Incidence of Knee Injuries on Artificial Turf Versus Natural Grass in National Collegiate Athletic Association American Football: 2004-2005 Through 2013-2014 Seasons

Galvin J. Loughran,*† BS, Christian T. Vulpis,† BS, Jordan P. Murphy,† MS, David A. Weiner,‡ MD, Steven J. Svoboda,§ MD, Richard Y. Hinton,‡ MD, MPH, PT, and Dave P. Milzman,† MD
Investigation performed at Georgetown University School of Medicine, Washington, DC, USA

Background: The use of artificial turf in American football continues to grow in popularity, and the effect of these playing surfaces on athletic injuries remains controversial. Knee injuries account for a significant portion of injuries in the National Collegiate Athletic Association (NCAA) football league; however, the effect of artificial surfaces on knee injuries remains ill-defined.

Hypothesis: There is no difference in the rate or mechanism of knee ligament and meniscal injuries during NCAA football events on natural grass and artificial turf playing surfaces.

Study Design: Descriptive epidemiology study.

Methods: The NCAA Injury Surveillance System Men's Football Injury and Exposure Data Sets for the 2004-2005 through 2013-2014 seasons were analyzed to determine the incidence of anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), medial meniscus, and lateral meniscal tear injuries. Injury rates were calculated per 10,000 athlete exposures, and rate ratios (RRs) were used to compare injury rates during practices and competitions on natural grass and artificial turf in NCAA football as a whole and by competition level (Divisions I, Divisions II and III). Mechanisms of injury were calculated for each injury on natural grass and artificial turf surfaces.

Results: A total of 3,009,205 athlete exposures and 2460 knee injuries were reported from 2004 to 2014: 1389 MCL, 522 ACL, 269 lateral meniscal, 164 medial meniscal, and 116 PCL. Athletes experienced all knee injuries at a significantly higher rate when participating in competitions as compared with practices. Athletes participating in competitions on artificial turf experienced PCL injuries at 2.94 times the rate as those playing on grass (RR = 2.94; 95% CI, 1.61-5.68). When stratified by competition level, Division I athletes participating in competitions on artificial turf experienced PCL injuries at 2.99 times the rate as those playing on grass (RR = 2.99; 95% CI, 1.39-6.99), and athletes in lower NCAA divisions (II and III) experienced ACL injuries at 1.63 times the rate (RR = 1.63; 95% CI, 1.10-2.45) and PCL injuries at 3.13 times the rate (RR = 3.13; 95% CI, 1.14-10.69) on artificial turf as compared with grass. There was no statistically significant difference in the rate of MCL, medial meniscal, or lateral meniscal injuries on artificial turf versus grass when stratified by event type or level of NCAA competition. No difference was found in the mechanisms of knee injuries on natural grass and artificial turf.

Conclusion: Artificial turf is an important risk factor for specific knee ligament injuries in NCAA football. Injury rates for PCL tears were significantly increased during competitions played on artificial turf as compared with natural grass. Lower NCAA divisions (II and III) also showed higher rates of ACL injuries during competitions on artificial turf versus natural grass.

Keywords: football (American); knee, ligaments; ACL; PCL; epidemiology; NCAA; artificial turf

Football is one of the most popular sports in the United States, and it has the highest injury rate of any American collegiate sport.[6,10] Every season, athletes competing in National College Athletic Association (NCAA) football sustain devastating injuries that require surgery and extensive rehabilitation, resulting in significant lost playing time. Artificial playing surfaces are now widely used as a low-maintenance, cost-effective, and weather-resistant alternative to traditional natural grass playing fields at the high school, collegiate, and professional levels.[3,7,12,16,20] However, studies have found that the overall incidence of football injuries is significantly higher on artificial playing surfaces.[1,8,9,11,22]

Knee injuries are one of the most common injury types that result in medical disqualification, and they result in sustained decreases in postoperative performance among elite athletes.[18,24] Previous studies found that knee

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injuries account for 33.6% of all lower extremity injuries in NCAA football and that the most common types of knee injuries among elite college football players include medial collateral ligament (MCL), anterior cruciate ligament (ACL), and meniscal injuries.[4,25] While many risk factors for football knee injuries are well established, the current literature reporting the effect of playing surfaces on knee injuries remains divided. Some studies found no difference in the incidence of knee injuries on grass versus artificial turf, while others indicated a decrease in overall, minor, substantial, and severe injuries when play occurs on turf.[19-21] Other studies reported increased rates of specific knee injuries on artificial turf as compared with natural grass playing surfaces.[7,9,15,17,23] Previous studies were limited by sample size or the types of knee injuries investigated. Specifically, in a 2013 study, Dragoo et al[7] analyzed NCAA Injury Surveillance System (ISS) data from the 2004-2005 through 2008-2009 football seasons and found that the rate of ACL injury on artificial surfaces was 1.39 times higher than the injury rate on grass surfaces. While this is the largest study investigating the effect of playing surface on the incidence of knee injuries in NCAA football, it examined only ACL injuries.

The NCAA ISS has collected comprehensive injury and athlete exposure (AE) data from a large sample of collegiate institutions since 1982.[14] As the largest ongoing collegiate sports injury database in the world, the NCAA ISS has proven to be a powerful tool for researchers investigating injury trends among collegiate athletes.[5] Data from the 2009-2010 through 2013-2014 NCAA football seasons were recently collected by the NCAA ISS. In light of this additional data collection and the lack of consensus among previous studies, the goal of the current study is to analyze this now decade-long data set to determine the effect of artificial turf on the rates of ACL, posterior cruciate ligament (PCL), MCL, medial meniscal, and lateral meniscal injuries in NCAA American football.

METHODS

The NCAA ISS annually collects data that are voluntarily submitted by collegiate institutions sponsoring varsity football programs. During the 2004-2005 through 2013-2014 NCAA football seasons, the ISS collected data on injuries and exposures during organized practices and competitions for preseason, regular season, and postseason periods. Data were collected by the ISS from all 3 NCAA divisions via a web-based platform. During these 10 seasons, all injury mechanism and exposure data were submitted by athletic trainers from participating programs. Only teams that submitted at least 8 weeks of exposure activities consisting of preseason and regular season events qualified for inclusion in the NCAA ISS. These submitted data did not have to be from consecutive weeks. All data fields for each exposure had to be complete for a participating program's data to be included in the NCAA ISS data set. Between the 2004-2005 and 2008-2009 academic years, a mean of 60 teams per year met these requirements, representing 9.74% of all NCAA programs (12.17% of Division I, 6.49% of Division II, and 9.91% of Division III). Between the 2009-2010 and 2013-2014 academic years, a mean 25 teams per year met these requirements, representing 3.87% of all NCAA programs (6.67% of Division I, 3.01% of Division II, and 4.17% of Division III).[14]

For each event, athletic trainers reported exposure and injury data. Exposure data included the number of AEs, event type, season segment, NCAA division, and playing surface. An AE was defined as 1 athlete participating in a practice or competition in which he was exposed to possible injury, regardless of time played. For example, if 60 athletes played in a competition, the reported number of AEs for that event was recorded as 60. For competitions, an AE was recorded only if the athlete received actual playing time. Participating in a practice was counted as an exposure regardless of whether it was a formal scrimmage or game-like scenario. Athletes with a history of knee injuries were not excluded from analysis. Injury data included injury code, basic mechanism of injury, NCAA division, event type, and playing surface on which the injury occurred. A reportable injury was any injury that satisfied the following criteria: occurred as a result of participation in an organized NCAA intercollegiate practice or competition, subsequently required medical attention, and resulted in restriction of the student-athlete's participation in practice or competition for at least 1 calendar day beyond the initial day of injury.

The Men's Football Injury Data Set for the 2004-2005 through 2013-2014 seasons was analyzed with 5 injury codes: ACL tear (partial or complete), PCL tear (partial or complete), MCL tear (partial or complete), medial meniscal tear (partial or complete), and lateral meniscal tear (partial or complete). These injuries were chosen for

*Address correspondence to Galvin J. Loughran, BS, Georgetown University School of Medicine, 3900 Reservoir Road NW, Washington, DC 20007, USA (email: gjl42@georgetown.edu).
†School of Medicine, Georgetown University, Washington, DC, USA.
‡MedStar Union Memorial Hospital, Baltimore, Maryland, USA.
§MedStar Georgetown University Hospital, Washington, DC, USA.

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TABLE 1
Number of Injuries on Natural Grass and Artificial Turf During the 2004-2005 Through 2013-2014 Seasons[a]

	Injuries			Division I			Division II			Division III		
Injury	Total	NG	AT	Total	NG	AT	Total	NG	AT	Total	NG	AT
ACL tear	522	261	261	269	150	119	73	28	45	180	83	97
PCL tear	116	44	72	72	31	41	14	6	8	30	7	23
MCL tear	1389	742	647	773	411	362	163	80	83	453	251	250
MT												
Medial	164	86	78	77	45	32	20	10	10	67	31	36
Lateral	269	136	133	141	81	61	37	15	22	91	40	51
AEs	3,009,205	1,683,534	1,325,671	1,651,784	919,170	732,614	437,082	254,818	182,264	920,339	509,546	410,793

[a]ACL, anterior cruciate ligament; AE, athlete exposure; AT, artificial turf; MCL, medial collateral ligament; MT, meniscal tear; NG, natural grass; PCL, posterior cruciate ligament.

analysis as they represent the majority of knee injuries suffered by NCAA football athletes.[4,15,25] All ligament and meniscal injuries were collected whether partial or complete and analyzed as 1 injury type. Additionally, each injury type was analyzed separately regardless of whether an injury occurred in isolation or in conjunction with other injury types.

The proportion of events played on natural grass and artificial turf was not the same for competitions and organized practices in this data set (more competition AEs occurred on artificial turf than natural grass, and more organized practice AEs occurred on natural grass than artificial turf). As the intensity of play during competitions is typically far greater than during practices, combining competition and practice AEs to calculate injury rates would artificially increase the apparent injury rates on artificial turf. To control for this confounding variable, all data analysis in this study was stratified by event type (organized practices or competitions). The number of injuries occurring on natural grass and artificial turf during competitions and practices was calculated for each injury to be used as the numerator to determine injury rates. The total number of AEs was determined for each event type on natural grass and artificial turf surfaces by analyzing the Men's Football Exposure Data Set for the 2004-2005 through 2013-2014 seasons. AEs on each surface were used as the denominator to calculate injury rates. Analogous methods were used to calculate injury rates during competitions stratified by level of competition (NCAA Division I or Divisions II and III). Finally, mechanisms of injury were calculated for each knee injury on natural grass and artificial turf surfaces. Mechanisms of injury included contact with another player, contact with the playing surface, no apparent contact, and other.

Statistical Analysis

Injury rates were calculated according to the frequency of each injury documented per 10,000 AEs. Rate ratios (RRs) for injury rates during competitions versus practices were calculated to determine whether players experienced different injury rates depending on event type. RRs for injury rates on artificial turf versus natural grass were calculated to determine whether playing surface has a significant effect on the incidence of a given injury during competitions, during practices, and at different levels of NCAA competition (Division I, Division II and III). Ninety-five percent confidence intervals for injury rates and RRs were calculated per the standard large-sample formula assumptions of a Poisson distribution, which was implemented with the poisson.test() function in RStudio (v 0.99.902; RStudio Inc). The RRs were deemed statistically significant if the 95% CI did not include 1. To test whether mechanisms of injury varied on each playing surface, the Fisher exact test was implemented to assess whether the proportion of injury mechanisms differed statistically between injuries occurring on natural grass and artificial turf. A P value $<.05$ was deemed statistically significant.

RESULTS

During the 2004-2005 to 2013-2014 seasons, there were 3,009,205 AEs and 2460 knee ligament and meniscal tears reported by the NCAA ISS. Of these injuries, MCL tears predominated (1389), followed by ACL tears (522), lateral meniscal tears (269), medial meniscal tears (164), and PCL tears (116). AEs varied among divisions (Division I programs, 1,651,784 AEs; Division II programs, 437,082 AEs; Division III programs, 920,339 AEs). All divisions reported more AEs on natural grass (1,683,534) than artificial turf (1,325,671) (Table 1). Additionally, more AEs during competitions were on artificial turf than natural grass (136,059 vs 133,421 AEs), while more AEs during practices were on natural grass than artificial turf (1,550,113 vs 1,189,612).

Injury rates for all ligament and meniscal tears were significantly higher during competitions as compared with practices. Athletes participating in competitions experienced ACL tears at 10.25 times the rate (RR = 10.25; 95% CI, 8.60-12.21), PCL tears at 10.89 times the rate (RR = 10.89; 95% CI, 7.44-15.97), MCL tears at 12.95 times the rate (RR = 12.95; 95% CI, 11.63-14.42), medial meniscal

TABLE 2
Incidence and Rate Ratios of Knee Injuries During Competitions and Practices During 2004-2005 Through 2013-2014 Seasons[a]

Injury	Total	Competitions	Practices	Competitions vs Practices,[b] RR
ACL tear	1.73 (1.59-1.89)	9.72 (8.58-10.97)	0.95 (0.84-1.07)	10.25 (8.60-12.21)
PCL tear	0.39 (0.32-0.46)	2.23 (1.70-2.87)	0.20 (0.15-0.27)	10.89 (7.44-15.97)
MCL tear	4.62 (4.38-4.87)	28.87 (26.88-30.97)	2.23 (2.06-2.41)	12.95 (11.63-14.42)
Meniscal tear				
Medial	0.54 (0.46-0.64)	2.41 (1.86-3.07)	0.36 (0.29-0.44)	6.68 (4.80-9.22)
Lateral	0.89 (0.79-1.01)	3.90 (3.19-4.72)	0.60 (0.51-0.70)	6.51 (5.05-8.37)

[a]Data are reported as incidence per 10,000 AEs (95% CI). ACL, anterior cruciate ligament; AE, athlete exposure; MCL, medial collateral ligament; PCL, posterior cruciate ligament; RR, rate ratio.
[b]All rate ratios were statistically significant.

TABLE 3
Incidence and Rate Ratios of Knee Injuries on Artificial Turf vs Natural Grass During the 2004-2005 Through 2013-2014 Seasons[a]

Injury	Natural Grass	Artificial Turf	Artificial Turf vs Natural Grass, RR
Competition			
ACL tear	8.92 (7.39-10.67)	10.51 (8.86-12.38)	1.18 (0.92-1.52)
PCL tear	1.12 (0.63-1.85)	3.31 (2.41-4.43)	2.94 (1.61-5.68)[b]
MCL tear	29.31 (26.47-32.36)	28.44 (25.68-31.42)	0.97 (0.84-1.12)
Meniscal tear			
Medial	2.32 (1.58-3.30)	2.50 (1.73-3.49)	1.08 (0.64-1.81)
Lateral	3.82 (2.85-5.03)	3.97 (2.98-5.18)	1.04 (0.69-1.55)
Practice			
ACL tear	0.92 (0.77-1.08)	0.99 (0.82-1.19)	1.08 (0.84-1.39)
PCL tear	0.19 (0.13-0.27)	0.23 (0.15-0.33)	1.21 (0.69-2.12)
MCL tear	2.26 (2.03-2.51)	2.19 (1.93-2.47)	0.97 (0.82-1.14)
Meniscal tear			
Medial	0.35 (0.27-0.46)	0.37 (0.27-0.50)	1.04 (0.68-1.58)
Lateral	0.55 (0.44-0.68)	0.66 (0.53-0.83)	1.21 (0.88-1.66)

[a]Data are reported as incidence per 10,000 AEs (95% CI). ACL, anterior cruciate ligament; AE, athlete exposure; MCL, medial collateral ligament; PCL, posterior cruciate ligament; RR, rate ratio.
[b]Statistically significant rate ratio.

tears at 6.68 times the rate (RR = 6.68; 95% CI, 4.80-9.22), and lateral meniscal tears at 6.51 times the rate (RR = 6.51; 95% CI, 5.05-8.37) as compared with athletes participating in practices (Table 2).

Injury Incidence on Turf vs Grass

During competitions on artificial turf, ACL tears occurred at a rate of 10.51 per 10,000 AEs; PCL tears, 3.31 per 10,000 AEs; MCL tears, 28.44 per 10,000 AEs; medial meniscal tears, 2.50 per 10,000 AEs; and lateral meniscal tears, 3.97 per 10,000 AEs (Table 3). During competitions on natural grass, ACL tears occurred at a rate of 8.92 per 10,000 AEs; PCL tears, 1.12 per 10,000 AEs; MCL tears, 29.31 per 10,000 AEs; medial meniscal tears, 2.32 per 10,000 AEs; and lateral meniscal tears, 3.82 per 10,000 AEs. The rate of PCL tears during competitions on artificial turf was significantly higher as compared with competitions on natural grass (RR = 2.94; 95% CI, 1.61-5.68). No statistically significant difference was found among the rates of ACL, MCL, medial meniscal, and lateral meniscal tears during competitions on turf and grass.

During practices on artificial turf, ACL tears occurred at a rate of 0.99 per 10,000 AEs; PCL tears, 0.23 per 10,000 AEs; MCL tears, 2.19 per 10,000 AEs; medial meniscal tears, 0.37 per 10,000 AEs; and lateral meniscal tears, 0.66 per 10,000 AEs (Table 3). During practices on natural grass, ACL tears occurred at a rate of 0.92 per 10,000 AEs; PCL tears, 0.19 per 10,000 AEs; MCL tears, 2.26 per 10,000 AEs; medial meniscal tears, 0.35 per 10,000 AEs; and lateral meniscal tears, 0.55 per 10,000 AEs. RRs for each injury showed no statistically significant differences among the rates of ACL, PCL, MCL, medial meniscal, and lateral meniscal tears during practices on turf and grass.

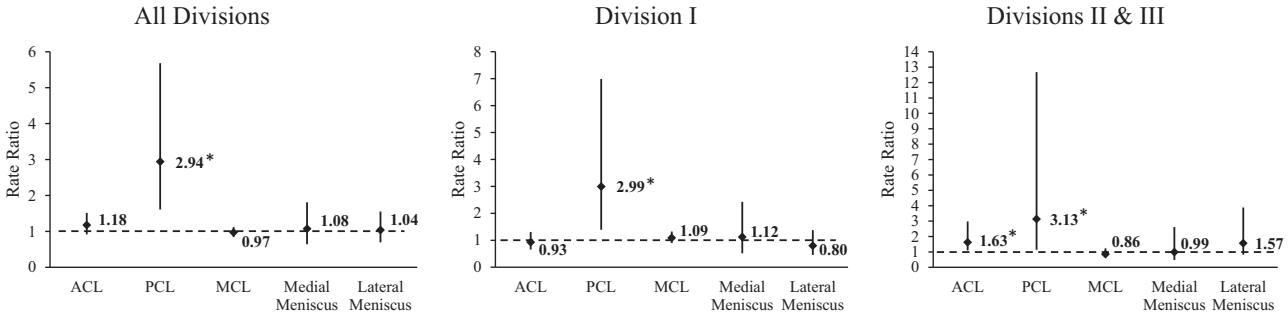

Figure 1. Rate ratios and 95% CIs for artificial turf vs natural grass competition injury rates stratified by level of NCAA competition. Asterisks indicate statistical significance. ACL, anterior cruciate ligament; MCL, medial collateral ligament; NCAA, National College Athletic Association; PCL, posterior cruciate ligament.

Injury Incidence by Level of NCAA Competition

When knee injuries on artificial turf versus natural grass during competitions were stratified by level of NCAA competition, Division I athletes participating in competitions on artificial turf experienced PCL tears at 2.99 times the rate (RR = 2.99; 95% CI, 1.39-6.99) as those playing on natural grass (Figure 1). Division II and III athletes participating in competitions on artificial turf experienced ACL tears at 1.63 times the rate (RR = 1.63; 95% CI, 1.10-2.45) and PCL tears at 3.13 times the rate (RR = 3.13; 95% CI, 1.14-10.69) as those playing on natural grass. These increased injury rates on artificial turf were statistically significant. There was no statistically significant difference in the rates of MCL, medial meniscal, and lateral meniscal tears on artificial turf versus natural grass in Division I or Divisions II and III.

Mechanism of Injury on Turf vs Grass

Contact with another player was the predominant mechanism of injury for all injury types on artificial turf and natural grass. No statistically significant difference was found in the mechanism of ACL, PCL, MCL, medial meniscal, or lateral meniscal injuries on natural grass and artificial turf, indicating that the proportion of injury mechanisms was independent of playing surface (Table 4).

DISCUSSION

Our findings demonstrate an increased risk of PCL injuries associated with playing collegiate football competitions on artificial surfaces. We found significantly increased injury rates for PCL tears on artificial surfaces as compared with natural grass during competitions (RR = 2.94). No statistically significant differences in the rates of any knee injuries on turf versus grass were noted during organized practices. Additionally, injury rates for all knee injuries were significantly higher during competitions versus practices. There was a discrepancy in the effect of artificial turf on injury rates at different levels of NCAA competition. Division I demonstrated a statistically significant increase in injury rate for PCL tears during competitions on artificial turf (RR = 2.99), while Divisions II and III demonstrated statistically significant increases in ACL (RR = 1.63) and PCL (RR = 3.13) injury rates during competitions on artificial turf. Differences in mechanisms of knee injuries on natural grass and artificial turf were not statistically significant.

These findings identify artificial turf as an important risk factor for knee ligament injuries in NCAA football competitions. In particular, PCL injuries showed the greatest increase in injury rates on turf overall, while lower divisions (II and III) also demonstrated increased ACL injury rates on turf. Increased injury rates on artificial turf in lower divisions may stem from differences in athletic ability, rigor of training for injury prevention, equipment, or maintenance of playing surfaces; however, the reason for this discrepancy remains unclear. It is also possible that the increased injury rates seen in lower divisions could be due to inaccurate reporting, by either overreporting in the lower divisions or underreporting in the upper division. Division I athletes may have greater access to sports orthopaedic surgeon subspecialists, whereas lower division athletes may be treated more frequently by nonorthopaedic, nonsports primary care physicians who may overdiagnose injuries.

The findings of this study are consistent with a number of previous studies investigating the effect of playing surface on knee injury rates. Specifically, Dragoo et al[7] and Hershman et al[9] found that athletes playing on artificial turf experienced ACL injuries at 1.39 and 1.68 times the rate as those playing on grass, respectively. In a systematic review, Balazs et al[2] reported similar injury patterns, finding increased rates of ACL injuries on artificial turf in 4 of 6 studies conducted with American football cohorts. A study examining injury rates on synthetic turf during National Football League games by Mack et al[17] revealed that play on synthetic turf resulted in a 16% increase in lower extremity injuries per play than on natural grass. These results demonstrate an association between synthetic playing surfaces and increased knee injuries and

TABLE 4
Mechanism of Injury on Natural Grass vs Artificial Turf Playing Surfaces[a]

	Surface Type		
Injury: Mechanism	Natural Grass	Artificial Turf	*P* Value[b]
ACL tear			.07
Contact: person	56	54	
Contact: surface	4	6	
No apparent contact	35	38	
Other	5	2	
PCL tear			.53
Contact: person	55	50	
Contact: surface	25	36	
No apparent contact	18	13	
Other	2	1	
MCL tear			.95
Contact: person	87	87	
Contact: surface	3	3	
No apparent contact	8	8	
Other	2	2	
Medial meniscal tear			.33
Contact: person	44	50	
Contact: surface	7	3	
No apparent contact	42	35	
Other	7	12	
Lateral meniscal tear			.91
Contact: person	50	46	
Contact: surface	8	10	
No apparent contact	32	34	
Other	10	10	

[a]Data reported as percentages, unless noted otherwise. ACL, anterior cruciate ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

[b]$P \geq .05$ indicates that the proportion of injury mechanisms is independent of playing surface.

are consistent with our findings of increased PCL injury rates during competitions on turf in the NCAA overall and increased ACL injuries on turf during competitions in the lower NCAA divisions (II and III).

Our results are inconsistent with a previous study by Meyers[19] investigating the incidence, mechanisms, and severity of college football injuries, which found a decrease in overall, minor, substantial, and severe injuries on turf. Similarly, a study of high school football injuries by Meyers and Barnhill[20] reported a higher incidence of ACL injuries on natural grass as compared with artificial turf. These studies included only games played on third-generation FieldTurf, perhaps suggesting that this turf type is not associated with increased injury rates. However, studies showing increased rates of knee injuries on artificial turf have included those analyzing games played only on first-generation AstroTurf,[23] only on third-generation FieldTurf,[9] and on all types of turf combined.[7] Additional quality studies that break injury rates down by specific artificial turf type are needed to reconcile discrepancies within the literature and determine if artificial turf indeed increases knee injury rates or if specific turf types are associated with more injuries while others are protective.

This study illustrates the increase of specific knee injury rates on artificial surfaces, and conclusions regarding contributing factors (play type, shoe type, turf type, etc) or the specific mechanism by which artificial turf increases injury risk can only be speculated. The likely mechanism is an increase in traction and a static position of the foot during athletic moves and contact during play on artificial turf. In a study investigating the biomechanics of American football cleats on grass and turf, Kent et al[13] found that while cleats on natural grass experienced force-limiting mechanisms, such as surface divoting or cleat sliding, artificial turf failed to experience acute tearing, resulting in significantly greater forces and torques. The inability of artificial surfaces to divot or shear as a load-limiting mechanism may help explain the increased rates of specific knee injuries on artificial turf observed in this study. Additionally, PCL injuries in our study resulted from contact with the playing surface more commonly than other knee injuries. Perhaps differences in the attenuation and cushioning properties of artificial turf and natural grass contributed to the increased rate of PCL injuries observed on artificial turf. The statistically significant increases in knee injury rates warrant further investigation into why artificial turf increases specific knee injury risk, whether specific turf types increase injury rates while other might be protective, and strategies to improve turf substrates and prevent such injuries.

This study has a number of strengths and limitations. This is the largest study to date investigating the effect of artificial playing surfaces on the incidence of knee injuries in NCAA football. Previous studies compared lower extremity injury rates on grass and artificial turf; however, these studies grouped all knee injuries, focused on 1 particular injury (eg, ACL), or were limited by small sample size.[7,9,19-21] By evaluating each injury type individually, we were able to compare rates of 5 distinct knee injuries on natural grass and artificial turf over the course of 10 NCAA football seasons, which included a total of 3,009,205 AEs. Unlike previous studies that focused primarily on ACL and occasionally MCL injuries, this study provides data on the previously uncharacterized associations between playing surface and PCL injury rates. Additionally, by stratifying injury rates by event type, we avoided the confounding effects of the disproportionate number of competition AEs that took place on artificial turf. Competitions had significantly higher injury rates than practices, and failing to control for this variable in a comparison of injury rates on turf and grass would have artificially increased apparent injury rates on artificial turf.

Study limitations include that our findings can be applied only to specific knee injuries occurring among Division I, II, and III NCAA football athletes. Additionally, AEs in this data set were defined as participation in an event rather than the actual time played in an event, and AEs during practices were not further classified according to practice intensity or contact/noncontact practices. Given the nature of this extremely large database, it was not possible to discern whether injuries to ligaments or menisci were complete or partial tears. All injuries, whether partial or complete tears, were analyzed as 1 injury type.

Similarly, each injury type was analyzed separately regardless of whether an injury occurred in isolation of or in conjunction with other injury types. Because injuries that may have occurred in conjunction were counted individually (eg, each component of an ACL, MCL, and medial meniscal injury were counted separately), the total incidence of knee injuries in general cannot be accurately portrayed, as it would be artificially inflated. However, the incidence of each specific knee injury remains accurate, as each injury type was counted only once.

Additionally, the NCAA ISS collects data that are voluntarily submitted by various athletic programs; therefore, a substantial number of programs could not be included in our analysis. A total of 9.74% of NCAA programs from the 2004-2005 through 2008-2009 academic years and 3.87% of NCAA programs from the 2009-2010 through 2013-2014 academic years participated in NCAA ISS data collection. Programs were also required to submit at least 8 weeks of data, which did not have to come from consecutive weeks. Thus, programs could have theoretically withheld data from weeks with particularly high injury rates, therefore artificially decreasing our reported knee injury incidence rates. Because the NCAA ISS is a voluntary system, competitive athletic programs that are more protective of their injury data may have been less inclined to submit data. However, because all data submitted to the NCAA ISS is completely deidentified, there is no clear incentive for programs to intentionally withhold data from weeks with high injury rates or altogether. Overall, this decade of injury data comes from only a portion of the NCAA each season and therefore may not be completely representative of college football as a whole. However, with 10 seasons of data from all 3 NCAA divisions and with >3 million AEs reported, this analysis includes a greater proportion of NCAA exposures and injuries than any previous study investigating the effect of playing surface on athletic injuries.

Finally, turf surfaces vary widely in quality and composition, and specific product lines and surface types could not be isolated within our data. All turf surfaces, whether first, second, or third generation, were recorded simply as artificial turf surfaces by the NCAA ISS database. This is perhaps the greatest limitation of this study, as we cannot determine if all types of artificial turf are associated with increased rates of specific knee injuries or if some types of turf are associated with increased injury rates while other types are protective. Additional studies are needed to further characterize the effects of specific turf types on knee injuries in college football. Despite these limitations, the NCAA ISS remains a powerful and highly regarded tool that has been used extensively to examine injury trends in collegiate sports.

CONCLUSION

Our findings add to the growing body of evidence that playing collegiate football on artificial turf surfaces is associated with increased rates of specific knee injuries. With the increasing popularity of artificial turf, it is important that the effect of these surfaces be thoroughly investigated to further player safety. It is our hope that this study will spur research examining the risks associated with artificial turf and whether specific turf surfaces are associated with more injuries while others are protective. Additional information regarding these surfaces and how they affect the athletes who play on them will encourage the development of innovative football playing surfaces that bolster athletic performance while minimizing athletic injuries.

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