The Effect of 3G Artificial Turf and Natural Grass on Knee Injuries in High School Football

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Abstract

The number of knee injuries per player exposure in boy's high school football was analyzed in comparison to the percentage of 3G(third generation) turf in a sample study of high schools across the United States in order to test the hypothesis that there is an increase of knee injuries on artificial playing surfaces. From the 2006-2007 season to the 2016-2017 season, the number of knee injuries per game and practice exposure was calculated using the data from the high school RIO data available on the University of Colorado Denver's school of public health's website. The correlation between the number of injuries per game exposure as well as practice exposure both proved to disprove the hypothesis. In both practice and games, the artificial playing surfaces resulted in safer playing conditions.

Introduction

Countless high schools across the United States participate in American Football as a school sponsored sport. With player safety being a large concern and an average of 600,000 injuries in all contact sports every year, there has been a large push for safety reform in high school football. Major areas of reform have been the rules regarding illegal

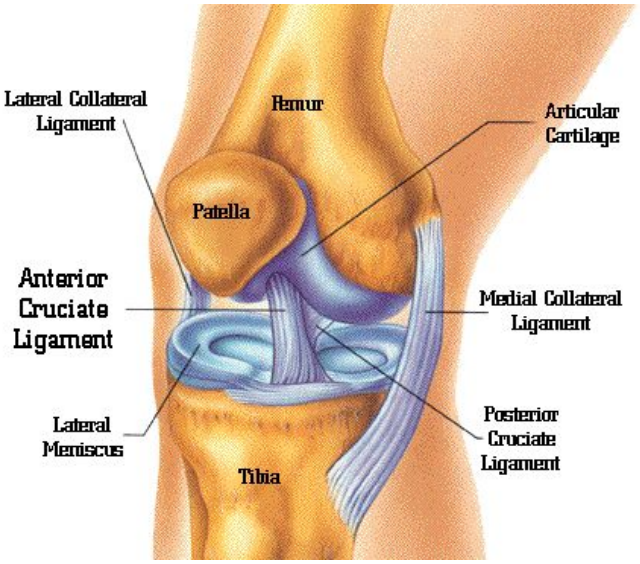


Figure 1: Anatomical diagram of the knee.

hits to the head, as well as an advanced and rigid concussion protocol. Further, new training regimes to prevent non contact knee injuries. With an increase of study on the mechanisms causing knee injuries in football, one important factor to be considered is the playing surface. The most common surfaces for football in United States high schools are natural grass and artificial turf surfaces.

The main difference between natural grass and third generation artificial turf (3G) is the fact that one is completely artificial. A natural grass field is any playing field that is either sod or grass, most commonly bermudagrass and kentucky bluegrass which are, in essence, the same. It is because of the similarity between the many types of natural grass that all natural playing surfaces in this study will be considered the same. Both of these surfaces require maintenance in the form of cutting and or trimming, as well as watering and aeration in some cases. As shown on their website FieldTurf, a prominent turf provider in the NFL, states that the average cost per hour of use for a natural grass field is $91.20 where a FieldTurf field sits at $25.07. This difference in cost is calculated taking in variables such as cost of installation, materials necessary, and maintenance. The cost is then divided by how many hours the field can operate for a ten year span. The FieldTurf field, like all other artificial

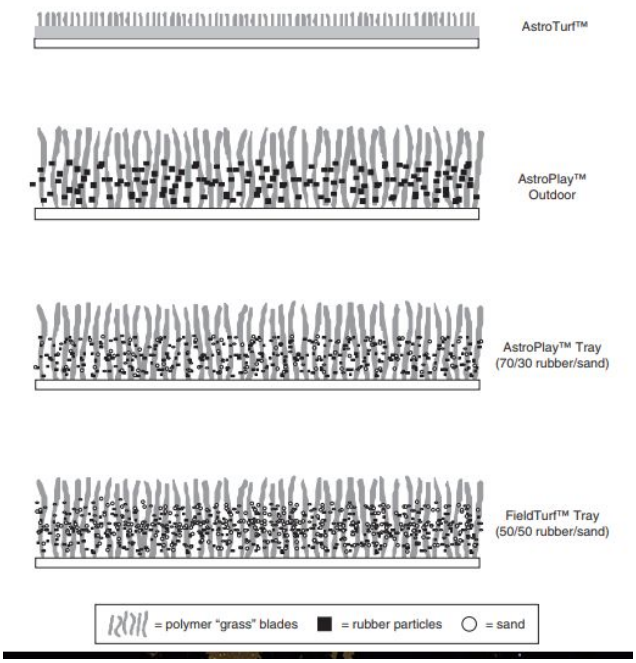


Figure 2: Multiple types of artificial turf with emphasis on the lower three 3G turf fields with a "fill"(Glen A. Livesay, 2006).

surfaces, does not have to be closed for parts of the year to let the grass recover from a season of play, but can be scheduled for use practically year round.

3G turf is composed of synthetic 'blades' of grass that are made from a nylon or polypropylene material that is cut into the desired shape (Pavilonis et al, 2014). All synthetic nylon is non biodegradable, meaning it will persist indefinitely in the environment. Where the material is not the most environmentally stable choice, both nylon and polypropylene are synthetic polymers made with relative ease, but polypropylene is not made to absorb water (Pavilonis et al, 2014). This makes it ideal for outdoor surfaces, such as turf. 3G turf is also an artificial playing surface that has a 'fill'. Fills consist, of tiny pieces of crushed car tires, that provides a cushion to the playing surface making it feel more similar to the feel of natural grass upon impact (Fleming, Forrester, 2014). Substantial research has been conducted on the health problems caused by the chemical composition of these tire particles. This paper, however, focuses on the injury rate on both surfaces to decide which is safer in terms of non contact knee injury. More recently, 3G fields have been made with an organic fill of coconut husk particles and cork. These coconut and cork fields as well as car tire fields will be considered to be 3G turf for this experiment.

The implementation of artificial turf fields began in the 1970's when the first National Football League teams began to play on artificial surfaces. In the years following, many safety issues have appeared regarding the safety of these fields to players. One issue was the belief that artificial surfaces led to a higher rate of injury to the knee in game scenarios. This belief resulted

in research on the friction, sometimes referred to as grip, on artificial surfaces vs natural grass. Several tests have been done including comparison of shoe interfaces between the two surfaces. Studies suggest ranges of traction, or grip, that are not excessive, but are also sufficient in allowing the player to complete all possible movements as to alleviate strain caused by excessive traction as well as eliminate the possibility of inadequate grip. This sufficient traction is also known as utilised traction (Torg et al, 1974). According to recent studies, the goal for an effective and safe shoe is in between the range of excessive and utilised traction (Glen A. Livesay et al, 2006). Further studies found that traction could be broken down into translational and rotational forces. Translational forces moved forward to backwards, where rotational traction, also known as torque, was a force that involved the pivoting of the shoe interface around a fixed point. This rotational traction is believed to contribute to a higher risk of injury. Further, it was proposed that the artificial surfaces, as well as the currently used third generation artificial turf surfaces (3G turf), result in a higher friction exposure to players than natural grass fields (Howard et al. 1996).

In Ariel V. Dowling's paper, *Shoe-Surface Friction Influences Movement Strategies During a Sidestep Cutting Task Implications for Anterior Cruciate Ligament Injury Risk*, she discusses the belief of increased shoe traction leading to an increased risk of Anterior Cruciate Ligament(ACL) injury. Using eleven male and eleven female human test subjects, her and her team set up and evaluated a thirty degree cutting motion using camera recording as well as pressure plate technology to find out if certain cutting motions contributed to an even higher increase of injury risk in the ACL. This increased risk of ACL injury is caused by changed

biomechanical movement caused by the increased friction between the surface and the shoe interface(2010). With this knowledge it can be decided that either of the two playing surfaces, either artificial turf or natural grass, with the higher friction with any shoe interface will be causing a greater risk of non contact injury to the ACL.

Additionally, there is an article written by Jason L. Dragoo titled, *The effect of playing surface on the incidence of ACL injuries in National Collegiate Athletic Association American Football*, that studied the amount of ACL injuries in football players of the NCAA(National Collegiate Athletic Association), from the 2004-2005 football season to the 2008-2009 season. Both practice and game scenarios were recorded. In their conclusion, it was found that per 10,000 players, there was 1.73 ACL injuries on artificial turf as opposed to 1.24 ACL injuries per 10,000 athletes when playing on natural grass. This is difference amounts for an increase 1.39 times higher on artificial turf.

Furthermore, 44.29% of ACL injuries on turf were non contact injuries where only 36.12% of ACL injuries on natural grass were non contact. This data allows for the conclusion that there is a greater risk of both non contact and contact ACL injuries on artificial turf as opposed to natural grass. In 1994, *The*

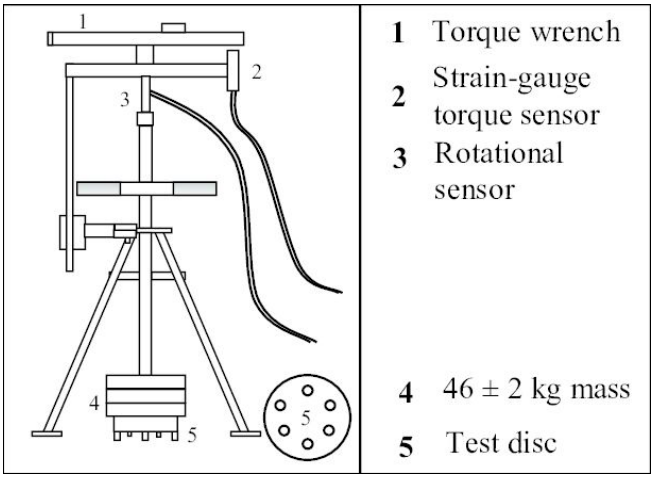


Figure 3: Model of measurement device from Webb's 2014 study.

shoe-surface interface and its relationship to football knee injuries, was published by Joseph S. Torg, Theodore C. Quedenfeld, and Steven Landau. This paper discussed the idea of some shoes, ones most commonly used at the time, to be safe on natural grass, but likely not safe on many of the types of turf used in 1994. Since this article was written, there has been no change to the requirement of players to be wearing a standardized shoe as to avoid the increase in risk to the ankle and knee in players training or playing or artificial turf. It is further discussed in, *Peak Torque and Rotational Stiffness Developed at the Shoe-Surface Interface: The Effect of Shoe Type and Playing Surface*, by Glen A. Livesay and his team, that an increase in rotational traction may be the contributing factor to the cause of increased injury with an increase in traction. Livesay and his team constructed a machine that measured the torque opposed to the rotational development of two types of shoe interfaces on five different playing surfaces(Natural grass and four types of artificial surface).

It can be concluded from these papers that there is a likely increase of chance of injury to the knee on artificial turf fields. Ultimately, with a continued increase of turf fields being implemented into the high school football stadiums concerns about safety, stemming from parents and coaches alike, will continue to increase. It is because of this assumption that it becomes necessary to further investigate the connections between artificial turf, natural grass, and knee injury in high school football athletes.

Purpose

With new safety concerns among coaches and trainers alike, it is necessary to understand if a correlation between playing surface, either artificial turf of natural grass, and the rate of knee injuries.

Research Question: How Do Both 3G Artificial Surfaces and Natural Grass Effect Injuries to the Knee in High School Football?

Hypothesis

Alternate: 3G artificial turf will result in a higher knee injury per exposure as compared to natural grass.

Null: There will be no difference in knee injury per exposure between 3G turf and natural grass.

Methods

This paper is a secondary data analysis Dr. Comstock's work on HIGH SCHOOL RIO (REPORTING INFORMATION ONLINE): INTERNET-BASED SURVEILLANCE OF INJURIES SUSTAINED BY US HIGH SCHOOL ATHLETES. The dataset spans from 2005 to 2017 and has a section each year in which it gives a total number of knee injuries in football as well as a total number of player exposures. Exposures in the RIO datasets are simply the number of games played by every player. Say there is 11 men on the field for both teams at one point in

the game. This would mean there is a total of 22 game exposures for those players in that game. These are the numbers that were used for data collection. For the ten year span of data that was worked with, 2006-2007 season to 2016-20017 season, the percent of turf fields in high school football programs, found via email survey sent to to over 150 high schools across the country, will be compared to the number of knee injuries per exposure for each season. For the data collection in this project, it is important to note that the school field information, collected via email survey, was spread across the United States with the intent to contact more schools in more densely populated states as opposed to having equal data from every state regardless of size. This injury per exposure is calculated from the numbers from Dr. Comstock's data in order to prevent the skewing of data as result of more knee injuries in one season simply as a result of more exposure to receiving said injury.

From the collected data, the number of injuries per exposure can be calculated. The injuries per exposure calculation is essential to the data collection of this paper as it prevents the appearance of more injuries on turf one year simply due to more players playing in games. It prevents the skewing of data by creating an average number of injuries per exposure. To calculate the number of injuries per exposure, the total number of knee injuries in game situations was divided by the number of exposures for each season. This data was then compared to the percentage increase of turf fields using a population correlation coefficient. The formula used to calculate a population correlation coefficient is as follows.

$$\rho X,Y = \operatorname{cov}(X,Y) / \sigma\chi\sigma\gamma$$

The population correlation coefficient is used to calculate a p value, between -1 and +1, that shows the correlation of one variable to a set of data. The cov is the covariance, or the relation of two datasets of different magnitudes or measures. The $\sigma\chi\sigma\gamma$ is the standard deviation of both variables, X and Y.

Results

Game Knee Injury Data

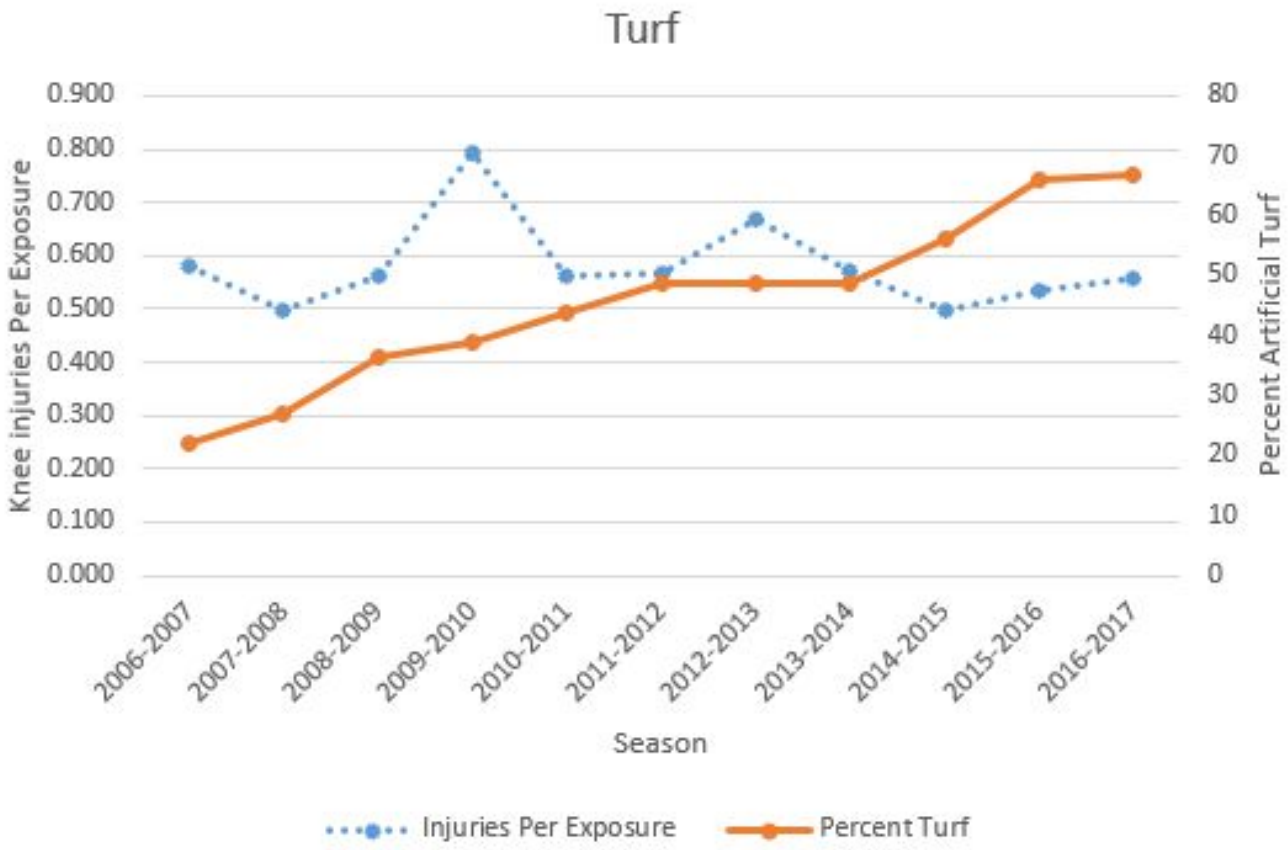
Injuries Per Exposure	Percent Turf	Year
0.5807	21.95	2006-2007
0.4989	26.83	2007-2008
0.5638	36.59	2008-2009
0.7934	39.02	2009-2010
0.5619	43.9	2010-2011
0.5662	48.78	2011-2012
0.6669	48.78	2012-2013
0.5711	48.78	2013-2014
0.4988	56.09	2014-2015
0.5326	65.85	2015-2016
0.5573	66.85	2016-2017

Practice Knee Injury Data

Injuries Per Practice	Percent Turf	Year

Exposure		
0.0978	21.95	2006-2007
0.0710	26.83	2007-2008
0.0669	36.59	2008-2009
0.0884	39.02	2009-2010
0.0566	43.9	2010-2011
0.0714	48.78	2011-2012
0.0767	48.78	2012-2013
0.0981	48.78	2013-2014
0.0663	56.09	2014-2015
0.0828	65.85	2015-2016
0.0645	66.85	2016-2017

The data collection from email surveys of approximately 150 United States high schools showed an increase in the growth of artificial turf fields by approximately 44 percent in a ten year period. According to the hypothesis of this study, an upward trend in the number of injuries per game exposure from year to year should be the case as the number of turf fields increase, but it was found that the numbers for injuries per exposure varied greatly. One example of this is the 2009-2010 season in which there was an average of .7934 injuries to the knee per game exposure. This rise in injury is not explained by the increasing number of turf fields because as the percentage of artificial fields continued to rise, the injuries per exposure dropped back down below the high mark of the 2009-2010 season and continued to vary.



The solid line, percent turf in high school fields, shows the growth in percentages of turf fields over the 2006-2007 season to the 2016-2017 season. The dotted line is the number of knee injuries per game exposure for each season. It is obvious that there is little to no connection between the playing surface and the number of knee injuries from year to year.

Written Description of Results

The data collection shows that there was no correlation between the increase of artificial turf surfaces from the sample size and the injury per exposure ratio for all knee injuries in a season. There was an overall increase of turf fields from 21.95% to 66.85% in the span of seven

total seasons of play. Where it was hypothesized that turf fields would lead to an increase in knee injuries per exposure, due to the available data on friction, the results show a correlation coefficient of -0.138066949, meaning that there is a slight decrease of injuries per exposure when playing on artificial turf. This data further states that there is far less of a trend between playing surface and injury that was previously believed.

Further, a CHISQ.TEST was conducted on the data to find the p value and to see if there was a connection between the total number of knee injuries per exposure. The p value was then used to deduct whether or not there was a correlation between the percentage of turf fields and the number of injuries per game exposure. The p value from this study was found to be extremely high, $p = 0.999$, meaning that there was no connection between the percentage of turf fields and the injuries per exposure.

For the *Practice Knee Injury Data*(not graphed), the same two tests, CHISQ.TEST and population correlation coefficient, were conducted to see if there was any change in the trends observed from the game data. The CHISQ.TEST value was identical to that of the game data's, sitting at $p = 0.999$. However, the population correlation coefficient test yielded a correlation coefficient of -0.2495359489, meaning that the turf field is contributes to statistically safer playing conditions in a practice setting.

Discussion

The data analysis conducted, CHISQ.TEST as well as the population correlation coefficient test, yield the result that turf has no connection to an increase in injury rate. This is in stark contrast to the literature discussed in the beginning of this paper. Further, the negative correlation coefficient states the opposite of the hypothesis that turf will cause an increase of injury. Not only does it not lead to more injuries, but it leads to less, making it safer than grass in the case of knee injury. The CHISQ.TEST yielded an extremely high *p* value meaning that the null hypothesis should be accepted and the alternate declined. With both of these values pointing to the acceptance of the null hypothesis, it is logical that it should be accepted and assumed correct.

Speculate

The likely reason for data pointing towards artificial turf as a safer playing surface is the fact that an artificial surface has minimal imperfections as opposed to a natural grass surface that is not only subject to an inherently uneven surface as the result of the ground becoming distorted overtime, but also the factor of weather and wear damage. The differences between the playing surfaces are that grass becomes worn by use at a far faster rate than turf does and this can result in the actual deterioration of grass in well travelled points on the field. Further, extreme weather of any kind causes damage to grass fields after they pass, where turf fields are durable and will maintain their level of safety. It is also not an impossibility that the grass fields in this study were at too much variation for a conclusion on the safety of all grasses to be made. Likewise, it is possible that turf fields of different varieties contribute to more injuries than others.

Logic

If the turf field is in fact superior to the natural grass field, then it should be heavily considered as a substitute for natural grass in all stadiums. This is not simply because it is slightly saferin games and even more so in practice, but because it is far more cost effective than a natural grass field. For example, the natural grass field is only able to operate for certain amounts of time. This lack of ability to play on a grass field is caused by one of two factors, weather interference, such as rain, or reseeding. The reseeding of a natural grass football field is most commonly performed in the months of August and September and the field is not to be played on during the time of reseeding to allow for a new base of grass to begin its growth before more wear is put onto the field by rigorous practice and games. The notion of practice is another factor that contributes to the appeal of the artificial turf field. Where it is common for teams to practice on a secondary field as to avoid wear on the game field, the turf field eliminates this precaution as the synthetic blades and rubber infill are far more durable than a natural playing surface.

	Natural Grass	FieldTurf
Base preparation	$150,000	$320,000

Materials	$2.75 per sq. ft. = $220,000	$4.75 per sq. ft. = $380,000
Maintenance	$20,000 x 10 years = $200,000	$5,000 x 10 years = $50,000
Total	$570,000	$750,000
Scheduling Possibilities	25 hours x 25 weeks x 10 years = 6,250 hours	68 hours x 44 weeks x 10 years = 29,920 hours
Average Cost Per Hour of Use	$91.20	$25.07

Figure 5: Average costs of various necessities for the installation and maintenance of FieldTurf artificial turf and natural grass(FieldTurf).

According to their website statistics, a FieldTurf field costs roughly 750 thousand U.S. dollars to be installed and maintained. With materials being more expensive than the natural grass competition, many schools are likely to choose the apparently cheaper alternative that is the natural grass field. Further, the school would have to either fundraise or be gifted less money through grant or state funding in order to get a new field installed. However, the numbers and the wear put on a natural grass field, especially at the high school level where multiple teams for multiple sports practice on the same field day after day. It becomes more and more apparent that a high school should

invest in an artificial turf field as the number of athletes and sporting teams is increasing. Just this past year, the California Interscholastic Federation made women's field hockey a sport. Just this one added sport per year has added minimum of half a season of play to a high school's football field. Where this man not seem like a large factor in choosing a new playing surface, the number of practices that are added by even one new sports team are enough to have a heavy impact on the maintenance costs of a natural grass field. Additionally, the average 3G artificial turf field is compatible with a minimum of three sports at the high school level. These sports include American football, soccer, and lacrosse. With the use of three teams on one field via colored lines signaling to athletes the boundaries for their said sport, the slight cost of painting a natural grass field is eliminated. Another notable factor in choosing the right surface would be the maximum output of said surface. It was previously discussed that due to the inherent durability of 3G artificial surfaces makes them suitable for play almost year round with minimal maintenance cost. The data collection for the percent turf composition of playing surfaces in high schools was taken from sample schools across the country, so for the sake of this cost analysis, the average school funding for new playing surfaces will be assumed for all schools.

Conclusion

The steady rise of turf fields since their initial introduction in the 1970's is likely to bring about more questions about player safety when playing on artificial surfaces, but one factor can be ruled out. That is, the common misconception that the artificial turf fields being implemented in high school and professional stadiums alike are leading to an increased chance of knee injuries in American football. With data showing no obvious connection between the increase of turf

fields in high school football and the number of injuries per game exposure from season to season, as well as the findings of a slight negative correlation between turf and knee injuries that hints at turf fields being slightly safer than their natural alternative, it is concluded that not only does turf have no effect on knee injury, but that the playing surface itself shows little connection at all to the number of injuries in a season.

The conclusion of playing surface not being a factor in knee injuries is vital to the medical world's understanding of the causes of knee injuries in adolescents playing football. Further, the lack of a definite correlation coefficient means that there is undoubtedly another factor that is a major contributor to the outlying seasons with high injury per exposure numbers. Take the 2009-2010 season for example. With a total of 0.7934 injuries per game exposure, 0.1265 more than the next closest season, it is an obvious outlier that shows the likelihood of some unknown variable affecting the number or injuries from one season to the next.

Further Work

The conclusion of the null hypothesis of turf having no effect on the number of knee injuries per game exposure opens the possible future research immensely. The number of variables that could play a role in the increasing or even decreasing of injury from year to year is large, but can be narrowed down into several testable areas. These areas include the shoe to playing surface interaction, the testing of non contact situations individually, and the type of movement or action that resulted in injury

The testing of shoe interfaces on playing surfaces is a method that dates back to Joseph S. Torg's 1974 paper, "The Shoe-Surface Interface and its Relationship to Football Knee Injuries," in which two shoes were tested on two surfaces. One shoe was a conventional football shoe with a normal stud pattern on the bottom, meaning there was protruding spikes at certain places on the plate of the shoe, and the other was an all purpose soccer type cleat. The test determined that the conventional cleat alloted for and average of almost twice, 1.93 times, the amount of force to rotate the shoe to a ninety degree mark as well as a sixty degree mark. Thus it can be assumed that the conventional shoe type creates more friction, and likely a higher risk of injury on either artificial or natural playing surfaces. A test of the most common shoe types from season to season on both surfaces to evaluate any increase in friction of the average shoe from one season to the next. If the outlying seasons for injury number, either statistically higher or lower than the average, have outlying results from a test such as this it could be concluded that the shoe and paying surface interface plays a role in the number of injuries per exposure. A test such as this has not been conducted before, but the methods would be similar to those of Torg and Livesay, who used a variation of the testing used in Torg's original study.

Another possible variable that could lead to the outliers of the injury per exposure data is the collection of data entirely pertaining to non contact situations. The purpose of a test such as this is to determine if there is a statistically relevant number of knee injuries caused by the playing surface entirely, meaning without influence from another player or the ball. The non contact injury rate would be calculated and analyzed similarly to the total knee injuries per exposure number that was found in this study. The number of total exposures would remain the

same, but the number of injuries would more than likely decrease due to the physical nature of American football leading to high numbers of injuries. Further, it is possible that the hypothesis from this paper, that a 3G artificial playing surface will contribute to an increase in number of injuries as the percentage of turf fields increases. This is possible because the research on friction being a contributor to knee injury applies to the non contact injury more so than a knee injury caused by an outside force, because the interaction is entirely between the player and the playing surface. If a study such as this were to find an increase in the number of non contact injuries per game exposure, then it would be accepted that the playing surface does play a role in the number of knee injuries and that one surface is likely safer than the other. Based off of literature and past studies it would likely be hypothesised that there would be an increased number of knee injuries per exposure when playing on a 3G artificial field due to its inherently higher friction, but further this research is necessary to make that conclusion.

Further, the type of kinesthetic movement that resulted in a knee injury should be studied and analyzed to understand if there is a connection between common movements in football like the cut, a one foot plant that is used to create an immediate change of direction and often speed, is responsible for an increase in the number of knee injuries. This method would require extensive data collection, but with the help of school athletic trainers, who often keep significant injuries on record, a relevant sum of data could be gathered and analyzed. In the event of a specific kinesthetic movement causing a relevant number of knee injuries, the movement could then be studied through the use of video recording. The method of video recording to analyze the kinesiological effects of common movements in athletes is currently utilized in the sports

rehabilitation and physical therapy disciplines to evaluate the form of an athlete looking to return to play. This method of video study would easily transfer to the study of knee movement in sample athletes to examine the movements statistically proven to cause injury. This study is not only looking to find a reason for injury in high school football players, but could be easily used to prevent knee injuries from incorrect form that is common in high speed movements like cutting, pivoting, and stopping after a burst of speed. This study in particular would be effective in identifying a the most common errors that could lead to injury. There are already training programs designed to strengthen the muscles involved in controlling the movement of the knee in game play. The most common of these programs involves the use of resistance bands placed above the knees combined with exercises, like squats, in order to strengthen the gluteus maximus, gluteus minimus, and the tensor fasciae latae. The purpose of strengthening these muscles, all located in the back to the outside of the hip, is to give the player control over the movement of their femur bone when conducting high speed movements. Without this control it is common for players, primarily athletes from the ages twelve to nineteen, to lose control over their motion resulting in the tweaking or buckling of the knee and, ultimately, a knee injury.

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