Comparing Sports-Related Orthopedic Injury Trends on Artificial Turf and Natural Grass: A 20-Year Nationwide Analysis of the NEISS Database

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ABSTRACT

OBJECTIVES: The impact of playing surfaces on sports-related injuries remains a subject of debate, with limited research comparing injury patterns across various sports and competition levels.

METHODS: This study utilized the National Electronic Injury Surveillance System (NEISS) database from 2004 to 2023. Sports-related injuries that occurred on artificial turf and natural grass playing surfaces were identified and analyzed.

RESULTS: Of 21,868 injuries, 76.3% occurred on grass and 23.7% on turf. Rugby (OR: 8.35) and lacrosse (OR: 8.42) injuries were more common on turf, while soccer and softball injuries were more frequent on grass. Dislocations (OR: 4.73) and lacerations (OR: 5.41) were more likely on grass, while strains/sprains (OR: 1.16) and contusions (OR: 1.96) were more common on turf.

CONCLUSION: This study reveals significant variations in injury patterns that occur on artificial turf and natural grass playing surfaces across various sports and age, providing valuable evidence on the potential risks and differences in injury patterns associated with each surface.

KEYWORDS: sports medicine; turf; grass; injury epidemiology; playing surfaces; sports injury

INTRODUCTION

In the United States, over 8.5 million individuals participate in high school and collegiate athletics each year, with an additional 10,000–15,000 athletes competing at the professional level.[1,2] Prior literature has estimated that 90% of high school athletes suffer at least one injury during their playing career, with 30–40% suffering multiple injuries.[3] The prevalence of injuries is particularly high in contact sports, affecting 75–80% of high school and 66–75% of collegiate athletes.[2-4] Given the high incidence of injuries among athletes, the identification of risk factors for injury and the implementation of appropriate prevention strategies is crucial. One recent area of focus has been the impact of playing surfaces on injury rates, particularly the comparison between natural grass and artificial turf. Despite these concerns, definitive conclusions about the injury risks of artificial turf remain unclear due to heterogeneity in study design and inconsistent findings regarding injury epidemiology across surfaces.[5-12]

While sports have traditionally been played on natural grass, artificial turf, first introduced in the 1960s, has gained popularity as an alternative to grass playing surfaces due to its lower maintenance costs and long-term durability. Current literature states that artificial turf systems are less compliant and thus stiffer than grass counterparts, leading to an overall decrease in shock absorption.[13] This decreased shock absorption is thought to inflict a greater rebound force on athletes leading to greater injury risk; however, the validity of this claim is debated and this effect may vary greatly with the type of turf used.[13]

Prior studies regarding the epidemiology of injuries sustained on artificial turf and natural grass surfaces have demonstrated variable results, depending on factors such as sport type, level of competition, artificial turf subtype, and whether an athlete is practicing or competing in a game.[14–22] As the use of artificial surfaces continues to increase, understanding the impact of these playing surfaces on athlete health is pivotal to addressing the high injury rates among athletes and between different sports. Therefore, our limited understanding of the impact of playing surfaces on athlete injury warrants further investigation.

The current study conducts a population-level analysis to compare sports-related injury rates on artificial turf and natural grass surfaces, seeking to provide a comprehensive breakdown of specific risk factors and injury patterns that may inform injury prevention strategies. We hypothesize that the distribution of injury location and injury type will differ considerably between the two playing surfaces. These findings will provide valuable information for athletic programs considering surface transitions and enable the implementation of targeted preventative measures.

MATERIALS AND METHODS

Data Collection

This retrospective cross-sectional analysis utilized data from the US Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS) over a 20-year study period from 2004 to 2023.[23] The NEISS database compiles data from a nationally representative sample of 100 hospital emergency departments. Each case includes pertinent patient- and encounter-level details from emergency departments. The NEISS database has been consistently used in several prior nationally representative orthopedic studies as a reliable source for analyzing injury epidemiology.[24-31]

Over the 20-year study period, the NEISS recorded 7,306,740 cases, representing a total of 269,671,422 nationally estimated cases. To isolate the relevant cases, injuries occurring in a place of recreation or sports (NEISS location code = 9) and injuries occurring specifically while playing a sport, as specified by the sport activity codes provided by the NEISS coding manual were isolated, leaving a total of N =19,835,980 sport-related cases.[32] To focus on orthopedic injuries, we excluded cases where the injured body part was the eyeball, head, mouth, face, ear, internal organs, pubic region, or other non-specific areas, leaving a total of N = 15,690,498 cases for investigation. The "Narrative" cases for this isolated group were then queried for "turf" or "grass." Cases where the narrative mentioned "turf" but not "grass" were considered "turf" cases. Cases where the narrative mentioned "grass" but not "turf" were considered "grass" cases. Narratives that mentioned both or neither were excluded. Remaining narratives were manually reviewed to ensure that the remaining cases included an accurate and relevant sport-related, turf-or-grass-related, orthopedic injury. This left us with N = 681 cases, representing a nationally estimated N = 21,868 cases, comprising N = 5,184 injuries occurring on turf and 16,684 injuries occurring on grass.

Data for each case include variables such as treatment date, patient age, sex, race, diagnosis, injured body part, patient outcome, place of injury, and two narrative descriptions. Age was categorized into the following groups: under 5, 5–14, 15–24, 25–44, 45–64, 65 and older. Injury data were categorized according to NEISS's coding system, which assigns to each case a diagnosis and injured body region. For example, a shoulder dislocation while playing rugby would be coded as: body part = 30 (shoulder); diagnosis = 55 (dislocation); activity/product code = 3234 (rugby). The NEISS does not use ICD-9 or ICD-10 diagnostic codes. Instead, it utilizes a proprietary coding system to categorize diagnosis types and body parts affected, allowing for standardized national surveillance and injury mechanism analysis.[32] Diagnoses included strain/sprain, contusion/abrasion, laceration/puncture, dislocation, fracture, burn, and "other." The NEISS dataset uses broad categories to describe the anatomical locations of fractures, which may encompass more specific fracture sites. For the upper extremity, fractures in the lower arm may involve the radius or ulna in the forearm. In the upper arm, the humerus may be fractured at the proximal, shaft, or distal sections. Elbow fractures can affect the distal humerus, proximal ulna, or proximal radius, including the olecranon or radial head. Finger fractures may involve the phalanges (proximal, middle, or distal) of specific digits, while hand fractures often involve the metacarpal bones. Neck fractures may involve the cervical vertebrae, whereas shoulder fractures may affect the clavicle, scapula, or proximal humerus. Wrist fractures may involve the distal radius, distal ulna, or carpal bones. For the lower extremities, ankle fractures may involve the distal tibia, distal fibula, or talus. Foot fractures may affect the tarsals, metatarsals, or phalanges. Knee fractures may involve the patella, distal femur, or proximal tibia, while lower leg fractures can affect the tibia or fibula, either in the shaft or distal ends. Upper leg fractures may involve the femur, specifically the proximal femur (hip), femoral shaft, or distal femur near the knee. Toe fractures may affect the phalanges (proximal, middle, or distal) of specific digits. For the trunk, fractures in the lower trunk may involve the lumbar spine, sacrum, coccyx, pelvis, or nearby bones. Upper trunk fractures may affect the thoracic spine, clavicle, scapula, ribs, or adjacent structures.

Statistical Analysis

Student's *t*-test and *chi*-square analyses were used to compare demographics between the artificial turf and natural grass cohorts. For each comparison, odds ratios and their respective 95% confidence interval (CI) were utilized to compare the likelihood of specific events occurring on turf versus grass. All statistical analyses were performed using Stata Statistical Software 18.0 (College Station, TX: StataCorp LLC). Following CPSC guidelines, statistical analyses, and tests were performed using weighted sampling techniques applied to the injuries, with the Survey Estimation Module in Stata used to account for the survey design of the NEISS database, including sampling strata and clustering variables. A p-value of <0.05 was determined to represent statistical significance.

RESULTS

A total of 21,868 sports-related injuries were identified with 16,684 (76.3%) injuries occurring on natural grass and 5,184 (23.7%) injuries occurring on artificial turf [**Table 1**]. There were no statistically significant differences in age or sex between the natural grass and artificial turf cohorts. The average age of athletes with injuries occurring on natural grass was 25.4 years old compared to 21.4 years old for athletes injured on artificial turf. This age difference was not statistically significant (p = 0.41). Both groups were predominantly male with 73.9% of athletes being male in the natural grass group and 82.2% males in the artificial turf group. The identified injuries were primarily sustained by white athletes (46.7%); a full demographic breakdown is provided in **Table 1** and **Figure 1**.

Injuries on artificial turf playing surfaces were most prevalent in football (53.2% of injuries) followed by soccer (29.8%) and rugby (4.9%) [**Table 2**]. When compared to injury rates on grass, rugby and lacrosse injuries were 8.35

and 8.42 times more likely on turf (p <0.01), respectively, whereas football injuries were 2.49 times more likely on turf (p <0.01). Injuries sustained on natural grass playing surfaces were most prevalent among soccer (35.4%), football (31.1%), and softball (7.7%) players. Compared to injury rates on turf surfaces, there was a higher injury rate on grass among athletes playing softball and soccer (p = 0.012).

Table 1. Demographics and Descriptive Statistics

	Grass	Turf
Total N = 21,868	N = 16,684 (76.29%)	N = 5,184 (23.71%)
Mean Age	25.41	21.37
Sex	N (%*)	N (%*)
Female	4,347 (26.06)	924 (17.83)
Male	12,337 (73.94)	4,260 (82.17)
Race		
White	8,248 (49.44)	1,968 (37.97)
Black/African American	1,337 (8.02)	713 (13.74)
Asian	204 (1.22)	20 (0.38)
American Indian/ Alaska Native	74 (0.45)	55 (1.06)
Not stated	2,009 (12.04)	525 (10.13)
Other	4,810 (28.83)	1,904 (36.72)

*Represents the column percentage of either total turf or total grass injuries.

Figure 1A. Age distribution of injuries: Turf

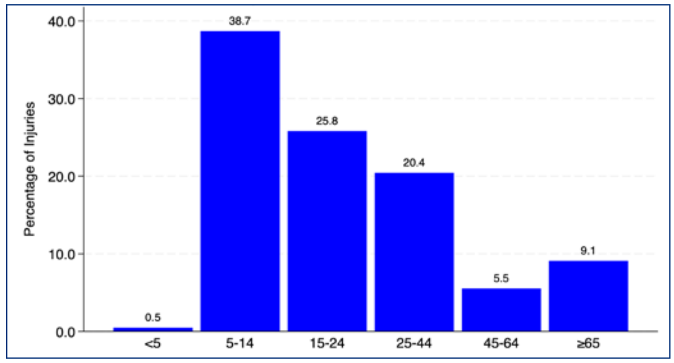

Figure 1B. Age distribution of injuries: Grass

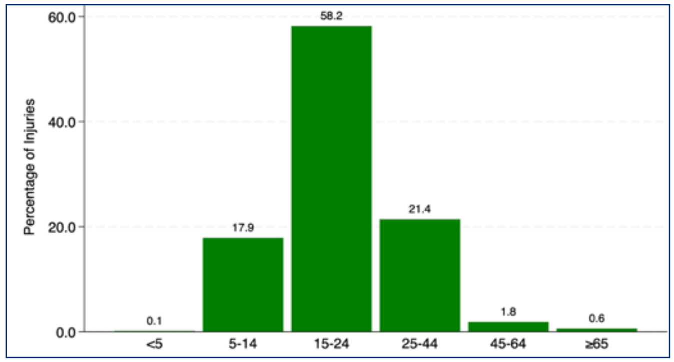

Table 2. Distribution of Athletic Injuries on Grass vs. Turf by Sport with Odds Ratio (OR)

Sport	Turf N (%*)	OR on Turf (95% CI, p-value)	Grass N (%*)	OR on Grass (95% CI, p-value)
Football	2,758 (53.19)	2.49 (2.35–2.62, p <0.01)	5,234 (31.37)	—
Soccer	1,542 (29.75)	—	5,887 (35.28)	1.29 (1.25–1.33, p <0.01)
Softball	356 (6.86)	—	1,253 (7.51)	1.1 (1.04–1.17, *p* = 0.012)
Rugby	251 (4.85)	8.35 (7.33–9.49, p <0.01)	101(0.60)	—
Lacrosse	180 (3.47)	8.42 (7.21–9.77, p <0.01)	71 (0.43)	—
Distribution of Athletic Injuries on Grass vs. Turf by Diagnosis with Odds Ratios (OR)				
Laceration	79 (1.53)	—	1,288 (7.72)	5.41 (5.10–5.72, p <0.01)
Dislocation	73 (1.40)	—	980 (5.87)	4.73 (4.09–4.66, p <0.01)
Fracture	1,109 (21.39)	—	4,717 (28.27)	1.45 (1.40–1.50, p <0.01)
Contusions/Abrasions	1,039 (20.04)	1.96 (1.83–2.10, p <0.01)	1,893 (11.34)	—
Strain/Sprain	1,795 (34.61)	1.16 (1.09–1.23, p <0.01)	5,232 (31.36)	—
Distribution of Athletic Injuries on Grass vs. Turf by Body Part with Odds Ratios (OR)				
Toe	554 (10.69%)	6.30 (5.76–6.88, p <0.01)	311 (1.87%)	—
Hand	189 (3.64%)	6.15 (5.28–7.11, p <0.01)	102 (0.61%)	—
Upper Leg	140 (2.69%)	2.05 (1.72–2.43, p <0.01)	223 (1.34%)	—
Foot	447 (8.62%)	1.67 (1.51–1.84, p <0.01)	894 (5.36%)	—
Lower Leg (excluding knee/ankle)	571 (11.01%)	1.59 (1.46–1.74, p <0.01)	1,203 (7.21%)	—
Elbow	448 (8.63%)	1.36 (1.23–1.50, p <0.01)	1,082 (6.49%)	—
Upper Trunk (excluding shoulder)	32 (0.62%)	—	895 (5.37%)	9.13 (8.52–9.76, p <0.01)
Lower Arm (excluding elbow/wrist)	81 (1.56%)	—	1,221 (7.32%)	4.90 (3.69–5.27, p <0.01)
Wrist	106 (2.04%)	—	973 (5.83%)	2.97 (2.78–3.17, p <0.01)
Ankle	481 (9.27%)	—	2,737 (16.41%)	1.92 (1.84–2.00, p <0.01)

Table 3. Odds Ratios (OR) by *Body Part and Diagnosis* on Turf vs. Grass

Body Part	Diagnosis	Grass (%*)	Turf (%*)	OR on Turf (95% CI, p-value)	OR on Grass (95% CI, p-value)
Lower Leg (excluding knee or ankle)	Contusion/Abrasion	1.99	98.01	56.04 (38.50–84.63, *p* <0.01)	—
Hand	Fracture	9.83	90.17	9.4 (7.71–11.73, *p* <0.01)	—
Foot	Strain/Sprain	19.32	80.68	4.36 (3.87–4.89, *p* <0.01)	—
Elbow	Fracture	26.36	73.64	2.85 (2.33–3.50, *p* <0.01)	—
Wrist	Fracture	88.99	11.01	—	8.16 (7.46–8.11, *p* <0.01)
Knee	Dislocation	86.02	13.98	—	6.36 (5.74–7.02, *p* <0.01)
Lower Trunk	Strain/Sprain	87.34	12.66	—	7.04 (6.30–7.85, *p* <0.01)
Upper Trunk (excluding shoulder)	Contusion/Abrasion	85.78	14.22	—	6.16 (5.49–6.89, *p* <0.01)
Shoulder (including clavicle)	Dislocation	82.63	17.37	—	4.82 (4.21–5.49, *p* <0.01)
Elbow	Strain/Sprain	79.43	20.57	—	3.91 (3.36–4.51, *p* <0.01)
Lower Leg (excluding knee or ankle)	Fracture	75.00	25.00	—	3.09 (2.75–3.47, *p* <0.01)
Lower Arm (excluding elbow or wrist)	Fracture	73.49	26.51	—	2.83 (2.61–3.08, *p* <0.01)
Ankle	Fracture	71.09	28.91	—	2.55 (2.37–2.74, *p* <0.01)
Foot	Fracture	71.30	28.70	—	2.53 (2.38–2.80, *p* <0.01)

*Represents the row percentage of either total turf or total grass injuries.

Table 4. Odds Ratios (OR) by *Body Part, Diagnosis, and Sport* on Turf vs. Grass

Body Part	Diagnosis	Sport	Grass (%*)	Turf (%*)	OR on Turf (95% CI, p-value)	OR on Grass (95% CI, p-value)
Knee	Dislocation	Soccer	8.06	91.94	10.77 (6.57–16.64, p <0.01)	—
Elbow	Fracture	Football	23.18	76.82	13.53 (10.87–16.65, p <0.01)	—
Elbow	Contusion/ Abrasion	Football	6.96	93.04	13.39 (10.63–17.3, p <0.01)	—
Shoulder (including clavicle)	Fracture	Football	8.38	91.62	11.10 (9.31–13.15, p <0.01)	—
Shoulder (including clavicle)	Dislocation	Soccer	9.18	90.82	9.68 (5.41–15.98, p <0.01)	—
Toe	Fracture	Soccer	9.48	90.52	9.68 (5.41–15.98, p <0.01)	—
Foot	Strain/Sprain	Soccer	14.62	85.38	6.01 (5.08–7.06, p <0.01)	—
Lower Leg (excluding knee or ankle)	Strain/Sprain	Soccer	23.50	76.50	3.31 (2.25–4.70, p <0.01)	—
Lower Arm (excluding elbow or wrist)	Fracture	Soccer	95.82	4.18	—	22.24 (20.13–24.50, p <0.01)
Wrist	Fracture	Soccer	90.36	9.64	—	9.38 (8.51–10.31, p <0.01)
Shoulder (including clavicle)	Fracture	Soccer	81.82	18.18	—	4.50 (4.00–5.05, p <0.01)
Lower Leg (excluding knee or ankle)	Fracture	Football	75.88	24.12	—	3.09 (2.54–3.73, p <0.01)

*Represents the row percentage of either total turf or total grass injuries

When looking at the prevalence of specific types of injuries that occurred on grass versus turf, we found that dislocations, lacerations, fractures, and ankle injuries were more likely to occur on grass playing surfaces [**Table 2**], whereas contusions/abrasions, strains/sprains, and burns were more likely to occur on turf surfaces [**Table 2**]. Dislocations were 4.73 times more likely on grass than on turf (p <0.01). Lacerations were 5.41 times more likely on grass than on turf (p <0.01). Fractures were 1.45 times more likely on grass than on turf (p <0.01).

When looking at specific body parts injured on grass versus turf, we found that toe, elbow, hand, upper leg, lower leg, and foot injuries were more likely to occur on turf, whereas upper trunk, forearm, wrist, and ankle injuries were more likely to occur on grass [**Table 2**]. Toe injuries were 6.30 times more likely on turf than on grass (p <0.01). Elbow injuries were 1.36 times more likely to occur on turf than grass (p <0.01). Hand injuries were 6.15 times more likely on turf than on grass (p <0.01). Upper leg injuries were 2.05 times more likely on turf than on grass (p <0.01). Lower leg injuries were 1.59 times more likely on turf than on grass (p <0.01). Foot injuries were 1.67 times more likely on turf than on grass (p <0.01). However, on grass playing surfaces, upper trunk injuries were 9.13 times more likely. Forearm injuries were 4.9 times more likely on grass than on turf (p <0.01). Wrist injuries were 2.97 times more likely on grass than on turf (p <0.01). Finally, ankle injuries were 1.92 times more likely on grass than on turf (p <0.01).

When looking at both common diagnoses and the specific anatomical location injured across all sports, we found that lower leg contusions, elbow and hand fractures, and foot strain/sprains were more likely on turf while forearm fractures, wrist fractures, knee dislocations, lower trunk strain/sprain, upper trunk contusion, shoulder dislocations, elbow strain/sprain, lower leg fractures, and ankle/foot fractures were more likely on grass than turf [**Table 3**]. Lower leg contusions/abrasions were 56.04 times more likely on turf (p <0.01). Elbow fractures were 2.85 times more likely on turf (p <0.01). Hand fractures were 9.4 times more likely to occur on turf (p <0.01). Foot strain/sprains were 4.36 times more likely on turf (p <0.01). Conversely, forearm and wrist fractures were 2.83 and 8.16 times more likely on grass, respectively (p <0.01). Knee dislocations were 6.36 times more likely on grass (p <0.01), whereas ankle fractures were 2.55 times more likely on grass (p <0.01). Foot fractures were 2.53 times more likely on grass (p <0.01). Lower trunk strain/sprains were 7.04 times more likely on grass (p <0.01). Upper trunk contusions were 6.16 times more likely on grass (p <0.01). Elbow strain/sprains were 3.91 times more likely on grass (p <0.01). Lower leg fractures were 3.09 times more likely on grass (p <0.01).

DISCUSSION

Artificial turf is widely used as an alternative playing surface to natural grass for all levels of athletic competition and offers improved cost, durability, and maintenance requirements.[33] However, concerns persist regarding its safety, particularly among professional athletes. Within the National Football League (NFL), for instance, players have expressed notable apprehension about the injury risks associated with artificial surfaces; these concerns have been substantiated by recent studies linking artificial turf to higher injury rates within the NFL.[34,35] Biomechanical studies also suggest artificial turf generates greater torque and rotational stiffness compared to natural grass, potentially increasing injury risk.[36-38]

These significant differences between playing surfaces suggest that biomechanical interactions between athletes and playing surfaces are complex and sport dependent. Biomechanical studies suggest artificial turf exhibits increased torque, rotational stiffness, decreased force absorption, and less cleat release than natural grass.[36-38] This increased "grip" may lead to greater forces being transmitted to an athlete's lower extremities during rapid changes in direction or when the foot becomes fixed to the surface. These factors likely contribute to the increased rate of lower extremity injuries observed on turf in this study. Additionally, the elevated surface temperatures, harder composition, and abrasive texture of artificial turf may explain the increased likelihood of contusions and abrasions and the exclusive observation of burns on this surface in the present study.[33,39]

In contrast, natural grass provides greater force absorption and cleat release under stress, potentially reducing some injury risks. Surface variability and maintenance-related inconsistencies may explain the increased prevalence of dislocations, lacerations, and fractures observed in this study.[33,35]

The observed differences in injury patterns between artificial turf and natural grass across various sports highlight the complex interplay between playing surface characteristics and sport-specific biomechanics. Injuries in football, rugby, and lacrosse were more likely on turf playing surfaces, whereas injuries in soccer (p <0.01) and softball (p = 0.012) were more likely on natural grass. For instance, the higher risk of knee dislocations in soccer players on artificial turf may be related to the sport's emphasis on rapid cutting movements and sudden stops, which could be exacerbated by the surface's higher friction. In contrast, the increased likelihood of shoulder and elbow fractures in football players on turf might be due to the harder surface leading to greater impact forces during tackles and falls. The characteristic hardness and reduced energy absorption of turf compared to natural grass supports a 96% higher contusion risk on artificial turf compared to grass. This biomechanical difference likely increases impact forces during ball-player collisions because it enables lacrosse balls and softballs to maintain greater post-bounce velocities. The surface-ball interaction hypothesis is supported by sport-specific injury patterns. Lacrosse injuries were 8.42 times more likely on turf, concentrated in upper extremity regions, suggesting faster-moving balls increase defensive reaction errors and impact severity.

Artificial turf's high energy return in comparison to grass surfaces facilitates faster movements but may inadvertently increase high-speed collision potential.[40] Turf-associated upper leg injuries (OR 2.05) and lower leg contusions (OR 56.04) could reflect both direct surface contact injuries and increased collision forces. However, this effect appears sport-dependent, as evidenced by soccer's grass-dominated injury pattern.

These results can inform preventive measures to reduce the rate of injury and provide valuable information for programs considering the benefits and risks of natural grass and turf playing surfaces. The higher incidence of contusions, abrasions, and burns on turf surfaces necessitates improved and directed protective measures, including appropriate clothing and equipment. For grass surfaces, interventions should focus on mitigating factors contributing to dislocations and fractures. This may include optimizing field maintenance practices where financially feasible, implementing player training programs to enhance balance and landing mechanics, exploring cleat designs that balance traction with joint protection, and educating athletes about surface-specific risks.

Strength and conditioning programs should also adapt to the primary playing surface, emphasizing upper-body strength and fall techniques for turf, and lower-body stability for grass. Equipment manufacturers can contribute by developing specialized protective gear, such as reinforced upper body padding for turf play and specialized cleats for grass surfaces. Similarly, sports medicine teams must be prepared for the distinct injury profiles of each surface, ensuring appropriate on–field and follow–up care. Educating athletes, coaches, and parents about these differential risks is essential for promoting proactive injury prevention across all levels of play.

Limitations

Our study has several limitations that warrant consideration. The main limitation involves the structure and specificity of the NEISS database. The coding system does not allow for granular anatomical or diagnostic specificity. For example, common injuries in athletic populations, such as hamstring strains and tears would be grouped broadly under "upper leg" (body part code = 81) and "strain/sprain" (diagnosis code = 64). This limits our ability to identify specific muscle injuries or detailed injury patterns. Similarly, broad, nonspecific categories like "upper trunk" or "lower trunk" include a wide range of potential body parts and injuries. These factors may reduce clinical specificity. Moreover, while NEISS data are coded by trained professionals at participating hospitals using standardized criteria, variability in chart interpretation and reporting may introduce inconsistency. Coding accuracy relies on both the detail of clinician documentation and the coders' interpretation of that information, which may result in some degree of misclassification or generalization of an injury or diagnosis.

Additionally, the retrospective design limits causal inferences about the relationship between surface type and injury risk. The majority of injuries (76.29%) were found to have occurred on grass, with only 23.71% on turf, however, it is most likely that far more games and practices were held on natural grass, so this may not necessarily reflect the differences in relative safety. Data collection from emergency room records may have skewed the results towards more severe injuries, as minor injuries are less likely to require emergency care. Additionally, reliance on narrative data to identify surface type may have introduced misclassification bias. The lack of exposure data (e.g., time spent playing on each surface) limits the ability to calculate true injury rates. Lastly, confounding factors such as shoe type, rest time, field conditions, generation of artificial turf, field maintenance conditions, previous injury history, and level of competition were unable to be controlled for.

CONCLUSION

In conclusion, this study reveals significant variations in injury patterns that occur on artificial turf and natural grass playing surfaces across various sports and age, providing valuable evidence on the potential risks and injury patterns associated with each surface. These findings can inform tailored interventions, equipment standards, and athlete education to improve player safety. Further research is needed to investigate biomechanical mechanisms underlying surface-specific risks and to develop comprehensive prevention strategies that address demographic and environmental factors.

References

1. NCAA Sports Sponsorship and Participation Rates Report. NCAA Sports Sponsorship and Participation. September 29, 2023. Accessed October 9, 2024. https://ncaaorg.s3.amazonaws.com/research/sportpart/2023RES_SportsSponsorshipParticipationRatesReport.pdf
2. Collins C, Anderson M, and Burus T. Original Sample Summary Report: National High School Sports-Related Injury Surveillance Study: 2022–23 School Year. Datalys Center for Sports Injury Research and Prevention. Accessed April 5 (2023).
3. Jastifer JR, McNitt AS, Mack CD, et al. Synthetic Turf: History, Design, Maintenance, and Athlete Safety. *Sports Health Multidiscip Approach*. 2019;11(1):84-90. doi:10.1177/1941738118793378
4. *Participation Statistics. NFHS MMS. (n.d.). Https://Members.Nfhs.Org/Participation_statistics.*
5. Dragoo JL, Braun HJ. The effect of playing surface on injury rate: a review of the current literature. *Sports Med Auckl NZ*. 2010;40(11):981-990. doi:10.2165/11535910-000000000-00000
6. Drakos MC, Taylor SA, Fabricant PD, Haleem AM. Synthetic playing surfaces and athlete health. *J Am Acad Orthop Surg*. 2013;21(5):293-302. doi:10.5435/JAAOS-21-05-293
7. O'Leary F, Acampora N, Hand F, O' Donovan J. Association of artificial turf and concussion in competitive contact sports: a systematic review and meta-analysis. *BMJ Open Sport Exerc Med*. 2020;6(1):e000695. doi:10.1136/bmjsem-2019-000695
8. Rennie DJ, Vanrenterghem J, Littlewood M, Drust B. Can the natural turf pitch be viewed as a risk factor for injury within Association Football? *J Sci Med Sport*. 2016;19(7):547-552. doi:10.1016/j.jsams.2015.07.009
9. Taylor SA, Fabricant PD, Khair MM, Haleem AM, Drakos MC. A review of synthetic playing surfaces, the shoe-surface interface, and lower extremity injuries in athletes. *Phys Sportsmed*. 2012;40(4):66-72. doi:10.3810/psm.2012.11.1989
10. Williams S, Hume PA, Kara S. A Review of Football Injuries on Third and Fourth Generation Artificial Turfs Compared with Natural Turf: *Sports Med*. 2011;41(11):903-923. doi:10.2165/11593190-000000000-00000
11. Winson DMG, Miller DLH, Winson IG. Foot injuries, playing surface and shoe design: Should we be thinking more about injury prevention. *Foot Ankle Surg Off J Eur Soc Foot Ankle Surg*. 2020;26(6):597-600. doi:10.1016/j.fas.2019.07.013
12. Balazs GC, Pavey GJ, Brelin AM, Pickett A, Keblish DJ, Rue JPH. Risk of Anterior Cruciate Ligament Injury in Athletes on Synthetic Playing Surfaces: A Systematic Review. *Am J Sports Med*. 2015;43(7):1798-1804. doi:10.1177/0363546514545864
13. Bushnell J, Dr. Zachary O. Binney, PhD, Emory University, Dr. Michael Goodman, MD MPH, Emory University. Exploring the Associations of Playing Surface and Lower Extremity Injuries Among National Football League Players. *Emory Univ Roll Sch Public Health*. Accessed October 27, 2024. https://etd.library.emory.edu/concern/etds/qn59q5437?locale=en
14. Venishetty N, Xiao AX, Ghanta R, Reddy R, Pandya NK, Feeley BT. Lower Extremity Injury Rates on Artificial Turf Versus Natural Grass Surfaces in the National Football League During the 2021 and 2022 Seasons. *Orthop J Sports Med*. 2024;12(8):23259671241265378. doi:10.1177/23259671241265378
15. Gould HP, Lostetter SJ, Samuelson ER, Guyton GP. Lower Extremity Injury Rates on Artificial Turf Versus Natural Grass Playing Surfaces: A Systematic Review. *Am J Sports Med*. 2023;51(6):1615-1621. doi:10.1177/03635465211069562
16. Loughran GJ, Vulpis CT, Murphy JP, et al. Incidence of Knee Injuries on Artificial Turf Versus Natural Grass in National Collegiate Athletic Association American Football: 2004-2005 Through 2013-2014 Seasons. *Am J Sports Med*. 2019;47(6):1294-1301. doi:10.1177/0363546519833925

17. Mack CD, Hershman EB, Anderson RB, et al. Higher Rates of Lower Extremity Injury on Synthetic Turf Compared With Natural Turf Among National Football League Athletes: Epidemiologic Confirmation of a Biomechanical Hypothesis. *Am J Sports Med*. 2019;47(1):189-196. doi:10.1177/0363546518808499
18. Xiao M, Lemos JL, Hwang CE, Sherman SL, Safran MR, Abrams GD. Increased Risk of ACL Injury for Female but Not Male Soccer Players on Artificial Turf Versus Natural Grass: A Systematic Review and Meta-Analysis. *Orthop J Sports Med*. 2022;10(8):23259671221114353. doi:10.1177/23259671221114353
19. Smoliga JM, Deshpande SK, Binney ZO. Interaction of Surface Type, Temperature, and Week of Season on Concussion Risk in the National Football League: A Bayesian Analysis. *Epidemiology*. 2023;34(6):807-816. doi:10.1097/EDE.0000000000001657
20. Williams JH, Akogyrem E, Williams JR. A Meta-Analysis of Soccer Injuries on Artificial Turf and Natural Grass. *J Sports Med*. 2013;2013:1-6. doi:10.1155/2013/380523
21. Howard M, Solaru S, Kang HP, et al. 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. *Orthop J Sports Med*. 2020;8(7):2325967120934434. doi:10.1177/2325967120934434
22. Kuitunen I, Immonen V, Pakarinen O, Mattila VM, Ponkilainen VT. Incidence of football injuries sustained on artificial turf compared to grass and other playing surfaces: a systematic review and meta-analysis. *eClinicalMedicine*. 2023;59:101956. doi:10.1016/j.eclinm.2023.101956
23. National Electronic Injury Surveillance System (NEISS). U.S. Consumer Product Safety Commission. Accessed September 6, 2024. https://www.cpsc.gov/Research--Statistics/NEISS-Injury-Data
24. DeFroda SF, Lemme N, Kleiner J, Gil J, Owens BD. Incidence and mechanism of injury of clavicle fractures in the NEISS database: Athletic and non athletic injuries. *J Clin Orthop Trauma*. 2019;10(5):954-958. doi:10.1016/j.jcot.2019.01.019
25. Kuczinski A, Newman JM, Piuzzi NS, et al. Trends and Epidemiologic Factors Contributing to Soccer-Related Fractures That Presented to Emergency Departments in the United States. *Sports Health*. 2019;11(1):27-31. doi:10.1177/1941738118798629
26. Meixner C, Loder RT. The Demographics of Fractures and Dislocations Across the Entire United States due to Common Sports and Recreational Activities. *Sports Health*. 2020;12(2):159-169. doi:10.1177/1941738119882930
27. Reiad TA, Peveri E, Dinh PV, Owens BD. Epidemiology of Shoulder Injuries Presenting to US Emergency Departments. *Orthopedics*. 2025;48(2):e81-e87. doi:10.3928/01477447-20250204-03
28. Dinh PV, Reiad TA, Peveri E, Marquis C, Gil JA. A 20-year national decline in wrist fractures: Unraveling trends and persistent challenges. *Hand Surg Rehabil*. Published online March 25, 2025:102151. doi:10.1016/j.hansur.2025.102151
29. Zaifman JM, Megalla M, Grace Z, et al. Orthopaedic Sports Injuries in an Aging Population: Current Trends and Future Projections. *Sports Health*. Published online January 29, 2025:19417381251314078. doi:10.1177/19417381251314078
30. Durand WM, Goodman AD, Giglio P, Etzel C, Owens BD. Epidemiology of Upper Extremity Soccer Injuries Among High School– and College-Aged Players in the United States: An Analysis of the 1999-2016 NEISS Database. *Sports Health*. 2018;10(6):552-557. doi:10.1177/1941738118795483
31. Painter DF, Ahn BJ, Byrne RA, et al. Upper extremity orthopedic softball injuries presenting to the emergency department: epidemiology across the lifespan. *Phys Sportsmed*. 2025;53(1):72-79. doi:10.1080/00913847.2024.2411574
32. US Consumer Product Safety Commission. 2023. NEISS Coding Manual. Available at: Https://Www.Cpsc.Gov/Cgibin/NEISSQuery/Data/Info%20Docs/2023%20NEISS%20Coding%20Manual.Pdf. Accessed December 3, 2024.
33. Jastifer JR, McNitt AS, Mack CD, et al. Synthetic Turf: History, Design, Maintenance, and Athlete Safety. *Sports Health*. 2019;11(1):84-90. doi:10.1177/1941738118793378
34. Venishetty N, Xiao AX, Ghanta R, Reddy R, Pandya NK, Feeley BT. Lower Extremity Injury Rates on Artificial Turf Versus Natural Grass Surfaces in the National Football League During the 2021 and 2022 Seasons. *Orthop J Sports Med*. 2024;12(8):23259671241265378. doi:10.1177/23259671241265378
35. Mack CD, Hershman EB, Anderson RB, et al. Higher Rates of Lower Extremity Injury on Synthetic Turf Compared With Natural Turf Among National Football League Athletes: Epidemiologic Confirmation of a Biomechanical Hypothesis. *Am J Sports Med*. 2019;47(1):189-196. doi:10.1177/0363546518808499
36. Dowling AV, Corazza S, Chaudhari AMW, Andriacchi TP. Shoe-surface friction influences movement strategies during a sidestep cutting task: implications for anterior cruciate ligament injury risk. *Am J Sports Med*. 2010;38(3):478-485. doi:10.1177/0363546509348374
37. Drakos MC, Hillstrom H, Voos JE, et al. The effect of the shoe-surface interface in the development of anterior cruciate ligament strain. *J Biomech Eng*. 2010;132(1):011003. doi:10.1115/1.4000118
38. Villwock MR, Meyer EG, Powell JW, Fouty AJ, Haut RC. Football playing surface and shoe design affect rotational traction. *Am J Sports Med*. 2009;37(3):518-525. doi:10.1177/0363546508328108
39. Villanueva NC, Chun IKH, Fujiwara AS, Leibovitch ER, Yamamoto BE, Yamamoto LG. Impact Deceleration Differences on Natural Grass Versus Synthetic Turf High School Football Fields. *Hawaii J Health Soc Welf*. 2024;83(1):4-9.
40. Sanchez-Sanchez J, Felipe JL, Hernandez-Martin A, et al. Influence of the artificial turf certification on physical performance and muscle damage in football players (QUALTURF PROJECT). *Sci Rep*. 2021;11:8625. doi:10.1038/s41598-021-88192-w

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