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Effect of field condition and shoe type on lower extremity injuries in American football

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EFFECT OF FIELD CONDITION AND SHOE TYPE ON LOWER EXTREMITY INJURIES IN AMERICAN FOOTBALL

by

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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

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To my loving and supporting father and mother, Chris and Gail Iacovelli

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CHAPTER 1

INTRODUCTION

American football is the single most popular sport in the United States. From August to January dedicated fans watch thousands of hours of football by attending live games or watching on television. The National Football League is the wealthiest sports league in the entire world, with an average team worth about $957 million (Badenhausen, Ozanian, & Settimi, 2007). Furthermore, when considering the entire football franchise of a NFL team, teams are worth up to $1.5 billion (Badenhausen, Ozanian, & Settimi, 2007).

Across the US, thousands of college students and fans attend football games weekly. Stadiums that hold between 70 and 110 thousand people are consistently sold out to fans cheering on their alma mater. When The University of Iowa football team went to the 2010 FedEx Orange Bowl, 7.8 million people tuned in to watch the game (hawkeyesports.com, 2011). The University of Iowa Athletic Department was granted $70 million for their 2010-2011 budget, and football can be attributed to generating about 70 percent of the revenue for the athletic department (hawkeyesports.com, 2011).

One of the main attractions of watching football is the aggressive nature of the sport. Defensive players try to tackle the offensive players with the ball to the ground before they can advance down the field. When any kind of contact is introduced into a sport, injuries may result.

With football becoming increasingly popular in the United States, more efforts have been made on technology and advancements to reduce the number of injuries sustained by athletes. Several methods include improving safety equipment, field types, shoes worn, and training the athlete to improve flexibility and agility. However, few studies have been conducted to evaluate how the field type, field condition, and shoe type interact with each other to induce injuries. Specifically, lower extremity injuries, such as the knee and ankle, have not been thoroughly investigated with these extrinsic risk factors. Few shoe studies exist, and many of these studies use a prosthetic leg machine or limit the athlete to a controlled situation or preconfigured obstacle course. To fill in the gap in the literature, this thesis research aims to use epidemiological methods to investigate the effect of field condition and shoe type on lower extremity injuries using real player data from the 2008, 2009, and 2010 football seasons at The University of Iowa.

CHAPTER 2

BACKGROUND AND TECHNICAL LITERATURE

2.1 Football as a Contact Sport

American football is an extremely physical contact sport, with the goal of the game being to tackle the player with the ball to the ground. For every play, 12 offensive players line up facing 12 defensive players to try to advance 10 yards or more down the field, until the end zone is reached. On offense, typically the quarterback starts with the ball and either hands it off to the running back, who runs with it as far as possible before being tackled, or throws it down to field to a receiver. Offensive linemen line up against defensive linemen to try to protect the quarterback from being tackled by the defense. On defense, linemen try to penetrate the offensive line to tackle the quarterback or running back, while the rest of the defense covers the open field that the offensive receivers are running into. By its nature, football is physical and dangerous because of the size, speed, and strength of the players colliding with each other. In comparison with other sports, football is consistently noted as being a high-risk activity for injury (Clanton, 1994). Even though all players wear facial protection, shoulder pads, and hip-thigh protection, injuries are unavoidable (Hagel, Fick, & Meeuwisse, 2003). Pritchett (1982) conducted a study almost thirty years ago using insurance claims for injuries sustained in high-school football and found that 19.5% of players sustained at least one injury during the season. In the 1990’s, it was estimated that participating in football caused over half of a million injuries in high school athletes (Clanton, 1994). Years later, as football has grown in popularity, football injuries are estimated to be approximately 10 to 35 per 1,000 playing hours and cost on average, about $150 per injury (Dvorak & Junge, 2000). Worldwide, these injuries quickly add up to billions of dollars spent annually (Orchard & Finch, 2002).

2.2 Lower Extremity Injuries

Athletes experience a variety of injuries, head to toe. It has been estimated that the number of injuries caused by sports in the world is similar to that of car accidents (Wolfel, et al., 2003). For every sport there are certain injuries that are more common than others, however, injuries in the ankles and knees are very frequent among all sports and levels of competition, and account for about 50% of reported injuries in children from 5 to 24 years old (Fernandez, Yard, & Comstock, 2007). For this age group, 20% of all emergency department visits were due to lower extremity injuries (Burt, 2001). In soccer, which is another physically demanding sport with running styles similar to football, ankle, knee, and thigh structures were the most frequently injured for male and female players (Fuller, et al., 2007). Of these injuries, the joint (non-bone)/ligament/cartilage injuries of the lower limb were the most common (Fuller, et al., 2007). The United States has approximately 80,000 anterior cruciate ligament (ACL) tears annually, with a majority coming from individuals ranging in age from 15 to 25 years old, who participate in pivoting sports (Griffen, et al., 2000).

In the 1970's, researchers had just begun analyzing injuries in football, specifically lower extremity injuries. Pritchett (1982) reported that in six western states studied from 1976 to 1977, ligament injuries of the knee were the most common injuries from playing high school football, accounting for 10% of all injuries. Furthermore, if an athlete experienced a knee-ligament injury, he was three times as likely to reinjure the same knee (Pritchett, 1982). More recently, Fernandez et al. (2007) reported that lower extremity injury rates in high school football players was 2.01 per 1,000 athlete exposures, which is much higher than the total of 1.42 per 1,000 athlete exposures for all boys sports and 1.14 per 1,000 athlete exposures for the total girl's sports. There is no surprise that football has the highest rate of lower extremity injuries and the highest proportion of post injury disability since the nature of the sport requires extreme physical contact between players (Fernandez, Yard, & Comstock, 2007). Internationally, American football has a higher risk of knee injuries (1.46 knee traumas/active members) than the two most popular European sports, soccer (0.31) and skiing (1.08) (Majewski, Habelt, & Steinbruck, 2006).

The physical strength and power of football players increases as players move up in the level of competition, and lower extremity injuries become more common. Meyers (2010) reported finding a greater incidence of ACL injuries in collegiate football when compared to high school football studies. In the highest level of competition achieved by a football player, ankle and knee sprains account for about 20% of all injuries reported in the National Football League (Powell & Schootman, 1992).

Despite the shear size and strength of the players, football lower extremity injuries, especially ACL injuries, occur more often in non-contact situations as opposed to player-to-player contact (Heinrichs, 2004; Griffen, et al., 2000). Contact injuries are reported when an injury due to contact with another player occurs and are commonly reduced by providing better protective equipment, enforcing stricter rules, and increasing athletic conditioning (Heidt, et al., 1996). Non-contact injuries occur when impact forces from the playing surface are transferred to the body, such as a running, jumping, or pivoting injury, or when muscle and tendons get fatigued due to overload (Heidt, et al., 1996). In a non-contact situation, foot fixation, when the athlete's foot is trapped in the ground, has been investigated as the leading cause of ankle and knee injuries in sports, specifically ACL injuries (D'Ambrosia, 1985; Torg J., 1982; Torg, Quedenfeld, & Landau, 1971). Foot fixation is common in planting and cutting, and the stronger, faster, and more powerful players generate a greater force when pivoting and maneuvering (Lambson, Barnhill, & Higgins, 1996). Rotational torque is also known to be one of the many causes of ligament injuries in the knee and ankle joints when players make sudden stops while running or change direction quickly (Andreasson, et al., 1986). Figures 2.1 and 2.2 provide additional visual representations of how forces impact the lower extremity region.

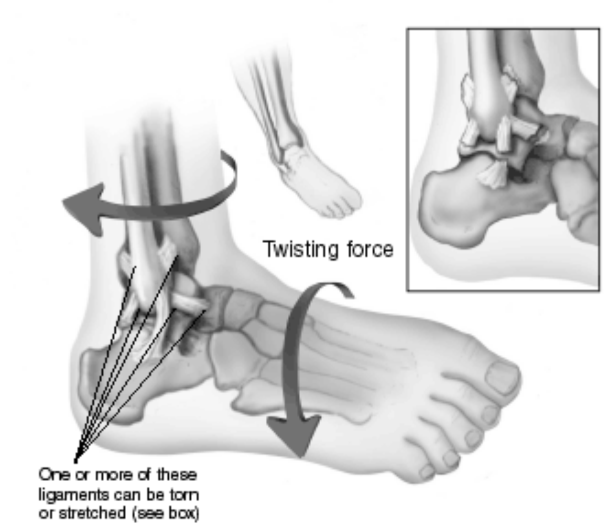

Figure 2.1: Twisting Ankle Force and Possible Resulting Injuries (American Orthopaedic Foot & Ankle Society, 2011)

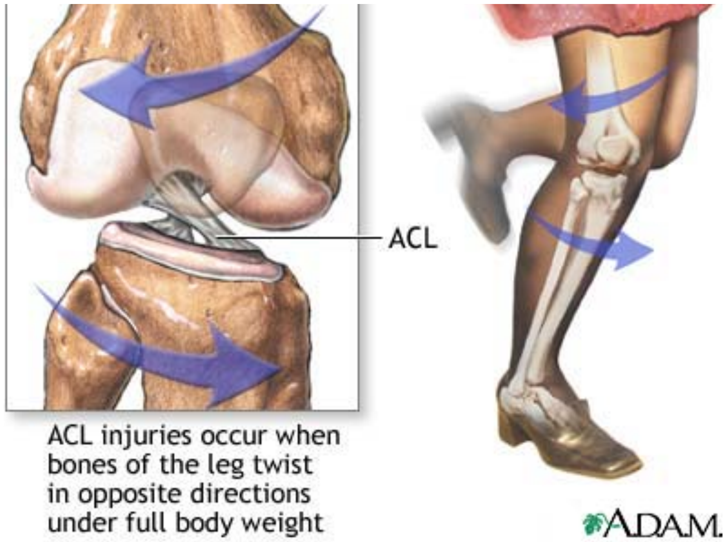

Figure 2.2: Running Forces that Result in ACL Injuries (Physio Works, 2011)

2.3 Intrinsic and Extrinsic Risk Factors

There is not one specific cause of lower extremity injuries, and research has shown that these injuries are a combination of intrinsic and extrinsic factors. Intrinsic (person-related) factors are biological or psychosocial characteristics of the athlete (Dvorak & Junge, 2000). Such factors include positions, age, previous injuries, joint flexibility, and muscle tightness (Dvorak & Junge, 2000). For many of these risk factors, such as previous injuries and age of players, players have to overcome adversity on their own to continue playing (Orchard & Powell, 2003). On the other hand, extrinsic (environmental-related) factors, such as field condition, shoe-surface interaction, weather conditions, and equipment, equally contribute to the causes of injury and can be studied to improve athletic performance (Dvorak & Junge, 2000).

2.3.1 Intrinsic Risk Factors

This study will focus on extrinsic risk factors, however, some intrinsic factors are important to note when focusing on lower extremity injuries in football. The position a player plays dictates the risk exposure of lower extremity injuries. Quarterbacks, wide receivers, running backs, fullbacks, and defensive tackles are the positions that require running and rapid change of directions (Ford, et al., 2006). Running backs were identified in one study for suffering 11 of the 42 injuries documented, however, linebackers and interior linemen accounted for almost half of the ACL tears endured (Ford, et al., 2006).

Dvorake et al. (2000) conducted an intrinsic risk factor analysis for injuries in soccer players and found an increased number of players who identified themselves as a “fighter” in getting past an opponent to have more injuries, in general. The authors argued that possibly these players were over compensating for a lack of skills and using aggressiveness as an alternative. However, when inferring this “fighter” attitude to injuries in football, it may be the case that aggressive play is one of the leading causes of injuries.

In an epidemiological study of athletic knee injuries by Majewski et al. (2006), 19,530 sports injuries were documented over a ten-year period of time, and almost 50% of the patients were between the ages of 20 to 29. This is the prime age for collegiate football players and rookie NFL players, and this age range possesses a great concern for these high-profile athletes. In the long term, people who sustain a knee injury before the age of 22 are three times as likely to be diagnosed with osteoarthritis in the knee by their mid-50s (Gelber, et al., 2000).

Pivoting, changing direction, jumping, and landing happen thousands of times to an athlete without injury, but Boden et al. (2000) suspects that the quadriceps are activated before the hamstrings for athletes who sustain ACL injuries. Much of the time with ACL injuries, the central nervous system activates the quadriceps to try to regain stability, but the forces of the quadriceps muscles over-power the knee ligaments (Griffen, et al., 2000). Working in opposition to the quadriceps, the hamstring muscles may also contribute significantly to ACL injuries if the athlete has insufficient hamstring flexibility or a delay motor signal to the hamstrings (Boden, Griffin, & Garrett Jr., 2000). These neuromuscular elements contribute to the amount of lower extremity injuries experienced by football players, and athletes can only work on improving their flexibility and joint stability through strength training and stretching to prevent these types of injuries (Boden, Griffin, & Garrett Jr., 2000).

Athletes who sustain a devastating lower extremity injury risk the possibility of re-injury once they continue play. Evidence suggests that a previous injury to the ACL, especially when coupled with poor rehabilitation, increases the likelihood of sustaining another injury to either ankle, re-injuring the same knee, or acquiring a new injury to the other knee (Murphy, Connolly, & Beynnon, 2003).

Overall, intrinsic risk factors are important to consider, but may be problematic since the biomechanics of every athlete is different and athletes experience a number of injuries through the years while competing in sports. It is of great value to further consider the extrinsic risk factors since they remain constant for the practice or game being observed.

2.3.2 Extrinsic Risk Factors

2.3.2.1 Field Type

Since the 1970's, scientists have been creating different field materials to replace natural grass in football stadiums. The first generation field turf, also known as AstroTurf, reduced the amount of maintenance to the field, but resembled a carpet instead of the natural ground. Next, several different models of turf, including AstroPlay Outdoor, added rubber particles to the turf, which in turn, was eventually replaced by turf with a 70/30 rubber/sand mixture. Most recently, FieldTurf has replaced AstroPlay and contains a 50/50 rubber/sand mixture, and currently best resembles the characteristics of natural grass (Livesay, Reda, & Nauman, 2006). Any turf containing mixtures of sand and rubber are known as third generation turf.

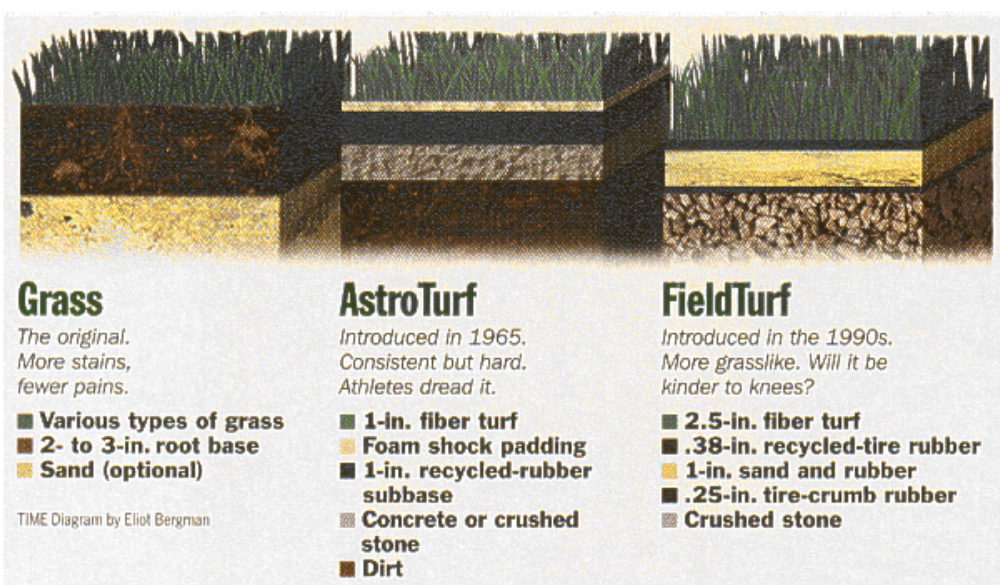

Figure 2.3: Comparison of Grass, AstroTurf and FieldTurf Materials and Structures (Northern Arizona University, 2001)

Over the last thirty years, several studies have been conducted to compare injury rates between artificial and natural grass. To date, there still exists conflict between studies as to which field type is safer for athletes. Not in favor of artificial turf, Orchard (2002) studied football players on artificial and natural grass and found that the number of knee and ankle ligament injuries was higher on artificial turf. Hagel et al. (2003) compared AstroTurf to natural grass in game competitions for Canadian footballers and reported finding the rate of injuries for lower extremity regions to be twice as high on AstroTurf. Focusing on the knee specifically, another study identified AstroTurf to be associated with an increase risk of medial collateral ligament (MCL) injuries, ACL injuries, and knee sprains (Powell & Schootman, 1992). This is consistent with Orchard and Powell (2003), who found an increase in the incidence of knee sprains on AstroTurf, but no overall difference for ACL injury rates. When considering shoe-surface friction interaction, FieldTurf and AstroPlay produced a higher peak-torque than natural grass surfaces, which could lead to an increase to lower extremity injuries (Villwock, et al., 2009).

On the other hand, Meyers (2010) concludes in his study on game-related injuries in college football that FieldTurf is indeed safer than natural grass, but is cautious in generalizing the findings to other levels of competition. Meyers (2010) also reports not finding any significant differences in knee trauma between the two surfaces. Focusing on the knee, Scanton et al. (1997) states that more ACL injuries occurred on natural grass compared to earlier generation turf during five seasons in the National Football League. This is further supported by Meyers and Barnhill (2004), who found a higher number of ACL injuries on natural grass than FieldTurf.

Yet, a third conclusion that artificial turf does not differ from natural grass has been reported. Fuller et al. (2010) examined rugby players on the two surfaces and concluded that there was no significant difference in the risk of injuries on artificial turf compared to natural grass, however, noted that for both surfaces the most common body location injured was the lower limb and the most common type of injury was a joint. This result is supported by another study, which examined elite soccer players on third generation artificial turf (Ekstrand, Timpka, & Hagglund, 2006). Fuller et al. (2007) deduced similar results for both practice and game conditions, however, found that incidence of ankle sprains did not differ significantly between the two surfaces.

Consequently, there exists a tradeoff between performance and risk of injury with artificial turf. FieldTurf is suspected to increase the athlete's speed, acceleration, and torque while playing, but this can ultimately lead to more injuries (Meyers & Barnhill, 2004).

Many arguments can be found both for and against the use of artificial turf for football fields, however, it seems that the reduced maintenance and long term cost savings outweigh the injury risk factors of artificial turf in collegiate football. About 64% of the Big 10 conference uses FieldTurf, while the remaining use natural grass (Suppes, 2010). In 2009, the athletic department at The University of Iowa replaced Kinnick Stadium's 2005 Prescription Athletic Turf with FieldTurf for approximately $2 million dollars. This new turf is believed to reduce the cost of field maintenance by about $80,000 per year and have a lifespan of about eight years (Board Approves Drainage System, Field Work at Kinnick, 2009). Other advantages include providing an all-weather training and game facility (Fuller, et al., 2007), in addition to the fact that third generation turf tends to have greater shock absorption due to the rubber cushion (Ekstrand, Timpka, & Hagglund, 2006). However, over two-thirds of the National Football League stadiums still use natural grass (Ford, et al., 2006), which leaves people wondering if money is the underlying concern of colligate football. In 2006, a survey completed by 1,400 active NFL players was conducted to see how the players felt about playing on artificial or natural grass. The player's top request remained to make all stadiums grass to prevent injuries and if that was not possible due to inclement weather cities, then resort to using artificial turf (NFLPlayers.com, 2008).

2.3.2.2 Weather and Field Condition

In addition to the field surface being played on, it is important to consider the weather and condition of the field at the time of use. Field condition, in combination with field type, can provide greater insight into reducing injuries. Few studies aim their interest at the weather and field condition at the time of injuries for athletes (Gusiewicz, et al., 2000; Orchard J. W., 2002; Meyers & Barnhill, 2004). Most studies classify the field as either wet or dry, and the temperature as either hot (>70° F) or cold (<70° F) (Orchard & Powell, 2003). Again, non-conclusive results have been demonstrated in the literature.

As reported in Hagel et al.'s 2002 study of Canadian footballers, wet compared to dry field conditions may be associated with greater risks of injuries overall. When focusing on the lower extremity injuries, 222 injuries occurred during dry field conditions and only 61 injuries for wet conditions, and furthermore, when adjusted to the number of exposures, the rate for injury on a dry playing ground was 1.83 as compared to a 2.31 for a wet ground. The authors note that statistically, the confidence intervals of the two conditions overlap, which may leave room for error.

Temperature wise, Meyers (2010) found a significantly higher rate of injuries on cold days on FieldTurf compared with natural grass. On the other hand, hot days had a significantly lower incidence of injuries on FieldTurf compared with natural grass. This however, contradicts a previous Meyer study, which reports finding a higher incidence of knee trauma during hot days on FieldTurf than on cold days (Meyers & Barnhill, 2004). The evidence for knee trauma seems inconclusive, since another report found that ACL injuries are significantly less for open AstroTurf stadiums in the later (cooler) months of football season for NFL players from 1989 to 1998. These findings may contradict each other due to ACL injuries being under reported in the 1990's and the technological advancement to use MRI machines to diagnose knee injuries (Orchard & Powell, 2003). Sports with similar running, cutting, and contact maneuvers to football also show findings that knee and ankle injuries are more likely when the ground surface is warmer, drier, and harder (Orchard J. W., 2002; Orchard & Powell, 2003).

Despite all the contradicting results from these studies, it is increasingly important to consider that the game, in general, may be slower in worse weather conditions. This consequently, may results in the speed of the players being slower, or the players may be more cautious of their maneuvers (Orchard & Powell, 2003).

2.3.2.3 Shoe Considerations

Perhaps the most important and under studied correlation may be the interaction between the player's shoe and the incidence of lower extremity injures. Shoes offer external support, joint stability, and surface traction, which are necessary for the success of the player. Collegiate football players are constantly getting new shoes every season, sometimes receiving several shoes if a major sporting company, such as Nike, Adidas or Reebok, sponsors the team. In 2006, the NFL Players Associated conducted an equipment survey to see how players select a shoe, and 39% based their decision on comfort, 22% on weight of the shoe, 21% on appearances, and only 18% picked the shoe for its safety rating (NFLPlayers.com, 2008).

Despite the reason the shoe was chosen, if the shoe is not performing well for the athlete, injuries can occur. Specifically, the lower extremity regions will obviously be affected. As mentioned previously, many lower limb injuries occur in non-contact situations, such as when a player is cutting, turning, or jumping. It has been speculated that the translational and rotational forces that the lower limb endures could be a result of the shoe-surface traction. These forces can be translated into vertical forces through the limb and may affect the bones and soft tissue (Kaila, 2007; Nigg, 1990; Hagel, Fick, & Meeuwisse, 2003).

Shoe surface interaction may be the missing link in minimizing lower extremity injuries after already considering field type and field condition. As mentioned previously, cold weather possibly could be associated with less ankle and knee injuries, which might be a product of reducing the shoe-surface interactions experienced (Ford, et al., 2006; Orchard & Powell, 2003). As outside temperatures rise, the turf temperature also increases, which corresponds to an enhanced shoe-surface interaction. The greater the shoe-surface interaction, the more likely the athlete is to experience a knee trauma (Meyers, 2010). In soccer, lower limb injuries tend to occur when there is an increase in surface hardness on natural grass and first generation artificial turf, or and increase in shoe-surface traction (Orchard, et al., 2005). The increased resistance to rotation at the shoe-surface interaction may lead to the twisting motion that produces ACL injuries (Cawley, et al., 2003).

The few studies conducted on athletic cleats served a variety of interests. Ford et al. (2006) conducted a study on 17 male football players that completed a specific slalom course to test a Nike cleat on two types of surfaces, artificial and natural grass. Players were instructed to perform at top level so the researchers could evaluate the peak pressure and relative load in nine regions of the foot. The study found no significant differences between grass and turf, however, the medial forefoot region of the shoe, the ball of the foot, had the greatest load force. The amount of force placed on this region, especially if on natural grass, in addition to the high-frictional shoe-surface interaction, may contribute to the "cleat catch" mechanism, which is where cleats are caught in the surface but the body keeps moving (Heidt et al., 1996; Ford, et al., 2006).

Traction is critical for the athlete's ability to accelerate, decelerate, and change direction (Severn, Fleming, & Dixon, 2010). Many different stud designs for cleats on the market promise athletes high traction (Grund & Senner, 2010). However, excessive rotational traction can cause foot fixation, which increases the risk factors of sustaining an ACL injury (Grund & Senner, 2010; Lambson, Barnhill, & Higgins, 1996; Shorten & Himmelsbach, 2003). On the other hand, insufficient traction could lead to slippage (Ekstrand & Nigg, 1989). In addition, shoe-surface combinations that create higher torques may put the athlete at risk for injury (Andreasson, et al., 1986; Livesay, Reda, & Nauman, 2006). In a study of two cleats, one grass and one turf, against four playing surfaces, AstroTurf, AstroPlay Outdoor, AstroPlay Tray, and FieldTurf, the highest peak torques were seen between the grass shoe-FieldTurf and the turf shoe-Astroturf combinations (Livesay, Reda, & Nauman, 2006). Reassuring, these results reveal that the development of shoes for certain field types is geared in the right direction.

Lower torques may be better for the safety of the athlete, yet the performance of the athlete may be compromised (Livesay, Reda, & Nauman, 2006). High shoe-surface friction has been correlated with better performance but also a greater risk for injury (Griffen, et al., 2000). For instance, non-cleated shoes resulted in smaller torques on both artificial and natural grass (Bonstingl, Morehouse, & Niebel, 1975; Andreasson, et al., 1986), however, these “carpet” or “basketball” shoes are seldom seen in competitive football. Athletes may be hesitant to switch to a shoe with a lower torque if they are not as fast or agile as with a higher torque shoe. The difference between success and failure could be as simple as a small difference in traction, and shoe developers are faced with a dilemma to balance between maximum performance and maximum safety (Grund, Senner, & Gruber, 2007).

Arguments have been made that aggressively cleated shoes generate higher torques than other cleats (Lambson, Barnhill, & Higgins, 1996). Four types of cleat designs were tested for torsional resistance on artificial and natural grass surfaces in Lambson et al. (1996) study. The results showed that the Edge cleat design, which had more studs around the perimeter of the shoe, produced significantly more torsional resistance on artificial turf compared to the Flat, Screw-in, and Pivot disk shoes. Edge cleats had an injury rate 3.4 times higher than non-Edge cleat designs. In addition, after a statistical analysis, the Edge cleat design showed a significantly greater ratio of ACL injuries. Other types of cleats the authors expressed concern for were cleats that "included round spiked cleats on the interior portion of the soles with longer irregular cleats on the outer rim" because these types of cleats improved traction and were also known to be worn by athletes who had previously experienced a severe knee injury (pg. 156).

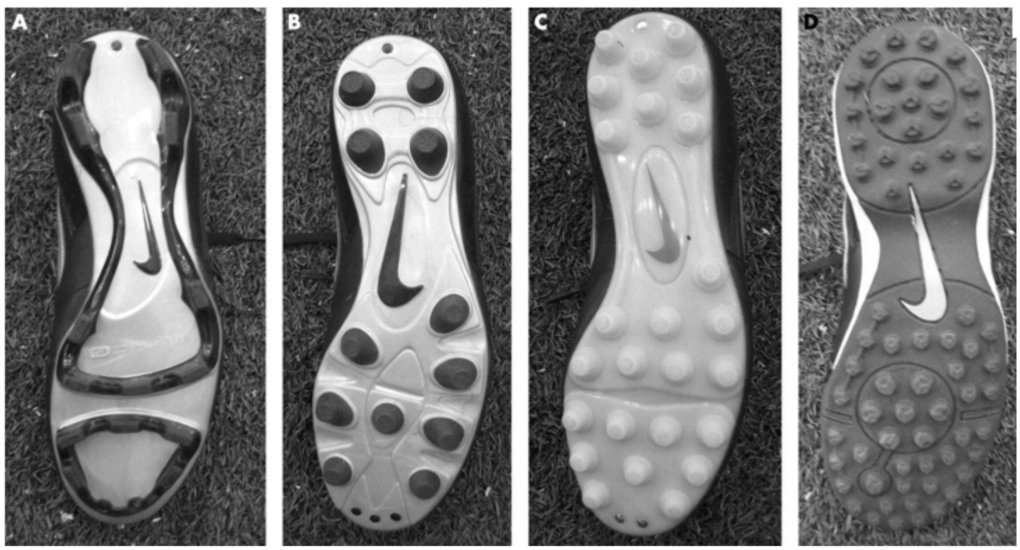

Figure 2.4: Comparison of Cleat Studs (Queen, et al., 2007)

Lower extremity joint injuries can also be a product of the number of studs on the cleat (Peterson, 1982; Andreasson, et al., 1986). Some studies found that shoes with 6 to 10 cleats had a small number of injuries on natural grass, while shoes with 13 to 17 cleats had fewer injuries on artificial turf (Torg, Quedenfeld, & Landau, 1971; Bonstingl, Morehouse, & Niebel, 1975). However, few studies have been conducted to investigate this topic, especially in recent years. In addition, shoes with longer cleats may be associated with more ACL injuries (Lambson, Barnhill, & Higgins, 1996).

Combining ambient temperature and shoe-surface interaction between five different shoe models, a flat-soled basketball-style turf shoe, a natural grass soccer-style shoe, and three different multistudded turf shoes, revealed that only the turf-style basketball shoe could be considered “safe” or “probably safe” for football players to use on turf for all five temperatures tested (52°, 60°, 78°, 92°, 110°F) (Torg, Stilwell, & Rogers, 1996). Supporting this claim, The University of Pennsylvania football team wore this shoe for the 1993 and 1994 seasons, and only one player had a severe knee injury that required surgery (Torg, Stilwell, & Rogers, 1996). The other shoes used in the study were classified from “probably safe” to “not safe” at higher temperatures because of the increase in the release coefficient, which is the necessary force to release the shoe attached to a prosthetic leg from the artificial turf (Torg, Stilwell, & Rogers, 1996).

Few shoe-surface interaction studies have been conducted since the development of third-generation turf. More recently, Villwock et al. (2009) set forth to study ten different models of football shoes that fall into five categories of cleats, to understand rotational traction. These cleat categories included 12-studded peripheral molded, edge, hybrid (15+ molded), 7-studded replaceable, and turf cleats. The only cleat to produce significantly lower torques was the turf cleat compared to all other groups. Looking at the specific model of cleat, the Adidas Turf Hog was found to have a significant effect on the peak torque, and the Adidas Blitz had significantly higher rotational stiffness than the six other models. On the other hand, the Nike Superbad had significantly lower rotational stiffness compared to five other models. The authors suggest the difference in rotational stiffness may be due to the construction and material of the upper sole of the shoe, which is where the ball of the foot is located.

2.4 Thesis Objectives

There is a significant monetary cost associated with lower extremity injuries in sports. Just ACL injuries are estimated to cost almost a billion dollars a year (Griffen, et al., 2000). Considering the shear number of lower extremity injuries, along with the cost of rehabilitation, cost of support tape/braces, and not to mention the pain the athlete suffers and the reduction in the quality of life because of the injury, there is a great potential to reduce the number of lower extremity injuries by understanding the risk factors involved. Prevention strategies have already been developed to help reduce intrinsic risk factors, such as strength training and balance programs (Boden, Griffin, & Garrett Jr., 2000; Caraffa, et al., 1996). However, since technology is constantly changing, extrinsic risk factors have to be frequently studied and altered.

Artificial turf has come a long way since its implementation in the 1970's, and researchers suspect that artificial turf, in combination with field conditions and shoe-surface interaction, are important factors to consider for reducing the amount of lower extremity injuries. Sporting companies work year-round to develop the best, safest, and most stylist shoes for the market. However, research and development can only go so far, and the true potential of the shoes is not justified until the athletes put them to use for games and practices.

Most studies that consider multiple extrinsic risk factors are outdated, do not evaluate third generation turf (Villwock, et al., 2009), are not specifically interested in American football, or use some sort of prosthetic leg attached to the shoe in question.

Biomechanical investigations typically conducted experiments in a laboratory (Ford, et al., 2006), use devices that are not portable to test actual playing surfaces (Villwock, et al., 2009), or direct the athlete in a controlled situation. Many shoe studies that use a prosthetic leg machine do not get realistic forces and load calculations to accurately measure football player's size and weight distribution (Grund, Senner, & Gruber, 2007; Livesay, Reda, & Nauman, 2006). However, designing controlled experiments to specifically cause ACL injuries to athletes would be extremely unethical. Research is heading in a direction that uses digital human modeling to simulate the forces in the knee, however it is difficult to simulate the properties of the shoe-surface interaction. Consequently, accurate digital modeling is very time consuming and complex (Grund, Senner, & Gruber, 2007).

While digital human modeling might be the new wave of the future, it is important to consider that the ideal extrinsic factors may be different for every sport, position/age of players, and level of competition (Livesay, Reda, & Nauman, 2006). The game of football will benefit by evaluating extrinsic factors with real player data. Furthermore, the evaluation of shoe-surface interactions with real player data may drastically change the way football cleats are designed, the material used, traction characteristics, or even the material used to construct new artificial turfs (Villwock, et al., 2009).

To the best of my knowledge, after an extensive review of literature, no study has been conducted using real collegiate football data to explore whether and how the field condition and shoe type worn may affect the potential risk of lower extremity injuries in football. The present study will examine the associations between these different extrinsic risk factors and lower extremity injuries based on available data from The University of Iowa Athletic Department for the 2008 to 2010 football seasons.

CHAPTER 3

METHODOLOGY

3.1 Data Collection

Data for this study was collected through three sources: 1) the Sports Injury Monitoring System (SIMS), which contains injury and activity (exposure) information, 2) pre-season physical exam information for the 2007-2008, 2008-2009 and 2009-2010 academic year, which contains demographic information and shoe type for non-injured athletes, and 3) baseline data from Dr. Yang's *Social Support and Athlete Resilience Research*, which contains sports and injury history information.

SIMS is an ongoing injury surveillance system established by the Big Ten Athletic Conference in the early 1980's. SIMS is the premiere tool for injury tracking and documentation, and includes the following information: a roster of all team members, a daily log for all team practices and games, and a detailed record of all reportable injuries, including type and location of injury, and the medical attention and rehabilitation received. Certified athletic trainers are responsible for data entry into SIMS of their respective athletic team. The University of Iowa Injury Prevention Center purchased the dataset from *FlanTech*, a computer service company that is the only authorized seller of SIMS software.

The pre-season physical examination data were obtained through The University of Iowa Athletic Department via Dan Foster, the Associate Director of Athletic Training, in a Microsoft Excel document. Data from August to November of each of the Fall 2008, Fall 2009, and Fall 2010 football seasons were used.

All tables for this chapter are located at the end of the chapter.

3.2 Variable Type

A master list of all variables collected are displayed in Appendix A. In order to focus the analysis on extrinsic risk factors, only selected intrinsic variables that were related to extrinsic risk factors were included in this study. The included variables were grouped into dependent, independent, and other variables categories.

3.2.1 Dependent Variables

Dependent variables were those that were analyzed as consequences of the independent variables. Since this study focused on lower extremity injuries, specifically knee and ankle injuries, the dependent variables were the lower extremity injuries, knee injuries, and ankle injuries. Table 3.1 displays the variable name, definition, initial coding and final coding for the dependent variables.

3.2.2 Independent Variables

Independent variables were the extrinsic variables that the study treats as potential sources of increasing the risk of lower extremity injuries. Table 3.2 displays the variable name, definition, initial coding and final coding for the independent variables.

3.2.3 Other Variables

The other variables category includes factors related to both dependent and independent variables, such as whether the injury involved surgery or the number of days of play and practice missed as a result of the injury, and were not explored as part of this study. Table 3.3 displays the variable name, definition, and initial coding for these variables.

3.2.4 Data Merging

Three existing data sets were merged by matching athletes' first and last name and year of participation. After the data was merged, students' names were removed and a variable of study ID was assigned to create a de-identified dataset for analysis. Five groups of data were included: 1) athlete demographics, 2) injuries and characteristics associated with injuries, 3) field condition, 4) shoe type, and 5) football related activities.

3.3 Athlete Demographics

Demographic data were defined as characteristics of the football player. Variables such as age, height, weight, race, year in school, player position, and history of previous injury were included in the analysis.

3.4 Injuries and Characteristics Associated with Injuries

3.4.1 Injury Definition

All injuries included in the SIMS study met the following two criteria: 1) clinical signs of tissue damage determined by team athletic trainers and/or team physicians, and 2) inability of the player to return to practice or game the same day. The injury definition used for this study was any reportable injury that occurred during the study period that required medical attention and restricted full sport participation, either in games or practices, for one day or more.

3.4.2 Injury Type and Body Region Coding

The initial dataset from SIMS was re-coded before being entered into a statistical program for analysis. The injury description variable (e.g. INJDESC) contained both the type of injury and the body region that the injury occurred. These two measures were separated into two variables based on the Barell injury diagnosis matrix (http://www.cdc.gov/nchs/injury/ice/barell_matrix.htm) and sports injury literature (Bahr R, 2009). A single-digit number was coded as a general category, such as Muscle and Tendon, and a double-digit number indicated the specific location or type of injuries, such as muscle rupture/tear/strain/cramps. Table 3.1 of the independent variables identifies the new coding associated with type of injury and body region of injury.

3.4.3 Dichotomous Coding

Four additional dichotomous variables of ankle injury, knee injury, game injury and practice injury were created to indicate if the injury was an ankle injury or a knee injury and if the injury occurred in a practice or game setting. The variables were coded as a "1" indicating an injury and "0" indicating otherwise. The following indicates the detailed coding:

For Ankle Injuries, (Ankle_Inj):

0=not an ankle injury

1=ankle injury

Knee Injury (Knee, Inj):

0=not a knee injury

1=knee injury

Practice Injury (PINJ):

0=injury did NOT occur during a practice

1=injury occurred during practice

Game Injury (GINJ):

0=injury did NOT occur during a game

1=injury occurred during game

3.5 Field Condition

The Field Condition group in SIMS (e.g. ACTSURFACE and SURF_COND) contained information about the playing surface used (Field Turf, Sports Grass, Grass, Practice Fields, Dura-Turf, Natural Surfaces P.A.T, and Grass and Turf), and the surface condition (hot_humid, normal, wet, abnormal, dry, indoor, or unknown).

3.5.1 Field Condition Coding

These two variables were re-coded further to reduce the number of groups in each. For the purpose of this study, the activity surface, (e.g. ACTSURFACE) was reduced to: 1) Artificial, 2) Natural, and 3) Other. The surface condition, (e.g. SURF_COND) was reduced to 1) Normal and 2) Not-Normal.

3.6 Shoe Type

All University of Iowa football players wore the brand, NIKE, as cleats during the 2008 to 2010 seasons. There were twenty-seven different shoe models of NIKE used by UI football players from the 2008 to 2010 seasons.

3.6.1 Shoe Type Coding

The existing twenty-seven different shoe models were reduced and coded into seven categories based on the number of cleats and the height of the top of the shoe as follows:

1=7 Cleat High-top

2= 7 Cleat Low-top

3= 9-12 Cleats High-top

4= 9-12 Cleats Low-top

5= >12 Cleats High-top

6= >12 Cleats Low-top

7= No Cleats

This variable was further coded into three new variables: one for the number of cleats on the shoe (7 cleats, 9-12 cleats, >12 cleats, and no cleats), one for the height of the top of the shoe near the ankle (high vs. low), and one for the length of the cleat on the shoe (short vs. long). Cleats were categorized as long if the cleat was ¾ an inch in length. All other cleats were deemed short. The name of the cleat distinguished the length of the cleat, such as, "Super Speed TD ¾" compared to "Super Speed TD Low". Table 3.4

illustrates the full list of shoes, classification, description, and a picture of all shoes used in this study.

3.7 Football Related Activities

Football related activities, (e.g. TMACTIVITY) included regular practice, scrimmage, game, light practice, conditioning, varsity competition, weight lifting and walk through.

3.7.1 Team Activity Coding

For the purpose of this study, football related activities, (e.g. TMACTIVITY) were grouped into three groups: 1) Practices 2) Games and 3) Other.

3.8 Research Questions

The aim of this study was to investigate the effects of specific extrinsic factors, including playing surface, field condition, and shoe type (measured by number of cleats on the shoe, height of the shoe opening, and length of the cleat) on lower extremity injuries (e.g. all lower extremity injuries and specifically knee or ankle injuries) in collegiate football players at The University of Iowa from the 2008 to 2010 seasons. Several research questions were addressed.

3.8.1 Frequency Analysis

1) What are the characteristics of the study population?

2) What is the prevalence rate of injuries?

3) What is the prevalence rate of lower extremity injuries?

4) How is the player position related to the frequency and type of football lower extremity injuries?

5) What are the distributions of playing surface, field condition, and shoe type (measured by number of cleats on the shoe and height of the shoe opening)?

3.8.2 Unadjusted Analysis

Research Question 1) What is the relationship between playing surface and football lower extremity injuries? A) Specifically knee injuries? B) Specifically ankle injuries?

Research Question 2) What is the relationship between field condition and football lower extremity injuries? A) Specifically knee injuries? B) Specifically ankle injuries?

Research Question 3) What is the relationship between the number of cleats on the shoe and football lower extremity injuries? A) Specifically knee injuries? B) Specifically ankle injuries?

Research Question 4) What is the relationship between the height of the shoe opening and football lower extremity injuries? A) Specifically knee injuries? B) Specifically ankle injuries?

Research Question 5) What is the relationship between the length of the cleat on the shoe and football lower extremity injuries? A) Specifically knee injuries? B) Specifically ankle injuries?

3.8.3 Adjusted Analysis Accounting for

Practice or Game Exposures

Research Question 6) What is the relationship between playing surface, and football lower extremity injuries, adjusting for team activity? A) Specifically in practices? B) Specifically in games?

Research Question 7) What is the relationship between surface condition and football lower extremity injuries, adjusting for team activity? A) Specifically in practices? B) Specifically in games?

Research Question 8) What is the relationship between number of cleats on the shoe and football lower extremity injuries, adjusting for team activity? A) Specifically in practices? B) Specifically in games?

Research Question 9) What is the relationship between the height of the shoe opening and football lower extremity injuries, adjusting for team activity? A) Specifically in practices? B) Specifically in games?

Research Question 10) What is the relationship between length of cleat, and football lower extremity injuries, adjusting for team activity? A) Specifically in practices? B) Specifically in games?

3.9 Hypothesis

3.9.1 Unadjusted Analysis

Research Question 1) Football players playing on artificial surfaces are more likely to have lower extremity (specifically knee or ankle) injuries than if playing on natural grass.

Research Question 2) Football players playing on not-normal field conditions are more likely to have lower extremity (specifically knee or ankle) injuries than on normal field conditions.

Research Question 3) Football players wearing shoes with more than 12 cleats are more likely to have lower extremity (specifically knee or ankle) injuries than players wearing shoes with 7, 9 to 12 cleats, or no cleats.

Research Question 4) Football players wearing shoes with high tops are more likely to have lower extremity (specifically knee or ankle) injuries than players wearing shoes with low tops.

Research Question 5) Football players wearing shoes with longer cleats are more likely to have lower extremity injuries than players wearing shoes with short cleats.

3.9.2 Adjusted Analysis Accounting for Practice or Game Exposures

It is hypothesized that football players are more susceptible to a lower extremity injury in a game setting compared to a practice setting. Thus, hypotheses for Research Questions 6-10 are the same versions as Research Questions 1-5, but adjusted for practice or game exposures.

3.10 Scientific Contribution

Unlike many of the current studies in the literature review, this study used real player data to evaluate a variety of cleat types and interactions instead of using a prosthetic foot or having a simulated, controlled environment. To the best of my knowledge, no study has been conducted to look specifically at lower extremity injuries by evaluating the effect of the playing surface, field condition, and shoe model worn simultaneously.

Table 3.1: Dependent Variables

VARIABLE NAME	DEFINITION	INITIAL CODING	FINAL CODING
Dependant Variables			
Inj_type	Type of injury	Categorical	
		1=Fractures and bone stress	1=Fractures and bone stress
		11=Fractures	
		12=Stress Fractures	
		13=Other Bone Injuries	
		2=Joint(non-bone) and ligament	2=Joint(non-bone) and ligament
		21=Dislocation/subluxation	
		22=Sprain/ligament injury	
		23=Lesion of meniscus or cartilage	
		24=Other Joint injuries	
		3=Muscle and Tendon	3=Muscle and Tendon
		31=Muscle rupture/tear/strain/cramps	
		32=Tendon injury/repture/tendonosis/bursitis	
		4=Contusions, lacerations and skin lesions	4=Contusions, lacerations and skin lesions
		41=Hematoma, contusion, bruise	
		42=Abrasion	
		43=Laceration	
		5=Central/peripheral nervous system	5=Central/peripheral nervous system
		51=Concussion	
		52=Nerve Injury	
		53=Other	
		6=Dental Injuries	6=Dental Injuries
		7=Other	7=Other

Table 3.1—continued

Inj_body	Area of injury	Categorical	
		1=Head/neck	
		11=Head/face	
		12=Neck/cervical spine	
		2=Upper Exremity	
		21=Shoulder/clavicle	
		22=Upper arm	
		23=Elbow	
		24=Forearm	
		25=Wrist	
		26=Hand/finger/thumb	
		3=Trunk	
		31=Sternum/ribs/upper back	
		32=Abdomen	
		33=Lower back/sacrum/pelvis	
		4=Lower Extremity	4=Lower Extremity
		41=Hip/Groin	
		42=Upper leg (thigh)	
		43=Knee	
		44=Lower leg/Achilles tendon	
		45=Ankle	43=Knee
		46=Foot/toe	45=Ankle
		5=Systems/Illness	
		51=Cardiovascular	
		52=Respiratory	
		53=Endocrine	
		54=More	
		55=Other	
Knee_Inj	If the injury is a knee injury	Binomial	
		0=no	
		1=yes	
Anke_Inj	If the injury is an akle injury	Binomial	
		0=no	
		1=yes	

Table 3.2: Independent Variables

VARIABLE NAME	DEFINITION	INITIAL CODING	FINAL CODING
Independent Variables			
TMACTIVITY	The specific type of activity the athlete was participating in	Categorical	
		Practice	1= Practice
		Scrimmage	
		Light Practice	
		Game	2=Game
		Varsity competition	3=Other
		Weight Lifting	
		Conditioning	
		Walk Through	
ACTSURFACE	The specific surface the team activity was played on	Categorical	1=Artificial
		Field Turf	
		Sports Grass	
		Dura-Turf	
		Artificial Turf	
		Grass	2=Natural
		Natural Surfaces P.A.T.	
		Grass and Turf	3=Other
		Practice Fields	
SURF_COND	The surface condition of the ground during play	Categorical	1=Normal
		Normal	
		Normal: Calm	
		Hot_Humid	2=Not Normal
		Wet	
		Abnormal	
		Dry	
		Dome/Indoor Field	
		Dome/Indoor Field: Normal	

Table 3.2—continued

GSHOE_MODL	Model of primary game shoe worn	Categorical	NUM_CLEATS 1=7 cleats 2=9-12 cleats 3=>12 cleats
		7HT=7 cleats with a High-top	
		Air Zoom Assassin	
		Air Zoom Blade II D	
		Air Zoom Blade Pro D	
		Air Zoom Boss D	
		Air Zoom Merciless D	
		Super Speed D 3/4	
		Super Speed Mid	
		7LT=7 cleats with a Low-top	
		Air Zoom Barracuda	
		Super Speed D Low	
		9-12HT=9-12 cleats with High-top	
		Air Zoom Blade II TD	TOP_HEIGHT 1=High 2=Low
		Air Zoom Blade III Shark	
		Air Zoom Blade Pro TD	
		Air Zoom Boss Shark 3/4	
		Air Zoom Super Bad	
		Merciess Shark	
		Speed TD	
		Speed TD 3/4	
		9-12HT=9-12 cleats with Low-top	
		Air Zoom Vapor Jet 4	CLEAT_LENGTH 1=Short 2=Long
		Vapor Jet TD	
		>12HT=greater than 12 cleats with High-top	
		Air Zoom Merciless TD	
		Super Speed TD 3/4	
		>12HT=greater than 12 cleats with Low-top	
		Air Legend	
		Air Zoom Total 90	
		Speed TD Low	
		NC=No Cleats	
		Air Zoom Total 90	
		Zoom Speed Low	

Table 3.2—continued

PSHOE_MODL	Model of primary game shoe worn	Categorical	NUM_CLEATS 1=7 cleats 2=9-12 cleats 3=>12 cleats
		7HT=7 cleats with a High-top	
		Air LT 2.1 Shark	
		Air Zoom Assassin	
		Air Zoom Blade II D	
		Air Zoom Blade Pro D	
		Air Zoom Boss D	
		Air Zoom Merciless D	
		Super Speed D 3/4	
		Super Speed Mid	
		7LT=7 cleats with a Low-top	
		Air Zoom Barracuda	
		Super Speed D Low	
		9-12HT=9-12 cleats with High-top	
		Air Zoom Blade II TD	TOP_HEIGHT 1=High 2=Low
		Air Zoom Blade III Shark	
		Air Zoom Blade Pro TD	
		Air Zoom Boss Shark 3/4	
		Air Zoom Super Bad	
		Merciless Shark	
		Speed TD	
		Speed TD 3/4	
		9-12HT=9-12 cleats with Low-top	
		Air Zoom Vapor Jet 4	CLEAT_LENGTH 1=Short 2=Long
		Vapor Jet TD	
		>12HT=greater than 12 cleats with High-top	
		Air Zoom Merciless TD	
		>12HT=greater than 12 cleats with Low-top	
		Air Legend	
		Air Zoom Total 90	
		Speed TD Low	
		NC=No Cleats	
		Zoom Speed Low	

Table 3.2—continued

ATH_POSIT	The position the athlete plays on the field	Categorical	
		WIDE RECEIVER	
		TIGHT END	
		SPECIAL TEAMS	
		RUNNING BACK	
		QUARTERBACK	
		OFFENSIVE LINE	
		LINEBACKER	
		DEFENSIVE SEC	
		DEFENSIVE LINE	
		SAFETY	
		DEFENSIVE BACK	

Table 3.3: Other Variables

VARIABLE NAME	DEFINITION	INITIAL CODING	FINAL CODING
Other Variables			
REINJURY	Whether or not the injury was from a previous injury	True/False FALSE TRUE	
SURGERYREQ	Whether or not the injury required a surgery for repair	True/False FALSE TRUE	
ONSET	Date the injury occurred	Date	
RETURN	Date the player returned to play	Date	
Playing Days missed	Number of days the player missed because of injury	Numeric	
GMISSED	Number of games missed because of injury	Numeric	
PMISSED	Number of practices missed because of injury	Numeric	

Table 3.4: Full list, Classification, Description and Pictures of All Shoes

Classification	Shoe	Cleat Description	Picture
1: 7 Cleats, High Top	Air Zoom Assassin	Round	
	Air Zoom Blade Pro D	Round	
	Air Zoom Boss D	Round	
	Air Zoom Blade II D	Round	

Table 3.4—continued

	Super Speed D 3/4	Round	
	Zoom Merciless D	Round	
	Super Speed D 3/4	Round	
	Super Speed Mid	Round	

Table 3.4—continued

	Air LT 2.1 Shark	Round	
2: 7 Cleats, Low Top	Air Zoom Barracuda	Round	
	Super Speed D Low	Round	
3: 9-12 Cleats, High Top	Air Zoom Blade Pro TD	Round	
	Air Zoom Boss Shark 3/4	Shaped	

Table 3.4—continued

	Air Zoom Super Bad	Round and Shaped	
	Air Zoom Blade II TD	Round	
	Air Zoom Blade III Shark	Shaped	
	Merciless Shark	Shaped	

Table 3.4—continued

	Speed TD	Round	
	Speed TD 3/4	Round and Shaped	
4: 9-12 Cleats, Low Top	Air Zoom Vapor Jet 4	Round and Shaped	
	Vapor Jet TD	Shaped	

Table 3.4—continued

5: >12 Cleats, High Top	Air Zoom Merciless TD	Round	
	Super Speed TD 3/4	Round and Shaped	
6: >12 Cleats, Low Top	Air Legend	Round and Shaped	
	Speed TD Low	Round and Shaped	

Table 3.4—continued

	Air Zoom Total 90	Round	
7: No Cleats	Air Zoom Speed Low	Carpet, No Cleats	

CHAPTER 4

RESULTS

In the previous chapter, five groups of data were discussed: 1) athlete demographic, 2) injuries and characteristics associated with injuries, 3) field condition, 4) shoe type, and 5) football related activities. This chapter discusses the results of the distributions of the five groups of data and the results from the unadjusted and adjusted Generalize Linear Models (GLM). All analysis was conducted using SAS statistical software.

All tables for this chapter are located at the end of the chapter.

4.1 Distributions

4.1.1 Athlete Demographics

Over three seasons, 189 athletes experienced approximately 38,000 football exposures in 312 days. Table 4.1 depicts the athlete demographics for all football players on the roster in the three seasons this study observed: 2007-2008, 2008-2009 and 2009-2010. The players were an average of 20 years old, 6’2” tall, and weighed an average of 234 pounds. Nearly three quarters of the players (71.3%) were Caucasian. More than half of the players (58.3%) reported having a previous injury of some sort. A majority of athletes reported having consumed alcohol in the last thirty days (50.78%), but reported that they did not consume alcohol in the last fourteen days (73.64%) or smoked cigarettes in the last thirty days (99.22%).

4.1.2 Injuries and Characteristics Associated with Injuries

The athletes endured 250 injuries, of which 129 (51%) occurred in the lower extremity. Of all injuries, 34 (14%) involved the knee and 30 (12%) involved the ankle. Most of the lower extremity injuries, specifically knee injuries and ankle injuries were of the joint (non-bone) and ligament type. Table 4.2 depicts the prevalence rates of lower extremity injuries by the type of injury. More lower extremity injuries, knee injuries, and ankle injuries occurred in a practice setting (69 lower extremity injuries) than in a game setting (37 lower extremity injuries), however, of all injuries that occurred in a game setting, 55% involved the lower extremity injury as opposed to 53% of all injuries were lower extremity injuries in a practice setting. Similar trends for practice and game settings can be seen with knee injuries and ankle injuries. Table 4.3 describes the frequency and type of lower extremity injuries by athlete position. The defensive line (16 lower extremity injuries) and the offensive line (14 lower extremity injuries) endured the most lower extremity injuries, of which the muscle and tendon were the most frequent type of injury (47% of all lower extremity injuries by athlete position). The defensive line had the most knee injuries (23% of all knee injuries by athlete position) compared to the offensive line, which had the most ankle injuries (18% of all ankle injuries by athlete position). For all knee and ankle injuries by athlete position, the joint (non-bone)/ligament was the most frequent type of injury (65% for knee injuries and 86% for ankle injuries).

Table 4.4 summarizes the number of injuries for all lower extremity injuries, knee injuries specifically, and ankle injuries specifically, for the field surface and field condition variables. Most lower extremity injuries, knee injuries, and ankle injuries occurred when the athletes played on an artificial surface (60%, 56%, and 59%, respectively) and in a normal surface condition (78%, 64%, and 88%, respectfully). In addition, Table 4.5 provides the frequency information for the number of lower extremity injuries, knee injuries specifically, and ankle injuries specifically for the shoe variables. Most lower extremity injuries, knee injuries, and ankle injuries occurred when athletes were wearing 9-12 cleats (46%, 54%, and 45%, respectively), had a high shoe opening (55%, 52%, and 60%, respectfully) and wore shoes with a short cleat length (94%, 96%, and 95%, respectfully).

4.1.3 Field Condition, Shoe Type, and Football Related Activities

Field surface, field condition, number of cleats, height the cleat opening, and length of cleat were coded and analyzed for distributions. Distributions were described by person-sessions, which were defined as the total number of sessions multiplied by the number of athletes. Table 4.6 summarizes the distributions of the team activity. Practices contributed to 73% of total exposures (227 sessions, 28,273 person-sessions), 11% for games (35 sessions, 4,324 person-sessions) and 16% for other (50 sessions, 6,337 person-sessions) over the three sessions studied. Table 4.7 summarizes the distributions of playing surface and surface condition, including exposures by practice and game settings. 65% of all exposures occurred on an artificial surface (181 sessions, 22,670 person-sessions) compared to 36% of all exposures that occurred on a natural surface (106 sessions, 13,247 person-sessions). Most games were played on a natural surface (56%), while most practices occurred on an artificial surface (56%). For surface condition, 89%

of all exposures were categorized as a normal condition (221 sessions, 27,485 person-sessions) compared to the 11% categorizes as a not-normal condition (27 sessions, 3,504 person-sessions). Most games and practices took place on normal surface conditions (73% and 85%, respectfully). Table 4.8 summarizes the shoe type distributions for athlete exposures (unit of analysis is one session of activity). Most athletes used shoes with 9-12 cleats (43% total, 45% for games, and 43% for practices) compared to shoes with 7, more than 12, or no cleats. In addition, most athletes used shoes with a high top at the shoe opening (60% total, 60% games, and 60% practices) compared to a low top, and shoes with short cleat lengths (93% total, 93% games, and 93% practices) compared to long cleat lengths.

4.2 Unadjusted Generalize Linear Models

Generalized Linear Models (GLM) with a binomial distribution and logit link functions were used to assess the relationship between lower extremity injury and each independent variable of interest (surface type, field condition, height of top of shoe, number of cleats on shoe, and length of the cleats on shoe). To account for the nested data structure of activities as well as injuries clustered within athletes and across time, Generalized Estimating Equations (GEE) were used to fit models. Within this framework, a working autoregressive correlation structure accounted for the temporal associations among the response observations. This structure assumes that the strength of the association between two response observations is determined by the amount of time that separates the observations. Thus, injury events that occur chronologically closer in time are assumed to be more highly correlated than events that occur further apart in time. The same analyses were performed for knee injury and ankle injury.

The field condition model (abnormal vs. normal) was the only model with significant results for all lower extremity injuries (Chi-square p-value=0.0307) and ankle injuries specifically (Chi-square p-value=0.0253). For all lower extremity injuries, the odds of having a lower extremity injury in a not-normal condition was 2.19 times as likely as in a normal condition[1]. In contrast, the odds of having an ankle injury in a normal condition was 0.323 times as likely as in a not normal condition[2]. Table 4.9 and 4.10 summarize the results obtained for the significant unadjusted GLM for the surface condition. Surface type, height of top, number of cleats, and length of cleats were not found to be significant in predicting lower extremity injuries, knee injuries specifically, or ankle injuries specifically at an α=0.05 significance level. Appendix B provides the summary tables for the non-significant variables for the unadjusted GLM models.

4.3 Adjusted Generalized Linear Models,

Accounting for Practice or Game Exposures

Generalized Linear Models (GLM) with a binomial distribution and logit link functions were used to assess the relationship between lower extremity injury and each independent variable of interest (surface type, field condition, height of top of shoe, number of cleats on shoe, and length of the cleats on shoe). To adjust for practice or game exposures, the variable team activity, along with an interaction term of team

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[1] Odds ratio: e^(0.7821)=2.19
[2] Odds ratio: e^(-1.1293)=0.3233

activity and the independent variable of interest, was also included in the models. To account for the nested data structure of activities as well as injuries clustered within athletes and across time, Generalized Estimating Equations (GEE) were used to fit models. Within this framework, a working autoregressive correlation structure accounted for the temporal associations among the response observations. This structure assumes that the strength of the association between two response observations is determined by the amount of time that separates the observations. Thus, injury events that occur chronologically closer in time are assumed to be more highly correlated than events that occur further apart in time. Further stratified analyses were conducted for models that had a statistical significance in team activity. Separate analysis was conducted for practices only or games only, using Generalized Linear Models with GEEs.

The playing surface model (artificial vs. natural) was the only model with statistical significance in the interaction term (Chi-square p-value=0.0189), along with significant findings in team activity (Chi-square p-value=0.0018) and playing surface (Chi-square p-value=0.029). Table 4.11 summarizes the results obtained for the playing surface model. The playing surface model was further analyzed separately for games and practices, and surface was found significant in the game model (Chi-square p-value=0.005) but not the practice model. Table 4.12 summarizes the results obtained for the playing surface model in a game. For all lower extremity injuries, the odds of having a lower extremity injury on an artificial surface in a game setting was 2.89 times more likely than on a natural surface[3]. Surface was not found to be significant in a practice setting.

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[3] Odds ratio: e^(1.0606)=2.89

The surface condition, top of height, and number of cleat models were all found to have no significance in the interaction term, but were significant for team activity (Chi-square p-value=0.0143, <.0001, and 0.0038, respectively). These models were further analyzed separately for games and practices. The only model of significances was the condition model in a practice setting. Table 4.13 summarizes the results obtained for the condition model in a practice setting. For all lower extremity injuries, the odds of having a lower extremity injury in a not normal condition in a practice setting was 2.04 times more likely than in a normal condition[4]. Condition was not found to be significant in a game setting. Top height and the number of cleat models were not found to be significant in either the practice or game settings.

The cleat length model was not found to be significant in any of the terms when accounting for games and practices. Appendix C provides the summary tables for the non-significant adjusted GLM models.

[4] Odds ratio: e^(0.7148)=2.04

Table 4.1: Roster Athlete Demographics (n=189)

	Mean(std)
Age	20(1.5)
Height (inch)	74.40(2.75)
Weight (lbs)	234.09(37.475)
BMI	29.63(3.71)
GPA	2.86(0.52)
Years Played In High School	3.98(0.53)
Year in College	1.9(1.11)
	N(%)
Race	
Caucasian	90(71.32)
African American	33(25.58)
Hispanic	1(0.78)
Other	3(2.33)
Missing	60
Previous Injury	
Yes	63(58.33)
No	45(41.67)
Missing	81
Alcohol in last 30 days	
Yes	63(49.22)
No	65(50.78)
Missing	61
Alcohol in last 14 days	
Yes	34(26.36)
No	95(73.64)
Missing	60
Cigarettes in last 30 days	
Yes	1(0.78)
No	128(99.22)
Missing	60

Table 4.2: Lower Extremity Injury Type

	N (%)		
	Total Injury	**Game Injury**	**Practice Injury**
ALL LOWER EXTREMITY	127(53.59)	37(55.22)	69(53.08)
Fracture and Bone Stress	9(7.96)	3(4.48)	6(4.62)
Joint(non-bone) and ligament	52(46.02)	23(34.33)	23(17.69)
Muscle and Tendon	45(39.82)	8(11.94)	36(27.69)
Contusions, lacerations and skin lesions	7(6.19)	3(4.48)	4(3.08)
Missing	14	-	-
KNEE	34(13.77)	10(14.93)	14(10.53)
Joint(non-bone) and ligament	17(62.96)	8(11.94)	7(5.26)
Muscle and Tendon	9(33.33)	2(2.99)	6(4.51)
Contusions, lacerations and skin lesions	1(3.70)	0	1(0.75)
Missing	7	-	-
ANKLE	30(12.15)	11(16.42)	14(10.53)
Fracture and Bone Stress	3(10.71)	2(2.99)	1(0.75)
Joint(non-bone) and ligament	24(85.71)	9(13.43)	12(9.02)
Muscle and Tendon	1(3.57)	0	1(0.75)
Missing	2	-	-

Table 4.3: Frequency, Type, and Player Position of Lower Extremity Injuries

	N (%)									
	ALL LOWER EXTREMITY (n=110)				**KNEE (n=26)**			**ANKLE (n=28)**		
Athlete Position	Fracture and Bone Stess	Joint(non-bone) and ligament	Muscle and Tendon	Contusions, lacerations and skin lesions	Joint(non-bone) and ligament	Muscle and Tendon	Contusions, lacerations and skin lesions	Joint(non-bone) and ligament	Muscle and Tendon	Contusions, lacerations and skin lesions
Defensive Back	-	3(1.41)	5(4.55)	-	-	-	-	3(10.71)	-	-
Defensive Line	-	10(9.09)	3(2.73)	1(0.91)	6(23.08)	-	-	2(7.14)	-	-
Defensive Line: Def-end	1(0.91)	1(0.91)	-	-				-	-	-
Defensive Sec	1(0.91)	2(1.82)	4(3.64)	-	2(7.69)	-	-	-	1(3.57)	1(3.57)
Linebacker	1(0.91)	4(3.64)	4(3.64)	-	3(11.54)	-	-	1(3.57)	-	-
Offensive Line	3(2.73)	9(8.18)	-	2(1.82)	2(7.69)	-	1(3.85)	5(17.86)	-	1(3.57)
Quarterback	-	3(2.73)	2(1.82)	-	-	-	-	1(3.57)	-	-
Running back	-	1(0.91)	2(1.82)	-	1(3.85)	1(3.85)	-	-	-	-
Safety	-	1(0.91)	2(1.82)	1(0.91)				1(3.57)	-	-
Special Teams	1(0.91)	-	1(0.91)	-				-	-	1(3.57)
Tight End	1(0.91)	6(5.45)	5(4.55)	-	-	2(7.69)	-	5(17.86)	-	-
Wide Reciever	-	2(1.82)	5(4.55)	1(0.91)	1(3.85)	-	-	-	-	-
Unknown	-	10(9.09)	10(9.09)	2(1.82)	2(7.69)	5(19.23)	-	6(21.43)	-	-
Totals	7(6.36)	8(7.27)	52(47.27)	43(39.09)	17(65.38)	8(30.77)	1(3.85)	24(85.71)	1(3.57)	3(10.71)

Table 4.4: Distributions of Field Surface and Condition for All Lower Extremity Injuries, Knee Injuries, and Ankle Injuries (unit of analysis=one injured athlete)

	All Lower Extremity Injuries	Knee Injury	Ankle Injury
Total	127	34	30
Field Surface			
Artificial	74(60.16)	19(55.88)	17(58.62)
Natural	39(31.71)	12(35.29)	10(34.48)
Other	10(8.13)	3(8.82)	3(6.90)
Fiend Condition			
Not Normal	20(21.74)	8(36.36)	3(11.54)
Normal	72(78.26)	14(63.64)	23(88.46)

Table 4.5: Distributions of Number of Cleats, Top Height, and Length of Cleats for All Lower Extremity Injuries, Knee Injuries, and Ankle Injuries (unit of analysis=one injured athlete)

	All Lower Extremity Injuries	Knee Injury	Ankle Injury
Total	98	26	20
Missing	29	8	9
Number of Cleats			
7	18(18.37)	4(15.38)	6(30.00)
9-12	45(45.92)	14(53.85)	9(45.00)
>12	34(34.69)	8(30.77)	5(25.00)
no cleats	1(1.02)	0	0
Height of Top			
High	54(55.10)	16(61.54)	12(60.00)
Low	44(44.90)	10(38.46)	8(40.00)
Cleat Length			
Short	92(93.88)	25(96.15)	19(95.00)
Long	6(6.12)	1(3.85)	1(5.00)

Table 4.6: Distributions of Team Activity

	Person-Sessions	**Sessions**	**Frequency (%)**
Total	38,934	312	
Practice	28,273	227	72.76
Game	4,324	35	11.22
Other	6,337	50	16.03

Table 4.7: Distributions of Playing Surface and Surface Condition

	Total			***Game***			***Practice***		
	Person-Sessions	**Sessions**	**Frequency (%)**	**Person-Sessions**	**Sessions**	**Frequency (%)**	**Person-Sessions**	**Sessions**	**Frequency (%)**
Total	38934	312	-	2388	35	-	28273	227	-
Field Surface									
Artificial	22670	181	60.74	1805	14	43.98	15576	126	56.73
Natural	13247	106	35.5	2299	19	56.02	10478	83	38.16
Other	1402	11	3.69	220	-	-	1402	11	5.11
Missing	1615	14	-	-	2	-	817	7	-
Surface Condition									
Normal	27485	221	89.11	1739	14	72.82	21040	170	88.05
Not Normal	3504	27	10.89	649	5	27.18	2855	22	11.95
Missing	7945	64	-	-	16	-	4378	35	-

Table 4.8: Distributions of Number of Cleats, Top Height, and Length of Cleats for All Athlete Exposures (unit of analysis=1 session of activity)

	Total	**Game**	**Practice**
Total	38934	4324	18273
Missing	8927	281	2309
Number of Cleats			
7	6621(22.06)	923(22.83)	5698(21.95)
9-12	12938(43.12)	1821(45.04)	11117(42.82)
>12	9461(31.35)	1202(29.73)	8259(31.81)
No cleats	987(3.29)	97(2.40)	890(3.43)
Top Height			
High	17979(59.92)	2418(59.81)	15561(59.93)
Low	12028(40.08)	1625(40.19)	10403(40.07)
Length of Cleat			
Short	27815(92.70)	3747(92.68)	24068(92.70)
Long	2192(7.30)	296(7.32)	1896(7.30)

Table 4.9: Estimates for Condition and Lower Extremity Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Condition	4.67	0.0307	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-5.9426	0.1242	<.0001
Not normal vs. Normal	0.7821	0.2686	0.0036

Table 4.10: Estimates for Condition and Ankle Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Condition	5.00	0.0253	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-1.6007	0.2443	<.0001
Not normal vs. Normal	-1.1293	0.6242	0.0704

Table 4.11: Estimates for Team Activity, Surface, and Lower Extremity Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Team Activity	9.79	0.0018	
Surface	4.77	0.029	
Team Activity*Surface	5.51	0.0189	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-5.9969	0.2292	<.0001
Game vs. Practice	0.8269	0.3813	0.0301
Artificial vs. Natural	-0.071	0.286	0.804
Game and Artificial vs. Game and Natural vs. Practice and Artificial vs. Practice and Natural	1.126	0.4669	0.0159

Table 4.12: Estimates for Game, Surface, and Lower Extremity Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Surface	0.06	0.8058	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-5.997	0.2292	<.0001
Artificial vs. Natural	-0.071	0.2861	0.8039

Table 4.13: Estimates for Practice, Condition, and Lower Extremity Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Condition	2.82	0.093	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-6.1022	0.1567	<.0001
Not normal vs. Normal	0.7148	0.3335	0.321

CHAPTER 5

DISCUSSION

The purpose of this study was to investigate the effect of the specific extrinsic factors, including playing surface, field condition, and shoe type (measured by number of cleats on the shoe, height of the shoe opening, and length of the cleat) on lower extremity injuries (e.g. all lower extremity injuries and specifically knee or ankle injuries) in collegiate football players at The University of Iowa from the 2008 to 2010 seasons. The results showed that field condition (normal vs. not-normal) was the only significant predictor for all lower extremity injuries and ankle injuries specifically, in the unadjusted GLM models at an α=0.05 significance level. When the predictor variables were adjusted for team activity (i.e., games and practices) only the playing surface model was significant for all terms, including team activity, surface, and the interaction term. This model was further analyzed for practice and games separately, and it was found that surface was significant in predicting lower extremity injuries in a game setting. For the condition, number of cleats, and the top height models, only the team activity term was found significant. When these models were further analyzed for practice and games separately, only field condition was found to be significant in a practice setting. The cleat length model was not found to be significant when adjusting for team activity.

5.1 Injury Discussion

Over half of all injuries (54%) acquired in this study were of the lower extremity region, which is consistent to the findings of Fuller et al. (2007) in their study of soccer players. Also consistent, most lower extremity injuries, specifically knee and ankleinjuries, were of the joint (non-bone)/ligament/cartilage type (47% for all lower extremity, 63% for knee, and 86% for ankle). The frequency of ligament injuries of the knee was slightly less (6.8%) than the 10% found by Pritchett (1982) as the most common injury in high school football players. However, this study found that about 10% of all injuries were ligament injuries to the ankle instead of the knee. Knee and ankle injuries accounted for about 26% of all injuries, which is more than the 20% the National Football League reports (Powell & Schootman, 1992).

Most lower extremity injuries (54%) occurred in the practice setting. However, the most frequent lower extremity injury in a practice setting was of the muscle or tendon type (28%). In contrast, most game related lower extremity injuries were of the joint (non-bone)/ligament/cartilage type (35% of all game injuries), suggesting that lower extremity injuries sustained in a game setting may be more severe than in a practice setting.

Although more lower extremity injuries occurred on artificial surfaces (60% for all lower extremity, 56% for knee, and 58% for ankle) compared to natural surfaces (32% for all lower extremity, 35% for knee, and 34% for ankle), there was no significant difference between the two types of surface in the unadjusted GLM analysis. This finding is supported by the Fuller et al. (2010) study, which examined rugby players on the two surfaces and found there was no significant difference in the risk of injuries on artificial turf compared to natural grass. However, as seen, the most common body location injured was the lower limb, and the most common type of injury was a joint. In addition, the lack of a significant difference in lower extremity injuries due to the type of surface is consistent with the findings of another study examining elite soccer players on third-generation artificial turf (Ekstrand, Timpka, & Hagglund, 2006). It is interesting to consider that even though about 64% of the Big 10 Conference fields use artificial turf, 56% of the games in this study occurred on natural surfaces. The Big 10 Conference rotates which teams play each other because there are 12 teams in the Big 10 Conference, but only 10 games are played a year. For the three seasons studied, it may be the case that The University of Iowa had a rotation where they played more teams with natural surfaces compared to artificial surfaces, since their home field is artificial turf.

5.2 Unadjusted GLM Discussion

The only significant result in the unadjusted GLM was the surface condition (not normal vs. normal) for lower extremity injuries and ankle injuries. The risk of injury was increased for not normal conditions by a factor of 2.186 for all lower extremity injuries, and decreased for ankle injuries by a factor of 0.3233. This may indeed be the case that ankle injuries are more common in normal conditions and lower extremity injuries are more common in not normal conditions because in a normal condition, the ankle might receive all of the forces from the ground, resulting in an injury. In a not normal condition, the athlete might slip or trip on the ground, resulting in the ground forces being transferred further up the leg producing a lower extremity injury. Even though condition was not found to be significant for the knee in the GLM analysis, it would have to have a positive trend for increasing the likelihood of knee injuries in not normal field conditions since there was a positive trend in all lower extremity injuries, which contains both knee and ankle injuries, and a negative trend in ankle injuries.

There are very few studies that focus on the influence of weather and field condition on athlete injuries, but the significant results of this study implies that more studies need to be conducted on this subject. Not normal conditions included wet and extremely dry fields, which may have differed in comparing results to other field condition studies. Several studies that looked at other sports with similar running, cutting, and contact maneuvers to American football found that knee and ankle injuries are more likely when the ground surface is warmer, drier, and harder, which would have been classified in the not normal condition (Orchard J. W., 2002; Orchard & Powell, 2003). However, there may be discrepancies since most studies examined wet vs. dry conditions.

In contrast to Torg et al. (1971) and Bonstingl, Morehouse, & Niebel (1975) this study could not confirm that either 6 to 10 cleats or 13 to 17 cleats created fewer injuries in football. There was not enough injury data to create a statistical model for the effect for any of the four categories of the number of cleats on a shoe (7, 9-12, >12, or no cleats). In addition, Lambson, Barnhill, & Higgins (1996) found that longer cleats may be associated with more ACL injuries, but again this study cannot confirm these results because the length of cleat (short vs. long) was not significant in the unadjusted GLM analysis.

5.3 Adjusted GLM Discussion

The adjusted analysis for surface, condition, number of cleats, and cleat length found that team activity (practice vs. game) was significant when predicting lower extremity injuries. This may suggest that players are more physical and more willing to take risks to win in a game setting compared to a practice setting. In addition, during games, players are playing against other universities and face players with whom they have fewer interpersonal ties and loyalties compared to the teammates they face in a practice setting. Players may be more aggressive and more willing to risk injuring a player from the opposing team in a game than they may be with a player of their own team in practice. However, when condition was analyzed further for practice and games independently, it was found that condition was significant only in a practice setting. For all lower extremity injuries, the odds of having a lower extremity injury in a not normal condition in a practice setting is 2.04 times more likely than in a normal condition. This result is consistent with the results in the unadjusted analysis. However, such relationship was not observed in a game setting. Further studies are needed to understand why the effects of the condition on lower extremity injuries differ in game and practice settings.

The only model significant for all terms, including team activity and the interaction term, was the playing surface model. When this model was analyzed separately for games and practices, it was found that the odds of having a lower extremity injury on an artificial surface in a game setting was about 3 times more likely than on a natural surface. This is consistent with Hagel et al. (2003) study which compared an artificial surface to natural grass in game competitions for Canadian footballers, which found that the rate of lower extremity injuries were higher on artificial turf than natural grass. In addition, this result is consistent with the survey conducted by the NFL where 1,400 active players expressed their desire to make all NFL stadiums natural surfaces because they felt that natural surfaces were safer for their bodies compared to artificial surfaces (NFLPlayers.com, 2008). However, the relationship between playing surface and lower extremity injuries was not statistically significant in a practice setting.

5.4 Strengths

This study was successful on several levels. First, this study used real player data to explore lower extremity injuries in collegiate football players. Unlike many of the current studies in the literature review, this study used real player data, in both a practice and game setting, to evaluate a variety of cleat types instead of using a prosthetic foot or having a simulated, controlled environment. In addition, the statistic models in this study accounted for correlation of multiple injuries sustained by one athlete and controlled for the passage of time, which means that injury events that occur chronologically closer in time are assumed to be more highly correlated than events that occur further apart in time. This study had both injury and activity data, which allowed for frequencies and exposure results. Finally, this study was able to conduct analysis on multiple extrinsic risk factors, including both field condition and shoe type, and their impact on lower extremity injuries.

5.5 Limitations

This study presented several limitations. First and foremost, the number of lower extremity injuries recorded was very low compared to the number of sessions the players played in for three seasons. This may have hindered results because of the very few cases used in the unadjusted and adjusted GLM analyses, especially when looking only at knee or ankle injuries. It is suspected that the number of lower extremity injuries, specifically ankle and knee injuries, was under reported. Injuries were probably only reported if a significant injury occurred, not just a simple knee or ankle sprain that did not require the athlete to be out of full participation, which is very common among running and jumping sports. Recording injury information is time consuming, especially when the injury form asked for many specific details about the injury. The athletic trainers who recorded the injury information may not have documented all the variables needed for this study, which may have contributed to the lack of lower extremity injuries and other missing data entries. In addition, since the data was obtained by outside sources, there was missing player information for the shoe type warn, surface played on, and surface condition that could not be attributed for. Therefore, when conducting the GLM analysis, missing information was essentially thrown out of the dataset. If an injury occurred for one of the missing data factors, the injury was not included in the analysis.

Using real player data presented its own set of limitations because the data was not collected in a controlled environment, with other variables held constant. Players could have easily switched the type of shoe they were using in the middle of the season, which would have not been recorded if an injury did occur since shoe data was obtained at the beginning of each season. Also, this study focused on the players on The University of Iowa football team, which may not be generalizable to other college football teams, high school players, or National Football League players.

5.6 Future Studies

The knowledge obtained from this study may be useful in helping reduce injury rates and directing future research. There have been very few studies conducted on multiple extrinsic risk factors in American football, especially focusing on the effects on lower extremity injuries and the types of shoes warn. Although no significant differences were found for the three shoe variables, future studies can build upon the methods presented in this study. It is important for future studies using real player data to have a large injury dataset to work with. Much of the analysis for this thesis could not be performed because of the lack of lower extremity injuries in the dataset, which in turn, reduced the capabilities of the statistical model to converge for analysis. Potential study designs may consider using more than one university for data collection, or if data is available, choosing multiple seasons with a high injury rate, in addition to different athletes, as opposed to consecutive seasons, where a lot of the players are the same. In addition, this study had a retrospective design. Future studies may aim to use a prospective study design.

Many of the variables in this study were reduced to one or two categories, such as normal vs. not normal field condition and artificial vs. natural playing surfaces, due to the limitations in the data. Future studies may consider using more specific categories, such as FieldTurf vs. DurfaTurf and the different types of natural surfaces for a more detailed and generalizable results, if the data is available.

Especially for analyzing shoe variables, during data collection future studies should frequently record what shoes the athletes are wearing, in case athletes change shoes during the season. Also, specific information about the shoes, such as the number of cleats, height of the shoe opening, and the length of the cleat can be reported on the spot instead of having to research later using product information. In addition, potential data collectors should make sure minor injuries are recorded, especially for knee and ankle injuries. It was suspected that knee and ankle injuries went under recorded in this study, specifically if an athlete did not have to undergo much treatment with the athletic trainers. This may mean having a researcher record the injuries instead of an athletic trainer.

Future studies may consider reporting the rate of injuries instead of the odds of lower extremity injuries. Injury rate analysis provides a more direct estimate of lower extremity injuries, and can also be analyzed for the rate of games and/or practices injuries separately.

5.7 Conclusions

The results of this analysis provide a foundation for future studies to understand why field condition, in terms of playing surface and surface condition, may be associated with lower extremity injuries. As seen by this study, the risk of having an ankle injury is greater for a normal condition compared to a not normal condition. This may indicate that athletic trainers need to look to other means to protect their players from ankle injuries besides changing the type of shoe warn, since none of the shoe variables were found significant in this study. In addition, this study found that players are more susceptible to having a lower extremity injury on an artificial surface in a game setting compared to a natural surface. The University of Iowa recently installed the third generation FieldTurf into Kinnick Stadium in 2009, but the results of this study suggests to change to a natural surface to reduce the risk of lower extremity injuries. The cost of maintaining a natural surface is more than the cost of having an artificial surface, however, players will be less prone to lower extremity injuries.

There are limitless study designs to conduct future analysis for how several extrinsic risks factors can contribute to the number of lower extremity injuries in

American football at all competition levels. As more studies are conducted, researchers can begin to understand how field condition, playing surface, and shoe variables interact with each other, and researchers can begin to design equipment and better playing surfaces to reduce lower extremity injuries, specifically knee and ankle injuries, in American football.

APPENDIX A: A FULL LIST OF INITIAL VARIABLES AND INITIAL CODING

Table A.1: A Full List of Initial Variables and Initial Coding

VARIABLE NAME	DEFINITION	CODING
Dependant Variables		
Inj_type	Type of injury	Categorical
		1=Fractures and bone stress
		11=Fractures
		12=Stress Fractures
		13=Other Bone Injuries
		2=Joint(non-bone) and ligament
		21=Dilocation/subluxation
		22=Sprain/ligament injury
		23=Lesion of meniscus or cartilage
		24=Other Joint injuries
		3=Muscle and Tendon
		31=Muscle rupture/tear/strain/cramps
		32=Tendon injury/repture/tendonosis/bursitis
		4=Contusions, lacerations and skin lesions
		41=Hematoma, contusion, bruise
		42=Abrasion
		43=Laceration
		5=Central/peripheral nervous system
		51=Concussion
		52=Nerve Injury
		53=Other
		6=Dental Injuries
		7=Other

Table A.1—continued

Inj_body	Area of injury	Categorical
		1=Head/neck
		11=Head/face
		12=Neck/cervical spine
		2=Upper Exremity
		21=Shoulder/clavicle
		22=Upper arm
		23=Elbow
		24=Forearm
		25=Wrist
		26=Hand/finger/thumb
		3=Trunk
		31=Sternum/ribs/upper back
		32=Abdomen
		33=Lower back/sacrum/pelvis
		4=Lower Extremity
		41=Hip/Groin
		42=Upper leg (thigh)
		43=Knee
		44=Lower leg/Achilles tendon
		45=Ankle
		46=Foot/toe
		5=Systems/Illness
		51=Cardiovascular
		52=Respiratory
		53=Endocrine
		54=More
		55=Other
Independent Variables		
ACT_DATE	The day the injury occurred	Time
TYPE	If injury occurred during practice or game	Categorical
		PR=practice
		GM=game
		CN=conditioning
TEMPERATUR	The actual temperature outside when the injury occurred	Continuous

Table A.1—continued

HUMIDITY	The humidity index outside when the injury occurred	Continuous
WIND	The wind level when the injury occurred	Categorical
		H=high
		L=low
		NA-not applicable
LIGHTNING	Whether or not there was lightning present when the injury occurred	Categorical
		y=yes
		n=no
		NA-not applicable
HEAT INDEX	What the temperature outside felt like when the injury occurred	Continuous
TMACTIVITY	The specific type of activity the athlete was participating in when the injury occurred	Categorical
		RP=regular practice
		S=scrimmage
		WT=walk through
		G=game
		LP=light practice
		C=conditioning
		W=weight training
		VC=varsity competition
ACTSURFACE	The specific surface the injury occurred on	Categorical
		1=ARTIFICIAL SURFACES: Field Turf-Outside
		2=ARTIFICIAL SURFACES: FieldTurf-Indoor
		3=ARTIFICIAL SURFACES: Sports Grass
		4=NATURAL SURFACES: Grass
		5=Practice Fields
		6=Grass
		7=Dura-Turf - New
		8=NATURAL SURFACES: P.A.T.
		9=Practice Fields: Grass and Turf
		10=Field Turf-Bubble
		11=ARTIFICIAL SURFACES

Table A.1—continued

SURF_COND	The surface condition of ground when the injury occured	Categorical
		1=Hot and Humid
		2=NORMAL
		3=NORMAL: Calm
		4=Wet
		5=ABNORMAL
		6=Dry
		7=DOME/INDOOR FIELD: Normal
		8=unknown
GSHOE_TYPE	Type of primary game shoe worn	Categorical
		Shoes(Low)Multiclt
		Shoes(Hi)Multiclt
		Shoes(Hi)Soccer 16-30 Clt
		Shoes(Low)Soccer Clt
		Unspecified
GSHOE_BRND	Brand of primary game shoe worn	Constant
		NIKE

Table A.1—continued

GSHOE_MODL	Model of primary game shoe worn	Categorical
		Air Zoom Assassin
		Air Zoom Barracuda
		Air Zoom Blade Pro D
		Air Zoom Boss D
		Air Zoom Boss D
		Air Zoom Boss Shark 3/4
		Air Zoom Merciless TD
		Air Zoom Super Bad
		Blade II D
		Blade II TD
		Blade III Shark
		Nike Air Legend
		Nike Air Zoom Vapor Jet 4
		Nike Merciess Shark
		Nike Speed Low
		Nike Super Speed D 3/4
		Nike Zoom Merciless D
		Nike Zoom Mercless TD
		Speed TD
		Speed TD 3/4
		Speed TD Low
		Super Speed D 3/4
		Super Speed D Low
		Super Speed D 3/4
		Super Speed D Low
		Super Speed Mid
		Total 90
		Vapor Jet TD
		Zoom Merciless D
PSHOE_TYPE	Type of primary practice shoe worn	Categorical
		Shoes(Hi)Multiclt
		Shoes(Low)Multiclt
		Shoes(Low)Soccer Clt
PSHOE_BRND	Brand of primary practice shoe worn	Constant
		NIKE

Table A.1—continued

PSHOE_MODL	Model of primary practice shoe worn	Categorical
		Zoom Merciless D
		Vapor Jet TD
		Total 90
		Super Speed TD 3/4
		Super Speed Mid
		Super Speed D Low
		Super Speed D 3/4
		Speed TD Low
		Speed TD 3/4
		Speed TD
		Nike Zoom Merciless TD
		Nike Super Speed D 3/4
		Nike Speed TD
		Nike Merciless Shark
		Nike Air Zoom Vapor Jet 4
		Nike Air LT 2.1 Shark
		Nike Air Legend
		Blade III Shark
		Blade II TD
		Blade II D
		Air Zoom Super Bad
		Air Zoom Merciless TD
		Air Zoom Boss Shark 3/4
		Air Zoom Boss D
		Air Zoom Blade Pro TD
		Air Zoom Blade Pro D
		Air Zoom Barracuda
		Air Zoom Assassin
ATH_POSIT	The position the athlete was taking when the injury occurred	Categorical
		Wide Receiver
		TIGHT END
		SPECIAL TEAMS
		RUNNING BACK: RB-Fullback
		QUARTERBACK
		OFFENSIVE LINE: OFF-Tackle
		LINEBACKER: LB-Mid Linebacker
		LINEBACKER
		DEFENSIVE SEC
		DEFENSIVE LINE: DEF-Tackle
		Defensive Back

Table A.1—continued

MECHANISM	Type of force used to cause injury	Categorical
		VARUS STRESS
		Valgus Stress
		Strain
		SHEAR
		ROTATION TRANSLATION
		ROTATION
		Repetitive stress/loading
		overuse injury
		NOT APPLICABLE
		MULTIPLE FACTORS
		LINEAR TRANSLATION: LINEAR-A/P Distrctn
		LINEAR TRANSLATION
		INVERSION
		Intrinsic - stress
		HYPEREXTENSION
		GENREAL STRESS
		HYPERFLEXION
		Flexion/Extension
		FLEXION: FLX-Compression
		EXTENSION
		Eversion: Rotation
		Eversion
		Distraction
		DIRECT FORCE
		Decelleration
		COMPRESSION/DISTRACT
		Compression
		ADDUCTION: ADD-Distraction
		Acceleration
		ABDUCTION
Other Variables		
REINJURY	Whether or not the injury was from a previous injury	Categorical
		0=FALSE
		1=TRUE
		3=not specified
SURGERYREQ	Whether or not the injury required a surgery for repair	Categorical
		0=FALSE
		1=TRUE
		3=not specified

Table A.1—continued

PROBLEM	Designated as "problem" as opposed to full-blown "injury"	Categorical
		0=FALSE
		1=TRUE
		2=Unknown
TMRELATED	Designated as having occurred as the result of a team-related activity	Categorical
		0=FALSE
		1=TRUE
		2=Unknown
ONSET	Date the injury occurred	Date
RETURN	Date the player returned to play	Date
PLAYING DAYS MISSED	Number of days the player missed because of injury	Numeric
GMISSED	Number of games missed because of injury	Numeric
PMISSED	Number of practices missed because of injury	Numeric

APPENDIX B: SUMMARY TABLES FOR THE NON-SIGNIFICANT UNADJUSTED GLM MODELS

Table B.1: Unadjusted Estimates for Surface and Lower Extremity Injuries

Parameter	Chi-Square	Pr > Chi-Square	
Surface	3.36	0.1865	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-5.7218	0.1273	<.0001
Artificial vs. Natural	-0.104	0.2152	0.6289
Artificial vs. Other	0.7853	0.3299	0.0173

Table B.2: Unadjusted Estimates for Height of Top and Lower Extremity Injuries

Parameter	Chi-Square	Pr > Chi-Square	
Height of Top	0.72	0.3957	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-5.6073	0.1711	<.0001
High Top vs. Low Top	-0.1978	0.2273	0.3842

Table B.3: Unadjusted Estimates for Number of Cleats and Lower Extremity Injuries

Parameter	Chi-Square	Pr > Chi-Square	
Number of Cleats	5.33	0.1494	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-6.8938	0.8023	<.0001
7 Cleats vs. No Cleats	0.9887	0.8507	0.2451
9-12 Cleats vs. No Cleats	1.2359	0.8187	0.1312
>12 Cleats vs. No Cleats	1.2687	0.8221	0.1228

Table B.4: Unadjusted Estimates for Length of Cleat and Lower Extremity Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Length of Cleat	0.15	0.6971	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-5.7084	0.01138	<.0001
Long vs. Short Cleat	-0.1898	0.5191	0.7147

Table B.5: Unadjusted Estimates for Condition and Knee Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Condition	0.97	0.3246	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-2.1567	0.2575	<.0001
Not normal vs. Normal	0.5226	0.4731	0.2693

Table B.6: Unadjusted Estimates for Height of Top and Knee Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Height of Top	0.24	0.6233	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-1.9879	0.3332	<.0001
High Top vs. Low Top	0.2172	0.4424	0.6235

Table B.7: Unadjusted Estimates for Length of Cleat and Knee Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Length of Cleat	0.19	0.6615	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-1.8437	0.2276	<.0001
Long vs. Short Cleat	-0.3535	0.9176	0.7000

Table B.8: Unadjusted Estimates for Height of Top and Ankle Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Height of Top	0.06	0.8004	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-2.238	0.3672	<.0001
High Top vs. Low Top	0.1178	0.4701	0.8022

Table B.9: Unadjusted Estimates for Length of Cleat and Ankle Injuries

Parameter	**Chi-Square**	**Pr > Chi-Square**	
Length of Cleat	0	0.9794	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-2.1675	0.2343	<.0001
Long vs. Short Cleat	-0.0297	1.1571	0.9795

APPENDIX C: SUMMARY TABLES FOR THE NON-SIGNIFICANT ADJUSTED GLM MODELS

Table C.1: Adjusted Estimates for Game, Surface, and Lower Extremity Injuries

<table>
<tr><th>Parameter</th><th>Chi-Square</th><th>Pr > Chi-Square</th><th></th></tr>
<tr><td>Surface</td><td>0.06</td><td>0.8058</td><td></td></tr>
<tr><td></td><td>Estimate</td><td>Standard Error</td><td>Z Pr > |Z|</td></tr>
<tr><td>Intercept</td><td>-5.997</td><td>0.2292</td><td><.0001</td></tr>
<tr><td>Artificial vs. Natural</td><td>-0.071</td><td>0.2861</td><td>0.8039</td></tr>
</table>

Table C.2: Adjusted Estimates for Team Activity, Condition, and Lower Extremity Injuries

<table>
<tr><th>Parameter</th><th>Chi-Square</th><th>Pr > Chi-Square</th><th></th></tr>
<tr><td>Team Activity</td><td>6</td><td>0.0143</td><td></td></tr>
<tr><td>Condition</td><td>1.22</td><td>0.2693</td><td></td></tr>
<tr><td>Team Activity*Condition</td><td>2.08</td><td>0.1497</td><td></td></tr>
<tr><td></td><td>Estimate</td><td>Standard Error</td><td>Z Pr > |Z|</td></tr>
<tr><td>Intercept</td><td>-6.1021</td><td>0.1567</td><td><.0001</td></tr>
<tr><td>Game vs. Practice</td><td>1.5962</td><td>0.2902</td><td><.0001</td></tr>
<tr><td>Not normal vs. Normal</td><td>0.7147</td><td>0.3335</td><td>0.0321</td></tr>
<tr><td>Game and Not normal vs Game and Normal vs. Practice and Not normal vs. Practice and Normal</td><td>-0.7277</td><td>0.4892</td><td>0.1369</td></tr>
</table>

Table C.3: Adjusted Estimates for Game, Condition, and Lower Extremity Injuries

<table>
<tr><th>Parameter</th><th>Chi-Square</th><th>Pr > Chi-Square</th><th></th></tr>
<tr><td>Condition</td><td>0</td><td>0.9879</td><td></td></tr>
<tr><td></td><td>Estimate</td><td>Standard Error</td><td>Z Pr > |Z|</td></tr>
<tr><td>Intercept</td><td>-4.569</td><td>0.2407</td><td><.0001</td></tr>
<tr><td>Not normal vs. Normal</td><td>-0.0062</td><td>0.4057</td><td>0.9879</td></tr>
</table>

Table C.4: Adjusted Estimates for Team Activity, Top Height, and Lower Extremity Injuries

<table>
<tr><th>Parameter</th><th>Chi-Square</th><th>Pr > Chi-Square</th><th></th></tr>
<tr><td>Team Activity</td><td>17.28</td><td><.0001</td><td></td></tr>
<tr><td>Top Height</td><td>0.92</td><td>0.3366</td><td></td></tr>
<tr><td>Team Activity*Top Height</td><td>0.63</td><td>0.4258</td><td></td></tr>
<tr><td></td><td>Estimate</td><td>Standard Error</td><td>Z Pr > |Z|</td></tr>
<tr><td>Intercept</td><td>-6.0699</td><td>0.2057</td><td><.0001</td></tr>
<tr><td>Game vs. Practice</td><td>1.6845</td><td>0.3191</td><td><.0001</td></tr>
<tr><td>High Top vs. Low Top</td><td>-0.0544</td><td>0.2786</td><td>0.8453</td></tr>
<tr><td>Game and High Top vs. Game and Low Top vs. Practice and High Top vs. Practice and Low Top</td><td>-0.3472</td><td>0.4301</td><td>0.4195</td></tr>
</table>

Table C.5: Adjusted Estimates for Practice, Top Height, and Lower Extremity Injuries

<table>
<tr><th>Parameter</th><th>Chi-Square</th><th>Pr > Chi-Square</th><th></th></tr>
<tr><td>Top Height</td><td>0.04</td><td>0.8456</td><td></td></tr>
<tr><td></td><td>Estimate</td><td>Standard Error</td><td>Z Pr > |Z|</td></tr>
<tr><td>Intercept</td><td>-6.0699</td><td>0.2057</td><td><.0001</td></tr>
<tr><td>High Top vs. Low Top</td><td>-0.0544</td><td>0.2786</td><td>0.8451</td></tr>
</table>

Table C.6: Adjusted Estimates for Game, Top Height, and Lower Extremity Injuries

Parameter	Chi-Square	Pr > Chi-Square	
Top Height	1.18	0.2779	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-4.3881	0.2622	<.0001
High Top vs. Low Top	-0.4004	0.3473	0.2491

Table C.7: Adjusted Estimates for Team Activity, Number of Cleats, and Lower Extremity Injuries

Parameter	Chi-Square	Pr > Chi-Square
Team Activity	8.38	0.0038
Number of Cleats	1.06	0.5897
Team Activity*Number of Cleats	1.59	0.4507

Table C.8: Adjusted Estimates for Team Activity, Cleat Length, and Lower Extremity Injuries

Parameter	Chi-Square	Pr > Chi-Square	
Team Activity	0.9	0.3415	
Cleat Length	0.19	0.6665	
Team Activity*Cleat Length	0.19	0.6604	
	Estimate	**Standard Error**	**Z Pr > |Z|**
Intercept	-6.0977	0.1464	<.0001
Game vs. Practice	1.5165	0.2259	<.0001
Long vs. Short	-0.0616	0.4416	0.889
Game and Long vs Game and Short vs. Practice and Long vs. Practice and Short	-0.348	0.9023	0.6997

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