion phases of a SCT, no significant differences exist in the GRF’s along the y and z directions between the football and soccer cleats used in this study. In most sports, the athletes, parents, and coaches continuously attempt to determine ways to simultaneously increase the performance and safety of the athletes. Concerning cleated footwear, no difference exists between the football and soccer cleat used in this study, thus giving neither footwear condition an immediate advantage in the area of performance during a SCT. Therefore, athletes can choose and wear either football or soccer cleats with similar stud characteristics due to the evidence neither provides a performance advantage in SCT.

References

Bentley, J.A., Ramanathan, A.K., Arnold, G.P., Wang, W., Abbound, R.J. (2011). Harmful cleats of football boots: A biomechanical evaluation. *Foot and Ankle Surgery,* 17, 140-144.

Butler, R.J., Russell, M.E., Queen, R. (2014). Effect of soccer footwear on landing mechanics. *Scandinavian Journal of Medicine & Science in Sports,* 24, 129-135.

Chaudhari, Ajit., Hearn, Brenna., Andriacchi, Thomas. (2005). Sport-dependent variations in arm position during single-limb landing influence knee loading implications for anterior cruciate ligament injury. *The American Journal of Sports Medicine,* 33(6), 824-830.

Cheung, Roy., Ng, Gabriel. (2008). Influence of different footwear on force of landing during running. *Physical Therapy,* 88(5), 620-628.

DeBiasio, Justin., Russell, Mary., Butler, Robert., Nunley, James., Queen, Robin. (2013). Changes in plantar loading based on shoe type and sex during a jump-landing task. *Journal of Athletic Training,* 48(5), 601-609.

Fedie, Rebecca., Carlstedt, Kristen., Willson, John., Kernozek, Thomas. (2010). Effect of attending to a ball during a side-cut maneuver on lower extremity biomechanics in male and female athletes. *Sports Biomechanics,* 9(3), 165-177.

Fredericks, William., Swank, Seth., Teisberg, Madeline., Hampton, Bethany., Ridpath, Lance., Hanna, Jandy. (2015). Lower extremity biomechanical relationships with different speeds in traditional, minimalist, and barefoot footwear. *Journal of Sports Science and Medicine*, 14, 276-283.

Gehring, D., Rott, F., Stapelfeldt, B., Gollhofer, A. (2007). Effects of soccer shoe cleats and knee joint loads. *International Journal of Sports Medicine*, 28, 1030-1034.

Havens, Kathryn., Sigward, Susan. (2015). Joint and segmental mechanics differ between cutting maneuvers in skilled athletes. *Gait & Posture*, 41, 33-38.

Iacovelli, Jaclyn., Yang, Jingshen., Thomas, Geb., Wu, Hongqian., Schiltz, Trisha., Foster, Danny. (2013). The effect of field condition and shoe type on lower extremity injuries in American Football. *British Journal of Sports Medicine*, 47, 789-793.

Kinchington, Michael., Ball, Kevin., Naughton, Geraldine. (2011). Effects of footwear on comfort and injury in professional rugby league. *Journal of Sports Sciences*, 29(13), 1407–1415.

Lambson, Rick., Barnhill, Bill., Higgins, Robert. (1996). Football cleat design and its effect on anterior cruciate ligament injuries: A three-year prospective study. *The American Journal of Sports Medicine*, 24(2), 155-159.

Livesay, Glen., Reda, Dawn., Nauman, Eric. (2006). Peak torque and rotational stiffness developed at the shoe-surface interface the effect of shoe type and playing surface. *The American Journal of Sports Medicine*, 34(3), 415-422.

McGovern, Andrew., Dude, Christopher., Munkley, Daniel., Martin, Thomas., Wallace, David., Feinn, Richard., Dione, Donald., Garbalosa, Juan. (2015). Lower limb kinematics of male and female soccer players during a self-selected cutting maneuver: Effects of prolonged activity. *The Knee*, 22, 510-516.

Queen, R.M., Charnock, B.L., Garrett Jr, W.E., Hardaker, W.M., Sims, E.L., Moorman III, C.T. (2007). A comparison of cleat types during two football specific tasks on FieldTurf. *British Journal of Sports Medicine,* 42, 278-284.

Queen, Robin., Abbey, Alicia., Verma, Ravi., Butler, Robert., Nunley, James. (2014). Plantar loading during cutting while wearing a rigid carbon fiber insert. *Journal of Athletic Training,* 49(3), 297-303.

Sankey, Sean., Azidin, Raja., Robinson, Mark., Malfait, Bart., Deschamps, Kevin., Verschueren, Sabine., Staes, Filip., Vanrenterghem, Jos. (2015). How reliable are knee kinematics and kinetics during side-cutting manoeuvers? *Gait & Posture,* 41, 905-911.

Sinclair, Johnathan., Atkins, Stephen., Richards, Jim., Vincent, Hayley. (2015). Modelling of muscle force distributions during barefoot and shod running. *Journal of Human Kinetics,* 47, 9-17.

Sinclair, Johnathan., Hobbs, Sarah., Curigan, Graham., Giannandrea, Marcus., Taylor, Paul. (2014). Tibiocalcaneal kinematics during barefoot and in barefoot inspired shoes in comparison to conventional running footwear. *Movement and Sports Science,* 83, 67-75.

Torg, Joseph., Quedenfeld, Theodore., Landau, Steven. (1974). The shoe-surface interface and its relationship to football knee injuries. *Journal of Sports Medicine*, 2(5), 261-269.

Vanrenterghem, Jos., Venables, Emma., Pataky, Todd., Robinson, Mark. (2012). The effect of running speed on knee mechanical loading in females during side cutting. *Journal of Biomechanics,* 45, 2444-2449.

Villwock, Mark., Meyer, Eric., Powell, John., Fouty, Amy., Haut, Roger. (2009). Football playing surface and shoe design affect rotational traction. *The American Journal of Sports Medicine,* 37(3), 518-525.

Wannop, John., Graf, Eveline., Stefanyshyn, Darren. (2014). The effect of lateral banking on the kinematics and kinetics of the lower extremity during lateral cutting movements. *Human Movement Science,* 33, 97-107.

Wannop, John., Worobets, Jay., Stefanyshyn, Darren. (2010). Footwear traction and lower extremity joint loading. *American Journal of Sports Medicine*, 38, 1221-1228.