The effect of field condition and shoe type on lower extremity injuries in American Football

Jaclyn Nicole Iacovelli,[1] Jingzhen Yang,[2,3] Geb Thomas,[1] Hongqian Wu,[2,4] Trisha Schiltz,[5] Danny T Foster[5]

[1]Department of Industrial Engineering, University of Iowa, Iowa City, Iowa, USA
[2]University of Iowa Injury Prevention Research Center, Iowa City, Iowa, USA
[3]Department of Social and Behavioral Sciences, Kent State University, Kent, Ohio, USA
[4]Department of Biostatistics, University of Iowa, Iowa City, Iowa, USA
[5]Department of Health and Human Physiology, University of Iowa, Iowa City, Iowa, USA

Correspondence to
Dr Jingzhen Yang, Department of Social and Behavioral Science, College of Public Health, Kent State University, 305E Lowry Hall, Kent, OH 44242-0001, USA, jyang23@kent.edu

Accepted 12 May 2013
Published Online First 12 June 2013

▶ http://dx.doi.org/10.1136/bjsports-2013-092266

To cite: Iacovelli JN, Yang J, Thomas G, *et al*. *Br J Sports Med* 2013;**47**:789–793.

ABSTRACT

Background/aim Considerable improvement has been made in football field surfaces and types of shoe, yet relatively few epidemiological studies have investigated their roles in the risk of football injuries. This study examined the effects of field surface, surface condition and shoe type on the likelihood of lower extremity football injuries.

Methods Deidentified data from 188 players from one division I university football team during the 2007–2010 seasons were analysed. Lower extremity injury rate and rate ratio, along with 95% confidence limits, were calculated by football activity, playing surface condition and shoe type.

Results A total of 130 lower extremity injuries were sustained, with an overall lower extremity injury rate of 33.5/10 000 athlete-sessions. The lower extremity injury rate was 2.61 times higher when the surface condition was abnormal compared with when the surface condition was normal. During games, the risk for lower extremity injury was 3.34 times higher (95% CI 1.70 to 6.56) on artificial turf compared with natural grass. However, this trend was not statistically significant in practice sessions. Furthermore, neither the number of shoe cleats nor the height of the shoe top was statistically associated with risk of lower extremity injuries.

Conclusions Football players who played on artificial turf or when the surface condition was abnormal were susceptible to lower extremity injuries. Evidence from this study suggests that further research into playing surfaces and shoe types may provide fruitful opportunities to reduce injuries to collegiate football players.

INTRODUCTION

American football is a high-injury-risk activity because of the size, speed and strength of the players colliding with each other. Even though all players are required to wear facial protection, shoulder pads and hip-thigh protection, injuries are unavoidable and occur in both contact and non-contact situations.[1] Football also has the highest rate of lower extremity injuries in comparison with all other team sports, and such injuries become more frequent as players move up in the level of competition.[2] Lower extremity injuries in football are the result of a complex interaction of both intrinsic risk factors such as football position, age, previous injuries, joint flexibility and muscle tightness, and extrinsic risk factors such as field condition, shoe-surface interaction, weather conditions and equipment.[3]

Of the many studies published over the last 30 years examining the risk factors of football injuries, relatively few have addressed the influence of extrinsic risk factors. Many lower limb injuries occur in non-contact situations, such as when a player is cutting, turning or jumping. The translational and rotational forces that the lower limb endures are affected by the shoe-surface traction.[1 4] It seems reasonable to assume that the extrinsic effects of field type (artificial or natural), surface condition and shoe type all influence the likelihood of football injuries to the lower extremities. Practical insight into these questions is important in order for athletic programmes to select the surface that best protects their players, and for athletes to select shoes in different weather conditions to avoid injuries. Unfortunately, there is a scarcity of published epidemiological studies that have examined these factors together. The few studies on surface type alone have yielded conflicting evidence.[1 5–10]

There have been considerable advances in technology intended to reduce football injuries, including better safety equipment, field surfaces and enhanced shoes. Studies addressing the effectiveness of field surfaces and shoes have been largely laboratory based, such as using a prosthetic leg machine or a controlled preconfigured obstacle course.[11 12] Consequently, fundamental questions regarding the epidemiological effectiveness of these improvements and their interactions are unresolved. Of immediate particular interest is the question of whether and how field condition and shoe type interact with each other and influence the risk of lower extremity injuries, especially to the knees and ankles. To fill the gap in the literature, this study considers the epidemiology of field type, surface condition and shoe type on the rate of lower extremity injuries based on data collected over 3 years from collegiate players.

MATERIALS AND METHODS

Data and study participants

This study analysed the deidentified data that were originally assimilated from two sources: (1) the existing data from the Sports Injury Monitoring System, an ongoing injury surveillance system which contains injury, football activity, field type and surface condition information, as well as the types of shoe a player was wearing during each football activity, and (2) the football team roster on the university website that included data on each player's height, weight, grade and football position. A cohort of collegiate football players from one Big Ten NCAA Division I university who were on the team roster during the 2007–2008, 2008–2009 or 2009–2010 seasons was retrospectively analysed.

A total of 250 injuries (incurred by 188 players) and 312 team activity sessions (eg, games or practices) were included in the analysis. The study was approved by the Institutional Review Board at the University where the study was conducted.

Main variables and measures

Injury was defined as any reportable injury that occurred during the study period that was acute in nature and required medical attention and restricted full sport participation, either in games or practices, for 1 day or more. For the purpose of this study, only lower extremity injuries, defined as any injury from the hips to the toes, were included in the analysis because these injuries were the most common injuries in football. *Field condition* was measured through two variables: field type (eg, artificial vs natural) and surface condition (eg, normal vs abnormal). Abnormal surface condition was defined when one of the following conditions was met: the temperature was over 82°F, the humidity was over 50% or visible water spots were seen on the surface.

Type of shoe was measured by two variables: number of cleats (eg, 7 cleats or less, 8–12 cleats, or 13 cleats or more), and the height of the top of the shoe near the ankle (high vs low). These two variables were created from the 27 Nike-brand shoe models (eg, Air Zoom Assassin, Super Speed D Low, Air Zoom Total 90) in the observational study.

Football related activities were: (1) practices and (2) games. Each time an athlete participated in one activity session, either game or practice, it was defined as one exposure or one athlete-session.

Statistical analysis

The number and rate of lower extremity injuries were described including the type of injury sustained. The lower extremity injury rate was calculated as the total number of lower extremity injuries divided by the total number of athlete-sessions and then multiplied by 10 000. Lower extremity game (or practice) injury rate was calculated as the total number of lower extremity injuries incurred in the games (or practices) divided by the total number of game (or practice) exposure sessions and then multiplied by 10 000. The same method was used to calculate the knee and ankle injury rates.

Generalised Estimating Equations were used to model the effect of exploratory factors including field type (artificial vs natural), surface condition (abnormal vs normal), number of shoe cleats (13 or more, vs 8–12, vs 7 or less) and height of shoe top (low vs high) on rate ratio (RR), along with 95% CI, of lower extremity, knee and ankle injuries. The model was adjusted for the four exploratory variables along with school year and football position. The same approach was used to assess the effects of exploratory factors on injury RRs during football games and practices. The level of statistical significance was set at α of 0.05. The analyses were conducted in SAS V.9.00.

RESULTS

Characteristics of players and football activities

Of the total of 188 football players included in the analysis, 112 (59.3%) players sustained at least one injury during the study period. The average weight and height of the enrolled players was 229.5 pounds and 6 feet 2 inches, respectively, with an average body mass index of 29.2 (table 1).

A total of 312 football activities were included in the analysis, with 38 (12.2%) game sessions and 274 (87.8%) practice sessions. After accounting for the number of football players who were present in each of the 312 sessions, the total number of exposures during the study period was 38 826 athlete-sessions, including game exposures of 4726 athlete-sessions and practice exposures of 34 100 athlete-sessions.

Table 1 Characteristics of football players and football activity

	Characteristics of players N (%)
Injury status	
Injured player	112 (59.3)
Not injured player	76 (40.7)
School year*	
Freshman	114 (62.0)
Sophomore	27 (14.7)
Junior	29 (15.8)
Senior or 5th year senior	14 (7.6)
Football position*	
Offensive backfield	17 (9.2)
Offensive receiver	24 (13.0)
Offensive line	33 (17.9)
Tight end	14 (7.6)
Quarterback	7 (3.8)
Defensive line	29 (15.8)
Defensive secondary	27 (14.7)
Linebacker	21 (11.4)
Kicker	12 (6.5)
Football activity	
All activity	312
Game	38 (12.2)
Practice	274 (87.8)
Football activity in which injury occurring	
All activity	114
Game	25 (21.9)
Practice	89 (78.1)

*Four players had missing values on school year, and four players had missing values on football position.

Number and rate of lower extremity, knee and ankle injuries

A total of 250 injuries were incurred by 112 football players, of which 130 (52%) occurred in the lower extremities and were sustained by 80 football players, with 51 (39.2%) occurring in games and 79 (60.8%) in practices. Of the 130 lower extremity injuries, 35 (26.9%) involved the knee and 29 (22.3%) involved the ankle (table 2). Nearly half of the knee injuries (48.6%) and over 80% of ankle injuries (82.8%) were of the joint (non-bone) and ligament type (table 3). Muscle and tendon injuries were more common in the knees than in the ankles (28.6% vs 3.5%). Compared with lower extremity game injuries, more muscle and tendon injuries and less joint (non-bone) and ligament type injuries occurred in practices. In particular, more joint (non-bone) and ligament knee injuries occurred in practices than in games.

The overall lower extremity injury rate was 33.5/10 000 athlete-sessions, with a lower extremity game injury rate of 107.9/10 000 athlete-sessions and a practice injury rate of 23.2/10 000 athlete-sessions (table 3). The injury RR of lower extremity game injury rate versus practice injury rate was 4.7, with 95% CI of 3.3 and 6.6, indicating that risk of lower extremity injuries was significantly higher in football games than in football practices. The same trend held true for knee and ankle injuries, with RRs of 5.4 (95% CI=2.8 to 10.6) for knee injuries and 7.7 (95% CI=3.7 to 16.0) for ankle injuries.

Table 2 Lower extremity, knee and ankle injuries by type of injury

	All injuries N (%)	Game injury N (%)	Practice injury N (%)
Any lower extremity injury	130	51	79
Fracture and bone stress	9 (6.9)	3 (5.9)	6 (7.6)
Joint (non-bone) and ligament	52 (40.0)	28 (54.9)	24 (30.4)
Muscle and tendon	47 (36.2)	9 (17.7)	38 (48.1)
Contusions, lacerations and skin lesions	7 (5.4)	3 (5.9)	4 (5.1)
Other	15 (11.5)	8 (15.7)	7 (8.9)
Knee injury	35	15	20
Joint (non-bone) and ligament	17 (48.6)	0 (0.0)	8 (40.0)
Muscle and tendon	10 (28.6)	9 (60.0)	7 (35.0)
Contusions, lacerations and skin lesions	1 (2.9)	3 (20.0)	1 (5.0)
Other	7 (20.0)	3 (20.0)	4 (20.0)
Ankle injury	29	15	14
Fracture and bone stress	3 (10.3)	2 (13.3)	1 (7.1)
Joint (non-bone) and ligament	24 (82.8)	12 (80.0)	12 (85.7)
Muscle and tendon	1 (3.5)	0 (0.0)	1 (7.1)
Other	1 (3.5)	1 (6.7)	0 (0.0)

Rate and RR of lower extremity injury by field condition and shoe type

The lower extremity injury rate was 2.61 times higher when the surface condition was abnormal than when the surface condition was normal after adjusting for other covariates, with an injury RR of 2.61 and 95% CI of 1.63 to 4.18 (table 4). Lower extremity injury rates tended to be higher when football players were playing on artificial turf than on natural grass, although statistical significance was not found in injury RRs. There were no significant differences in lower extremity injury rates between players who were wearing shoes with eight cleats or more compared with players who were wearing shoes with fewer cleats, or players who were wearing high or low top shoes.

During games, the lower extremity injury rate was higher when football players were playing on artificial turf than when playing on natural grass, with an injury RR of 3.34 (95% CI 1.70 to 6.56; table 4). Lower extremity game injury rates also tended to be higher when the surface conditions were abnormal compared with when they were normal. During practice sessions, the lower extremity injury rate was significantly higher when surface conditions were abnormal than normal, with an injury RR of 2.10 (95% CI 1.05 to 4.20). Lower extremity practice injury rates were likely to be higher for players who were wearing shoes with 8–12 cleats (RR=1.19, 95% CI 0.59 to 2.38) than for players who were wearing shoes with seven or less cleats; however, the result was not statistically significant.

DISCUSSION

This study compared lower extremity injury rates among collegiate football players by playing surface and shoe type during football games and practices. The findings revealed that the lower extremity injury rate was more than 2.5 times as high when the surface condition was abnormal compared with a normal surface condition, and this was particularly true during the practice sessions. A rather surprising finding was related to the risk posed during football games on artificial surfaces. The risk for lower extremity injury was increased by a factor of 3.34 on artificial turf compared with natural grass during games, although this trend was not observed in football practice sessions. Finally, the number of shoe cleats or height of the shoe top was not associated with injury rates. This is the third study in the last 2 years from the USA reporting a significantly greater injury risk on artificial turf.[9 10] Thus, it is unlikely that such a finding is by random chance. These results suggest that further research into playing surfaces and shoe types is warranted to

Table 3 Number and rate of lower extremity, knee and ankle injuries

	Injury N (%)	Exposure (Athlete-sessions)	Rate Per 10000 athlete-sessions	Rate ratio (95% CI)	
Any lower extremity injury	130	38826	33.5		
Game injury	51 (39.2)	4726	107.9	4.7	(3.3 to 6.6)
Practice injury	79 (60.8)	34100	23.2		
Knee injury	35	38826	9.0		
Game injury	15 (42.9)	4726	31.7	5.4	(2.8 to 10.6)
Practice injury	20 (57.1)	34100	5.9		
Ankle injury	29	38826	7.5		
Game injury	15 (51.7)	4726	31.7	7.7	(3.7 to 16.0)
Practice injury	14 (48.3)	34100	4.1		
Other lower extremity injury	66	38826	17.0		
Game injury	21 (31.8)	4726	44.4	3.4	(2.0 to 5.6)
Practice injury	45 (68.2)	34100	13.2		

Table 4 Adjusted rate ratio of lower extremity injuries by type of shoe, field condition

	Injury N (%)	Exposure (athlete-sessions)	Rate/10 000 athlete-sessions	Adjusted rate ratio (95% CI)*	
All injuries					
Playing surface					
Artificial turf	82 (63.1)	24164	33.9	1.41	(0.91 to 2.18)
Natural grass	48 (36.9)	14662	32.7		
Surface condition					
Abnormal	33 (25.4)	4889	67.5	2.61	(1.63 to 4.18)
Normal	97 (74.6)	33937	28.6		
Number of cleats					
>12	42 (32.3)	12558	33.4	0.79	(0.43 to 1.43)
8–12	67 (51.5)	17517	38.2	1.06	(0.61 to 1.83)
≤7	21 (16.2)	8751	24.0		
Height of shoe					
Low	49 (37.7)	14193	34.5	1.14	(0.68 to 1.90)
High	81 (62.3)	24633	32.9		
Game injuries					
Playing surface					
Artificial turf	38 (74.5)	2209	172.0	3.34	(1.70 to 6.56)
Natural grass	13 (25.5)	2517	51.6		
Surface condition					
Abnormal	17 (33.3)	1286	132.2	1.55	(0.81 to 2.96)
Normal	34 (66.7)	3440	98.8		
Number of cleats					
>12	17 (33.3)	1414	120.2	0.91	(0.36 to 2.32)
8–12	24 (47.1)	2223	108.0	0.90	(0.40 to 2.03)
≤7	10 (19.6)	1089	91.8		
Height of top					
Low	22 (43.1)	1744	126.1	0.97	(0.43 to 2.19)
High	29 (56.9)	2982	97.3		
Practice injuries					
Playing surface					
Artificial turf	44 (55.7)	21955	20.0	1.06	(0.60 to 1.86)
Natural grass	35 (44.3)	12145	28.8		
Surface condition					
Abnormal	16 (20.2)	3603	44.4	2.10	(1.05 to 4.20)
Normal	63 (79.8)	30497	20.7		
Number of cleats					
>12	25 (31.6)	11144	22.4	0.81	(0.36 to 1.82)
8–12	43 (54.4)	15294	28.1	1.14	(0.53 to 2.41)
≤7	11 (13.9)	7662	14.4		
Height of shoe					
Low	27 (34.2)	12449	21.7	1.19	(0.59 to 2.38)
High	52 (65.8)	21651	24.0		

*Adjusting for school year, football position, playing surface, surface condition, number of cleats, and height of shoe.

determine possible contributing factors to injuries. Additional efforts on designing effective injury prevention programmes and improving playing surfaces are urgently needed to reduce injuries to collegiate football players.

Several studies have been conducted in the past decade to investigate the effect of field type on the risk of injuries.[1 5–10] However, there is no agreement on the findings related to which playing surface has a lower injury risk. Looking at football players on artificial and natural grass, several studies found that the risk of knee and/or ankle injuries was higher on artificial turf than on natural grass.[1 8–10] However, these findings were not supported by other studies conducted on game-related injuries in college football, rugby and elite soccer players in which it was concluded that there were no significant differences in injury rates between artificial turf and natural grass.[5–7] Our results suggest that the effect of field type on the risk of lower extremity injuries differs by the exposure session. While artificial turf had a significant impact on the risk of lower extremity injuries in football games, such effect was not observed in football practices. One possible explanation is that artificial turf increases the athlete's speed and acceleration and thus produces a higher peak-torque than natural grass surfaces, which could potentially lead to an increase in lower extremity injuries.[12 13] Another possible reason is that 8 of 12 Big Ten universities play football games on artificial turf.[14] Perhaps players pushed themselves harder or played more aggressively for a game, which

frequently took place on an artificial surface in this study. It is also possible that other underlying personal and/or environmental risk factors that are unknown may have contributed to our observing a higher injury rate in football games.

There are few studies that have focused on the influence of weather and field surface conditions on athlete injuries, but the significant results of this study imply that more studies need to be conducted on this subject.[8 9 13 15] Most of the published studies classify the field surface as either wet or dry, and the temperature as either hot or cold.[16] In a study of Canadian footballers, wet compared with dry field conditions were found to be associated with greater risks of overall injuries, but the results on lower extremity injuries were not statistically significant.[1] In another study, researchers found a higher incidence of knee injury during hot days on FieldTurf than on cold days.[13] Several studies have also looked at other sports with similar running, cutting and contact manoeuvres to American football and found that knee and ankle injuries are more likely to occur when the ground surface is warmer, drier and harder.[8 14] It is possible that the results of this study may have been different from those of other studies because abnormal conditions were defined as wet, extremely hot or humid. It is worth noting that the effect of abnormal field surface conditions on the risk of lower extremity injury was statistically significant in football practices, yet such a relationship was not observed in the game setting. Despite all the contradictory results, it is increasingly important to consider that the game, in general, may be slower in worse weather conditions, causing players to be more cautious in their manoeuvres.[16] Further studies are needed to understand why the effects of the surface condition on lower extremity injuries differ in games and practices.

Previous research has demonstrated that traction is critical for the athlete's ability to accelerate, decelerate and change direction.[17] Many different study designs for cleats on the market promise athletes high traction,[18] and an increased number of cleats may help increase traction. However, excessive rotational traction can cause foot fixation, which increases the risk of sustaining lower extremity injuries and, in particular, an ACL injury.[18–20] The findings of this study did not show that types of shoes have an influence on a risk of lower extremity injuries. This finding was supported by the study conducted among 17 football players who tested a Nike cleat on two types of surfaces, artificial turf and natural grass, and found no significant differences between grass and turf.[9] However, another study showed that shoes with 6–10 cleats had a small number of injuries on natural grass, while shoes with 13–17 cleats had fewer injuries on artificial turf, suggesting that there might be a friction interaction(s) between the type of shoe and the playing surface.[21 22] More research is clearly needed to consider the impact of the shoe and the playing surface, as well as the shoe–surface friction interaction(s) when evaluating their effects on risk of lower extremity injuries.

Limitations

This study has several limitations. First, the number of lower extremity injuries, especially knee injuries or ankle injuries, was low, which limited our ability when conducting subgroup analyses. Second, players could have taped the outside of the shoe (modifying the effectiveness of the cleats), or switched the type of shoe they were wearing in the middle of the season, which would not have been recorded if an injury did occur. Third, the findings on the effect of the artificial surface on lower extremity injuries during games may be confounded by the type of artificial surface, and/or the players' risk behaviours during games, most of which were played on an artificial surface. Fourth, the abnormal field surface condition was aggregated in the existing data set and did not allow for the examination of the effect of specific abnormal surface conditions, such as hot, wet or humid. Finally, this study focused on the players on the football team from one university, which may not be generalisable to other college football teams.

CONCLUSION

As seen by this study, the risk of lower extremity injuries of football players was greater when the surface conditions were abnormal than normal, particularly during practice sessions. In addition, in a game setting, players are more susceptible to having a lower extremity injury on artificial turf compared with natural grass. These findings suggest that some adjustments are needed in football practices and training when the surface condition is not ideal in order to protect the players from lower extremity injuries. Such findings may also have important implications when evaluating the surface condition and injury risk for other sports such as soccer. While the cost of maintaining a natural grass surface is more than the cost of having artificial turf, the long-term savings may be greater with reduced injuries and medical costs associated with these injuries.

What are the new findings?

- The risk for lower extremity injury was increased by a factor of 3.34 on artificial turf compared with natural grass during games. However, this trend was not statistically significant in football practice sessions.
- The lower extremity injury rate was more than twice as high when the surface condition was abnormal compared with when the surface condition was normal, and this was particularly true during the practice sessions.
- The number of shoe cleats or height of the shoe top was not statistically associated with risk of lower extremity injuries.

Acknowledgements This research was made possible because of help from The University of Iowa Athletic Department. The authors would like to thank the individuals in The University of Iowa College of Engineering, College of Public Health and Department of Statistics and Actuarial Sciences who supported, assisted and collaborated on this project.

Contributors All six authors actively engaged in the preparation of this manuscript. Specifically, this manuscript was developed based on JNI's Master's thesis under the supervision of JZY and GT. After the thesis was completed, JZY, collaborating with JNI and GT, took the lead in developing the concept and analytic approach of the study, interpreting the results and writing the manuscript. HW assisted DTF, who collected the original study data, and JZY conducted additional analyses. TS and DTF assisted in interpretations of the results and the writing of the manuscript. All authors participated in writing and editing the manuscript.

Funding This research work was supported by the University of Iowa Injury Prevention Research Center, funded by grant #R49-CCD721682–03 of the Centers for Disease Control and Prevention (CDC)/National Center for Injury Prevention and Control.

Competing interests None.

Ethics approval The study was approved by the Institutional Review Board at the University of Iowa, USA, where the study was conducted.

Provenance and peer review Not commissioned; externally peer reviewed.

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