

Epidemiology of Anterior Cruciate Ligament Injury on Natural Grass Versus Artificial Turf in Soccer

10-Year Data From the National Collegiate Athletic Association Injury Surveillance System

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Background: Anterior cruciate ligament (ACL) injury is prevalent among National Collegiate Athletic Association (NCAA) soccer players. Controversy remains regarding the effect of the surface type on the rate of ACL injury in soccer players, considering differences in sex, type of athletic exposure, and level of competition.

Hypothesis: Natural grass surfaces would be associated with decreased ACL injury rate in NCAA soccer players. Sex, type of athletic exposure (match vs practice), and level of competition (Division I-III) would affect the relationship between playing surface and ACL injury rates.

Study Design: Cohort study; Level of evidence, 3.

Methods: Using the NCAA Injury Surveillance System (ISS) database, we calculated the incidence rate of ACL injury in men and women from 2004-2005 through 2013-2014 seasons. The incidence was normalized against athletic exposure (AE). Additional data collected were sex, athletic activity at time of injury (match vs practice), and level of competition (NCAA division) to stratify the analysis. Statistical comparisons were made by calculating incidence rate ratios (IRR). Statistical significance was set at an alpha of .05.

Results: There were 30,831,779 weighted AEs during the study period. The overall injury rate was 1.12 ACL injuries per 10,000 AEs (95% CI, 1.08-1.16). Women comprised 57% of the match data (10,261 games) and 55% of practice data (26,664 practices). The overall injury rate was significantly higher on natural grass (1.16/10,000 AEs; 95% CI, 1.12-1.20) compared with artificial turf (0.92/10,000 AEs [95% CI, 0.84-1.01]; IRR, 1.26 [95% CI, 1.14-1.38]) ($P < .0001$). This relationship was demonstrated consistently across all subanalyses, including stratification by NCAA division and sex. The injury rate on natural grass (0.52/10,000 AEs; 95% CI, 0.43-0.61) was significantly greater than the injury incidence during practice on artificial turf (0.06/10,000 AEs; 95% CI, 0.043-0.096). Players were 8.67 times more likely to sustain an ACL injury during practice on natural grass compared with practice on artificial turf (95% CI, 5.43-12.13; $P < .0001$). No significant difference was found in injury rates between matches played on grass versus turf (IRR, 0.93; 95% CI, 0.84-1.03; $P = .15$).

Conclusion: NCAA soccer players who practice on natural grass have increased risk of ACL injury compared with the risk of those practicing on an artificial surface, regardless of sex or NCAA division of play. No difference in risk of ACL injury between playing surfaces was detected during matches. Further research is necessary to examine the effect of multiple factors when evaluating the effect of the surface type on the risk of ACL injury in soccer players.

Keywords: soccer; surface; artificial; natural; ACL; injury

Proponents for artificial turf have argued improved durability, more consistent field conditions, and overall lower long-term costs.²² However, one significant concern is whether these synthetic surfaces increase the rate of lower extremity injury among athletes, which has been the subject of debate for many years. Although biomechanical studies have generally supported increased frictional forces on all types of artificial turf, clinical studies have demonstrated inconclusive results.^{6,19-21}

The National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) began its first web-based program in 2004 to track injury and exposure data from participating NCAA institutions in order to better assess injury rates and to identify the risk factors contributing to these injuries. Much of the evidence regarding the effect of the field surface on injury rates has originated from studies examining NCAA and National Football League football players, but less literature exists regarding soccer players.^{1,6,12,18,19,21} Among NCAA soccer athletes, lower extremity injuries, specifically anterior cruciate ligament (ACL) injuries, are among the most common form of sustained musculoskeletal injury.¹⁵

Regarding soccer, a systematic review showed that artificial grass did not increase the risk of injury compared with natural grass, but study heterogeneity limited the validity of the results.²³ Calloway et al⁴ recently reported no difference in overall injury rate or knee injury rate of elite soccer players who played on artificial turf versus natural grass. Similarly, in a study of elite soccer players, Ekstrand et al⁷ did not find any differences in the risk of acute knee injury during practice or games based on the type of surface played. In an attempt to clarify risks related to field surfaces, recent studies have attempted to examine additional potential risk factors contributing to overall injury rates and/or ACL injuries among soccer athletes, including demographic variables, type of shoe, weather conditions, level of competition, and others.^{4,9,11,15,16,23} None of the existing studies has focused on the risk of ACL injury in athletes of all NCAA divisions based on the surface played, nor have investigators examined whether the level of expertise (defined by the division) affects this risk.

The purpose of this study is to investigate the role of playing surface on the incidence and risk of ACL injury in collegiate soccer athletes through use of the NCAA ISS. We hypothesized that natural grass surfaces would be associated with decreased ACL injury rates. We also hypothesized that sex, type of athletic exposure (match vs

practice), and level of competition (Division I-III) would affect the relationship between playing surface and ACL injury rates.

METHODS

The NCAA ISS is a web-based database that collects reportable injury data from athletic trainers of participating institutions throughout the academic year. A reportable injury is defined as one that occurred as a result of participation in organized intercollegiate practice or competition, required evaluation by an athletic trainer or physician, and resulted in the restriction of the student-athlete's participation for 1 or more days beyond the injury.⁸ Although the severity of injuries and details of the diagnosis are not reported in the database, it provides information regarding type of injury, playing conditions during the time of injury, play time lost, and time of season. From 2003-2004 onward, all NCAA ISS data are weighted and poststratified by division and year in order to adjust for underreporting and to account for year-to-year variations. Further adjustment of data weights is achieved by scaling up weighted counts by a factor of 0.883⁻¹.

We examined the men's and women's soccer injury data set for the 2004-2005 through 2013-2014 seasons using the "anterior cruciate ligament (ACL)" injury code to calculate the incidence of injury after applying NCAA-provided sample weights. The ISS collects data on injuries and exposures that occurred in organized practice and competitions from the first day of preseason to the final postseason competition.⁸ The incidence was normalized against athletic exposure (AE), which was defined as 1 student-athlete participating in 1 NCAA-sanctioned practice or competition in which the athlete was exposed to the possibility of athletic injury.¹⁴ In addition to collecting information about the playing surface type (natural or artificial), we collected data regarding sex, athletic activity at the time of injury, and NCAA division to stratify the analysis. Included data points were categorized under the following types of surface: "natural grass," "grass," "artificial fill," "artificial no fill," "field turf," "other turf," and "synthetic." Data points excluded were those reported under the following surface types: "not specified," "other," "indoors," "water," and "track/trail."

Statistical comparisons were made by calculating incidence rate ratios (IRR).^{5,17} Statistical significance was set

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Ethical approval for this study was obtained from the University of Southern California Health Sciences Institutional Review Board (proposal HS-15-00063).

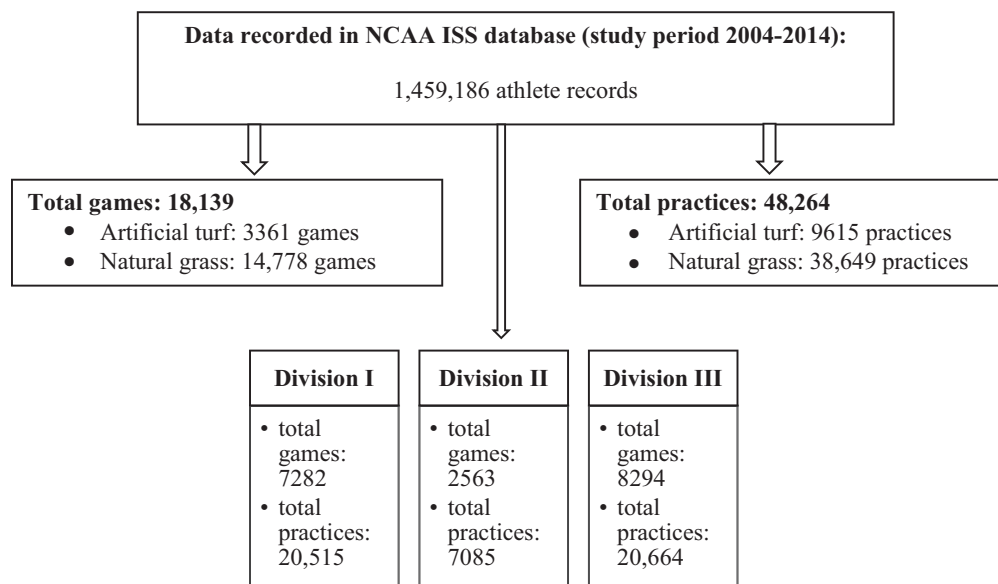


Figure 1. Flow chart presenting the data collection process using the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) database.

at an alpha of .05. The data analysis was performed using Microsoft Excel (Microsoft Corp), as well as MedCalc Statistical Software (Version 19.4.1, MedCalc Software BBVA).

RESULTS

Data from 1,459,186 total athlete records were collected and reported during the 10-year study period between 2004 and 2014 across all 3 NCAA divisions for collegiate soccer. During the study period, 18,139 games and 48,264 practices were recorded and logged. Of the total games, 3,361 were played on artificial turf, and 14,778 were played on natural grass. A total of 9615 practices were held on artificial turf, and 38,649 practices were held on natural grass. Women comprised 57% of the match data (10,261 games) and 55% of practice data (26,664 practices). There were 7282 games and 20,515 practices at the Division I level; 2563 games and 7085 practices at the Division II level; and 8294 games and 20,664 practices at the Division III level (Figure 1).

Overall ACL Injury Rates

A total of 3449 ACL injuries, occurring during either matches or practice, were reported during the 10-year collecting period between 2004 and 2014 across all 3 NCAA divisions for collegiate soccer, adjusted by the ISS weighting criteria. Of the total injuries, 2401 ACL injuries occurred during matches, and 1048 ACL injuries occurred during practice. There were 30,831,779 total weighted AEs during this time. The overall injury rate consisting of injuries occurring during matches or practice was 1.12 ACL injuries per 10,000 AEs (95% CI, 1.08-1.16) during the 10-year period. The overall injury rate was significantly higher on natural grass (1.16/10,000 AEs; 95% CI, 1.12-1.20)

TABLE 1
Overall Anterior Cruciate Ligament Injury IRs and IRRs on Natural Grass Versus Artificial Turf^a

	Natural Grass IR per 10,000 AEs	Artificial Turf IR per 10,000 AEs	IRR (95% CI)	P
Match	3.40	3.66	0.93 (0.84-1.03)	.15
Practice	0.52	0.06	8.67 (5.43-12.13)	<.0001

^aAE, athletic exposure; IR, incidence rate; IRR, incidence rate ratio.

compared with artificial turf (0.92/10,000 AEs [95% CI, 0.84-1.01]; IRR, 1.26 [95% CI, 1.14-1.38]) ($P < .0001$). Overall, matches produced significantly more ACL tears than did practice, with a 7.86-fold increase in incidence during matches (Table 1, Figure 2). Broken down further, of the 2401 ACL injuries that occurred during matches, 1926 were on natural grass, and 475 were on artificial turf. We found no significant difference in injury rates between matches played on grass versus turf (IRR, 0.93; 95% CI, 0.84-1.03; $P = .15$). The incidence rate (IR) during matches played on natural grass (3.40/10,000 AEs; 5,663,152 AEs; 95% CI, 3.25-3.56) was found to be nearly equivalent to the IR for matches played on artificial surfaces (3.66/10,000 AEs; 1,297,213 AEs; 95% CI, 3.34-4.01). However, natural grass practice led to significantly more ACL injuries compared with injuries during practice on turf. Of the 1048 ACL injuries that occurred during practice, 1021 were on natural grass, and 27 were on artificial turf. The IR on natural grass (0.52/10,000 AEs; 95% CI, 1.11-1.26) was found to be significantly greater than the IR during practice on artificial turf (0.06/10,000 AEs; 95% CI, 0.043-0.096). Players

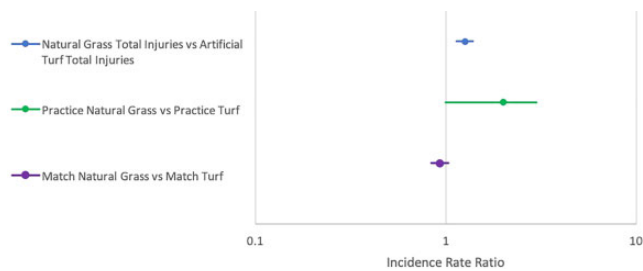


Figure 2. Forest plot of incidence rate ratios based on competition type given surface type.

TABLE 2
Anterior Cruciate Ligament Injury IRs and IRRs Based on NCAA Division, Given Both Type of Athletic Exposure (Match vs Practice) and Playing Surface^a

	Natural Grass IR per 10,000 AEs	Artificial Turf IR per 10,000 AEs	IRR (95% CI)	P
Division I				
Match	2.50	2.87	0.87 (0.67-1.13)	.27
Practice	0.93	0.12	7.69 (4.55-14.17)	<.0001
Division II				
Match	4.71	2.56	1.85 (1.45-2.38)	<.0001
Practice	0.33	0	NA	NA
Division III				
Match	2.78	3.97	0.70 (0.61-0.80)	<.0001
Practice	0.28	0.05	5.28 (3.03-10.05)	<.0001

^aAE, athletic exposure; IR, incidence rate; IRR, incidence rate ratio; NA, not applicable; NCAA, National Collegiate Athletic Association.

were 8.67 times more likely to sustain an ACL injury during practice on natural grass compared with practice on artificial turf (95% CI, 5.43-12.13; $P < .0001$).

ACL Injury Rates by NCAA Division

The data set was first stratified by NCAA division of competition (Table 2, Figure 3). In Division I, the highest level of competition, there were 549 total match injuries for 2,164,048 AEs. Of the 549 injuries, 480 occurred on grass, and 69 occurred on turf. There was an IR of 2.5 injuries per 10,000 exposures on natural grass, and an IR of 2.87 injuries per 10,000 exposures on artificial turf during match play. These results demonstrated no significant difference in injury incidence during matches on natural grass and artificial turf (IRR, 0.87; 95% CI, 0.67-1.13; $P = .27$). However, from the 603 ACL injuries occurring during practice, we found that Division I athletes were 7.69 times more likely to sustain said ACL injury on natural grass than artificial turf during practice (95% CI, 4.55-14.17; $P < .0001$).

For Division II athletes, there were 668 match injuries across 1,702,961 athletic match exposures on natural grass (4.71 injuries per 10,000 AEs). With only 73 ACL injuries

among 285,775 AEs during matches on artificial turf, this IR was significantly greater than the IR during matches on artificial turf (2.56 injuries per 10,000 AEs; IRR, 1.85; 95% CI, 1.45-2.38; $P < .0001$). No injuries were reported for practice on artificial surfaces in Division II athletes.

Division III reported 1111 injuries during matches, which was the largest number of injuries during matches. The 778 injuries on natural grass produced an IR of 2.78 injuries per 10,000 AEs on natural grass, and the remaining 333 injuries on turf yielded an IR of 3.97 injuries per 10,000 AEs during match play. Injuries were 1.42 times more likely on artificial turf than on natural grass during matches (95% CI, 1.13-1.89; $P < .0001$). However, data from 258 injuries during Division III practice showed that players were 5.28 times (95% CI, 3.03-10.05; $P < .0001$) more likely to sustain injury during practice on natural grass (0.28 injuries per 10,000 AEs; 245 injuries; 8,811,382 AEs) than on artificial turf (0.05 injuries per 10,000 AEs; 13 injuries; 2,466,188 AEs).

When we compared Division I and Division III data, the IR of ACL injury was significantly higher in Division I players compared with Division III athletes when practicing on natural grass ($P < .001$), but this rate was not different between Division I and Division III players during training on artificial grass ($P = .08$). In contrast, during matches, Division III players were found to have a higher IR of ACL injury on artificial turf ($P < .001$), but there was no difference in the rate of ACL injury on natural grass compared with that of Division I players ($P = .22$).

ACL Injury Rates by Sex

Finally, the data were stratified by sex (Table 3, Figure 4). Overall, men accounted for 831 of the total 3449 ACL injuries (24.1%) in the database for an incidence of 0.53 injuries per 10,000 AEs. Women accounted for the remaining 2618 injuries (76%) in the database, with an incidence of 1.58 injuries per 10,000 AEs. For both men and women, injury rates during practice on natural grass were significantly greater than rates on artificial turf. Men were 3.03 times more likely to sustain an injury on natural grass during practice than on artificial turf (95% CI, 1.75-5.66; $P < .0001$). Women were 11.13 times more likely to sustain an injury on natural grass during practice than on artificial turf (95% CI, 6.47-20.99; $P < .0001$). A small difference was found between injury rates during matches on natural grass and artificial turf for both sexes. Men were 0.82 times more likely to sustain an injury on natural grass during a match than on artificial turf (95% CI, 0.69-0.97; $P = .03$). In a similar trend, women were 0.85 times more likely to sustain an injury on natural grass during a match than on artificial turf (95% CI, 0.75-0.96; $P = .0083$).

DISCUSSION

This study found an increased absolute risk of ACL injury in NCAA soccer players during practice on natural grass compared with that on artificial turf, although the difference in risk was small (1.26 vs 0.93 per 10,000 AEs,

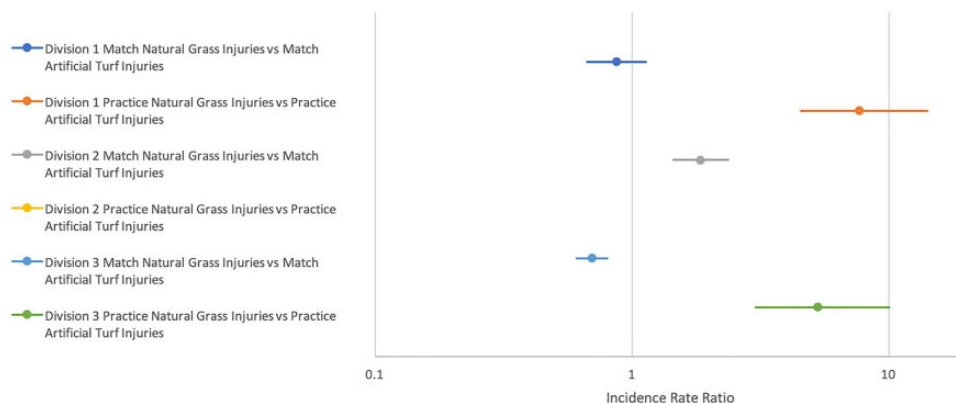


Figure 3. Forest plot of incidence rate ratios based on National Collegiate Athletic Association division, given both competition type and playing surface.

TABLE 3
Anterior Cruciate Ligament Injury IRs and IRRs Based on Sex, Given Both Competition Type and Playing Surface^a

	Natural Grass IR per 10,000 AEs	Artificial Turf IR per 10,000 AEs	IRR (95% CI)	P
Men				
Match	1.98	2.41	0.82 (0.69-0.97)	.03
Practice	0.18	0.06	3.03 (1.75-5.66)	<.0001
Women				
Match	4.45	5.26	0.85 (0.75-0.96)	.0083
Practice	0.83	0.07	11.13 (6.47-20.99)	<.0001

^aAE, athletic exposure; IR, incidence rate; IRR, incidence rate ratio.

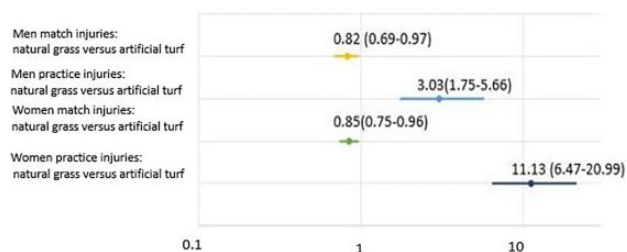


Figure 4. Forest plot of incidence rate ratios and 95% CIs based on sex, given both competition type and playing surface.

respectively). During practice, in all NCAA divisions, ACL injuries were more likely to occur on natural grass compared with artificial turf. However, during matches, Division III athletes were more likely to sustain an ACL injury on artificial turf, whereas Division II athletes had a significantly increased incidence of ACL injury on natural grass. An important secondary finding was that female soccer players were 11.13 times more likely to sustain an injury on natural grass than on artificial turf during practice, whereas male athletes were 3.03 times more likely to

sustain an injury on natural grass than on artificial turf during practice.

Our results differ from a recent systematic review by Balazs and colleagues,² who examined the effect of playing surface on the incidence of ACL injuries in professional football and soccer players. Their analysis included 4 soccer studies with a total of 143 ACL injuries, with no breakdown between match play versus practice. None of the soccer investigations demonstrated a statistically significant difference in the rates of ACL injuries among various playing surfaces. Gans et al⁹ reported higher rates of ACL rupture during competition compared with practice in both male and female soccer athletes, but women were more likely to experience a recurrent ACL rupture during practice. However, Gans et al did not examine the type of surface played, and therefore a comparison with our study results is irrelevant. We did not report whether the ACL injury was primary or recurrent, which might be a limitation of our analysis.

As mentioned above, Calloway et al⁴ found no difference in the rate of total knee injuries and ACL injuries between elite soccer players competing on artificial turf versus natural grass during matches, which is in agreement with our results. In contrast, during practice, we found a higher incidence of ACL injuries on natural grass compared with artificial turf. Also, our study population consisted of collegiate athletes, whereas an elite soccer player cohort might represent a broader spectrum of athlete ages. The current study was injury-specific and had the advantage of stratifying the epidemiologic data involving the type of surface played based on the type of activity (match vs practice), sex, and level of competition by NCAA division.

In an attempt to further elucidate factors influencing ACL injury rates, we analyzed injury rates by sex. Women accounted for >75% of reported ACL injuries, which is concordant with previously reported epidemiologic data.^{3,13} Both men and women were at increased risk of ACL injury during practice on natural grass compared with artificial turf, with IRs of 3.03 and 11.13, respectively. The risk of acute knee injury in male and female soccer players was similar in a study by Ekstrand et al,⁷ regardless of playing

surface (natural vs artificial) or level of competition (match vs practice). However, those results were not specific to ACL injury, in contrast to the current study. Meyers¹⁵ reported no difference in knee trauma rates in female soccer players who played on FieldTurf versus natural grass. In that study, the IR of ACL and associated tissue injuries combined ranged between 26% and 29% for both surfaces. Meyers reported that FieldTurf might be safer overall than natural grass for collegiate male soccer players; however, the knee injury rate did not differ based on the type of surface played. Both studies by Meyers^{15,16} focused exclusively on injuries during matches, whereas in the current study, we included data from practice as well. Our study population, however, was similar to the study by Meyers et al, and we found no difference in overall ACL injury rate on artificial surface versus natural grass during matches. In addition, our study did not specify the type or the generation of artificial surface, whereas Meyers^{15,16} reported the results on FieldTurf artificial surface.

We examined the incidence of ACL injury based on NCAA division during matches and practice in both types of field surface, and the results were interesting. For Division III athletes, an ACL injury during matches was more likely to occur on artificial turf. In contrast, players in Division II were more likely to sustain such an injury when competing on natural grass. Regarding the incidence of ACL injury during practice, both Division I and Division III athletes were more likely to be injured when training on natural grass compared with artificial turf. No injuries were reported for practice on artificial turf for Division II athletes, which may have skewed our subanalyses of injury rates for Division II athletes. Although the level of expertise (which is higher in Division I athletes) might play a role in the incidence of injuries during competition, the discrepancy in the risk of ACL injury when competing on a natural versus artificial field based on NCAA division is difficult to interpret. Harmon and Dick¹⁰ attempted to assess the effect of the NCAA division on ACL injury in female basketball players and found no relationship between “skill level” as assessed by NCAA division and ACL injury rate. One possible explanation of the higher rate of ACL injury on natural grass in practice but not in games could be the condition of the athletes, who might experience increased levels of fatigue during practice compared with games. In addition, natural grass might not be as well-maintained in training fields compared with game fields, where more attention is likely to be paid to keep the fields in good condition for the competing athletes. To our knowledge, no additional studies have reported the effect of the level of competition based on NCAA division played in collegiate athletes, and further research is necessary to explain the above findings.

A strength of our study is the use of the NCAA ISS database, which has provided a large sample size to assess ACL injury IRs when compared with that in previous studies examining this topic. Additionally, our study was sport-specific and injury-specific, which allowed for the examination of multiple variables. However, our study has the inherent limitations of a retrospective database study. We found an increased overall risk for ACL injury on natural

grass compared with artificial turf, with the difference in risk being statistically significant (1.16 vs 0.92; $P < .0001$). However, the clinical value of this finding is questionable because the difference in risk is relatively small and the statistical difference was likely the result of our large study population. Given the fact that far more games and practices were held on natural grass, this analysis may involve a type B error. Additionally, the NCAA ISS database is a voluntary reporting system, which may not account for the actual injury IR among NCAA soccer athletes. Furthermore, our study was unable to control for confounding factors, such as shoe type, rest time, field conditions, and type of synthetic field, as they are not recorded within the NCAA ISS database. Although we do not have evidence, we believe that athletic trainer coverage is not as thorough, especially with practice, at the Division II and III levels. The lack of any ACL injuries during practice in Division II suggests that there is probably a significant underreporting of ACL injuries during practice at the lower NCAA divisions. Similarly, the quality of both grass and synthetic fields may differ among Divisions I through III because of financial constraints at the lower divisions. Last, we did not subclassify the injuries as primary or recurrent events, which would be helpful information for orthopaedic surgeons. Overall, our study provides new information regarding ACL injury rates in NCAA soccer athletes, demonstrating an increased absolute risk of ACL injury in NCAA soccer players during practice on natural grass compared with artificial turf. Further studies are needed to investigate the validity of our results, as well to assess any possible confounding factors that may not be captured within the NCAA ISS database.

CONCLUSION

NCAA soccer players who practice on natural grass have an increased risk of ACL injury compared with that of those practicing on an artificial surface, regardless of sex or NCAA division. No difference in risk of ACL injury was detected during matches. Further research is necessary to examine the effect of multiple factors when evaluating the effect of the surface type on the risk of ACL injury in soccer players.

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