

Research Article

Analyzing Ankle Injuries in the NFL: A Video-Based Investigation of the Impact of Artificial Turf on Injury Mechanisms

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Purpose

Artificial turf is increasingly used in professional football due to its economic and logistical advantages. However, concerns persist that certain turf types, especially slit-film, may alter biomechanics and increase the risk of lower extremity injuries. This study aimed to evaluate the mechanism and frequency of ankle and foot injuries across three surface types, natural grass, monofilament/dual-fiber (MFDF) turf, and slit-film turf, during the 2022–2023 NFL season. We hypothesize that slit-film turf will show a higher rate of ankle and foot injuries compared to other types of turf and natural grass.

a My name is Mina Ghali, a third year medical student at the University of Central Florida College of Medicine. I have a strong academic interest in orthopaedic surgery, sports medicine, and clinical outcomes research. Throughout my training, I have worked on multiple orthopaedic projects evaluating injury mechanisms, surgical techniques, postoperative outcomes, and epidemiologic trends using national databases and video-based analysis. My work has focused on generating clinically meaningful data that can directly inform practice patterns, surgical decision-making, and patient counseling, particularly in adolescent athletes and older populations with fracture pathology. I am committed to pursuing a career in orthopaedic surgery, advancing evidence-based care, and contributing to high-quality scholarly work that improves patient outcomes.

[Conflicts of Interest Statement for Mina Ghali](#)

b I am a third year medical student currently attending the University of Central Florida College of Medicine. I was born and raised in Southeast Michigan and attended the University of Michigan, where I received my B.S. in Biopsychology, Cognition, and Neuroscience. I have a passion for sports medicine and adaptive sports, and am interested in pain management. I intend to apply into Physical Medicine and Rehabilitation as my specialty during my fourth year.

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d Heidi Israel, PhD, FNP, CCRC is a statistician with over 20 years experience in medical research.

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e Dr. Cannada is an Orthopaedic Trauma Surgeon. She is affiliated with Novant health, where she is the Director of Faculty Integration for the UNC School of Medicine Charlotte Campus, Medical Student Clerkship Director and Professor. She completed a 3-year term on the AAOS BOD in 2018 as the first female Chair of the Board of Specialty Societies. She was responsible for developing the current fellowship match process for orthopaedics. She is a member of the Orthopaedic Trauma Association and served on the BOD and received the first OTA DEI and Health Disparities Leadership Award in October 2022. She served as a president of the Ruth Jackson Orthopaedic Society in 2011 and received the inaugural "She for She" Award in 2022. Dr. Cannada has made it her mission to make the path better for those that follow, by her work and leadership roles. In 2021, with Drs. Jennifer Weiss, Nancy Yen Shipley and Arianna Gianakos she helped formed "Speak Up Ortho" to pave the way for change in orthopaedic surgery. She is chair of the AWS Publications Committee and received the Kim Updegrave Visiting Professor Award in 2025 and is a member of the AWS Shining Star Cohort for 2025. Her clinical interests and research include both upper and lower extremity fractures and outcomes. In 2025, she was received the PRIDE ORTHO Ally Award. She was recognized for her teaching with the Faculty Teaching Award for Surgery and the UNC Educational Mentor/Advisor Award. She has over 240 publications and 250 presentations at national meetings. She could not do this without the support of her family, her husband Jeff and daughter Annalise and her parents, the late John W. Metcalf MD and her mom, Theresa Metcalf. Her favorite role is "soccer mom" to her daughter playing Division I soccer after an ACL reconstruction.

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Methods

A retrospective review of NFL injury reports and game footage was conducted to identify 78 in-game ankle and foot injuries. Injuries were classified by mechanism (contact vs. non-contact) and correlated with surface type. Statistical analyses including Mann-Whitney U, Chi-Square, and logistic regression were employed to assess associations.

Results

Slit-film turf exhibited the highest rate of contact injuries (85.7%) but the lowest rate of non-contact injuries (14.3%), contrary to the hypothesis and prior research. Natural grass had the highest proportion of non-contact injuries (46.4%). Statistically significant differences were found between surface type and injury mechanism ($p = 0.015$). Fatigue may contribute to injury prevalence, as the fourth quarter saw the highest injury rate (41%).

Conclusion

This study challenges the prevailing belief that artificial turf, particularly slit-film turf, increases non-contact injury risk. Instead, slit-film turf may predispose players to more contact-related injuries due to its rigid surface properties. Findings underscore the need for multi-season, biomechanically informed research to guide player safety policies.

INTRODUCTION

Synthetic turf has been implemented into many sports as a standard playing surface due to its economic benefits and flexibility in use (Gould et al. 2023). Modern turf used in the NFL shares the same components of a stable base, a shock-absorbing pad, turf, and the fibers on top that mimic grass (Jastifer, McNitt, Mack, et al. 2019). Two main turf types are utilized today: slit-film and monofilament turf. Slit-film fibers are wide fibers designed to create a net while monofilament fibers are designed to sit straight up and tall, most closely mimicking natural grass. Dual fiber turf can also be used and is a mixture of slit-film and monofilament fibers. It most closely resembles the structure of monofilament turf and is only used by one stadium in the NFL (Highmark stadium). Slit-film turf is used for its high durability and flexibility for use amongst many different sports, while monofilament turf is considered for aesthetic appeal and comfort for athletes (Jastifer, McNitt, Mack, et al. 2019). Natural grass had been the standard for many years but required consistent maintenance such as aeration, watering, fertilization, irrigation, and most importantly, an adequate climate which varies based on location and season of the year (Williams, Hume, and Kara 2011). Lastly, the high maintenance cost of natural grass contributed to the adoption of turf, which reduces expenses by 15% and increases the space's versatility by a factor of 12 (Ekstrand, Timpka, and Hagglund 2006).

Despite the economic advantages of artificial playing surfaces, it has been associated with changes to the biomechanics of the lower extremity (LE) that cause increased strain on the ankle as opposed to natural grass (Kent, Yoder, O'Cain, et al. 2021). Artificial playing surfaces cannot deform at the enormous peak torques generated by athletes (Mack, Hershman, Anderson, et al. 2019). The force that could disrupt natural grass, and subsequently limit the force transmitted to the athlete's leg, is not released due to the resilient fibers of artificial turf (Mack, Hershman, Anderson, et al. 2019). This limitation of artificial playing sur-

faces leads to reduced shock-absorbing capacity compared to grass, affecting load bearing on the foot and leading to increased injury risks (Williams, Hume, and Kara 2011). This stems from the increased strain and torque translated to the structures in the LE which can cause joint, muscle, and ligament sprains and tears (Calloway, Hardin, Crawford, et al. 2019; Ekstrand, Timpka, and Hagglund 2006). "Cleat catching" on artificial turf, where the cleats are more likely to get stuck, also results in ankle and knee ligament injuries (Williams, Hume, and Kara 2011).

The ankle is commonly injured in the NFL and this has been analyzed several years ago by Hershman, et al. where it was found that the injury rate for all ankle injuries was 22% higher on synthetic playing surfaces compared to natural playing surfaces (Hershman, Anderson, Bergfeld, et al. 2012). Despite the ankle and foot being commonly injured sites in the LE, no studies provide coverage on these types of injuries based on artificial turf vs grass or comparing the variants of turf. This study aims to compare slit-film turf to other playing surfaces used in the 2022-2023 NFL season by examining the rates of non-contact ankle and foot injuries associated with each field type. We hypothesize that slit-film turf will exhibit a higher injury rate for ankle and foot injuries than other turf and natural grass variants.

METHODS

A retrospective review of publicly accessible injury reports directly provided by the NFL was conducted to find injuries of interest sustained by professional football players. Specifically, subjects included players who were labeled as having an "Ankle" or "Foot" injury. NFL players injured only during the 2022-2023 season were considered for the study. These professional football players must have sustained an ankle or foot injury during active gameplay, excluding scenarios such as team practices.

The cohort was further limited to those that played quarterback (QB), skill positions (wide receivers [WR], running backs [RB], and tight ends [TE]), and defensive backs (cor-

nerbacks [CB] and safeties [S]). Player position was also determined based on their listing on the NFL injury reports. A total of 78 injuries met the final inclusion criteria and were analyzed based on playing surface and injury mechanism. Game footage from the NFL+ platform was reviewed by two independent evaluators, E1 and E2, to confirm the mechanism of injury (MOI) of non-contact vs contact. A non-contact event was considered when the player in question did not collide with a second player and contact where the player was affected by another player during the play. A discrepancy arose between E1 and E2 regarding 4 injuries, therefore a third evaluator (E3) reviewed those cases to decide the MOI. The type of playing surface the injuries occurred on were also analyzed. More specifically, surfaces including slit film turf, monofilament and dual fiber (MFDF) turf, and natural grass that are used in the NFL were accounted for. Monofilament and dual fiber turf types were combined under one category as only one stadium uses dual fiber turf (Highmark Stadium) and it most closely resembles monofilament turf.

The temperature and weather during each game was recorded, with all indoor games standardized to 73 °F and weather categorized as clear, rain, or snow. Additional variables such as player age, days missed to return to game action, and the timestamp of the injury during the game were recorded. The primary analysis compared the rates of ankle and foot injuries on slit-film turf to other playing surfaces. Statistical analysis was performed to evaluate differences in injury distribution across all playing surfaces. A Mann-Whitney U test was conducted to compare the rank distribution of non-contact injuries between surfaces. A Pearson chi-square test was used to assess the association between playing surface type and injury mechanism. A logistic regression of two variables, MOI and playing surfaces, was also conducted. Statistical significance was set at $p < 0.05$ for all statistical analyses.

RESULTS

78 foot and ankle injuries occurred across all three surface types: natural grass, MFDF turf, and slit-film turf (38.5%, 35.9%, and 25.6%, respectively). Most injuries occurred due to contact, regardless of playing surface. However, the proportion of direct contact injuries was highest on slit-film turf (85.7%) while it was lowest on natural grass (53.6%) with MFDF showing intermediate proportions (72.4%). In addition, offensive players, especially skill positions, were more prone to injury (Table 1).

Statistical analysis using the Mann-Whitney U test revealed a significant difference in the ranked distribution of playing surfaces between non-contact and contact injuries ($U = 859.500$, $p = 0.015$). Additionally, the Pearson chi-square test confirmed a significant association between playing surface and MOI ($\chi^2 = 6.040$, $p = 0.049$). Furthermore, when comparing playing surfaces, injuries occurring on grass or MFDF turf did not have any significant association ($p = 0.14$). A similar lack of significance was found when comparing injuries on MFDF and slit turf ($p = 0.262$).

However, there was a significant association of MOI between grass and slit turf, ($p = 0.018$).

A logistic regression of the two variables, MOI and all three playing surfaces, was run with MOI coded as contact = 1, non-contact = 0 and grass as the reference category. The overall model was statistically significant ($p < 0.03$) and had an OR of 5.2 (CI 1.24 - 21.73).

Injuries were distributed across all quarters of play, with the highest frequency occurring in the fourth quarter (41.0%, $n = 32$). The remaining injuries occurred in the first quarter (17.9%, $n = 14$), second quarter (21.8%, $n = 17$), and third quarter (19.2%, $n = 15$). A Chi-Square Goodness-of-Fit test revealed a statistically significant difference in injury distribution across quarters ($\chi^2 = 10.92$, $df = 3$, $p = 0.012$), indicating that injuries did not occur evenly throughout the four possible quarters of the game.

The average age of injured players was 25.8 years, with a median of 25.1 years. The age range spanned from 21.2 to 34.1 years, and the standard deviation was 3.0 years. Injury events took place over a broad range of field temperatures. The mean temperature at the time of injury was 64.9°F, with a median of 72.0°F and a mode of 73°F. Temperatures ranged from a minimum of 10°F to a maximum of 88°F, with a standard deviation of 13.9°F. Regarding injury distribution, 28 injuries occurred below the average temperature, while 51 occurred above it. On natural grass, 26 injuries occurred in clear weather, 2 in rain, and 1 in snow. On monofilament/dual-fiber turf, 24 injuries occurred in clear weather, 4 in rain, and 1 in snow. On slit film turf, all 20 injuries occurred in clear weather, with none reported during rain or snow. The Chi-Square test of independence yielded a statistic of 4.05 with 4 degrees of freedom and a p-value of 0.40, indicating no statistically significant association between playing surface and weather conditions.

PLAYING SURFACE SUMMARY

DISCUSSION

The data collected in this study provides interesting trends regarding the relationship between playing surfaces and MOI. The prevailing sentiment in the sports world is that synthetic turf is more dangerous than natural grass due to differences in shock absorption and traction. However, the study's findings challenge this notion.

This study found that natural grass had the highest number of injuries (30 instances, not associated by weather), followed closely by the MFDF turf group (28 instances), with slit-film turf having the lowest number of injuries (20 instances). Notably, non-contact injuries were disproportionately lower on slit-film turf (14.3%) compared to natural grass (46.4%) and MFDF turf (27.6%). This trend is contrary to some sources that demonstrate an increased incidence of injury throughout the LE in football players who play on artificial playing surfaces compared with natural grass (Hershman, Anderson, Bergfeld, et al. 2012; Mack, Hershman, Anderson, et al. 2019). This could be explained by the notion that slit-film, with its consistent webbing pattern, provides a more flat and even playing surface. It is less

Table 1: Distribution of ankle and foot injuries by mechanism (non-contact vs. direct contact) and player position. Most injuries were contact-related (69.2%) and occurred in offensive players (67.9%), with skill positions (WR, RB, TE) comprising the bulk of offensive injuries (84.9%).

Category	Subcategory	Count	Percentage (%)
Mechanism of Injury (MOI)	Non-Contact	24	30.8
	Direct Contact	54	69.2
Player Position (All Injuries)	Offensive Players	53	67.9
	Defensive Players	25	32.1
Offensive Player Breakdown	Skill Positions (WR, RB, TE)	45	84.9
	Quarterbacks (QB)	8	15.1

affected by other variables such as wear-down, divots, and mud that natural grass is prone to. This allows athletes to have a more predictable response by the slit-film turf when running, jumping, and cutting. Additionally, athletes may feel more confident playing on natural grass which ironically puts them at higher risk of injury.

Conversely, direct contact injuries were more common on both types of turf, likely due to moments before, during, or after contact that cause unplanned movement or improper foot placement. Giesche et al. demonstrated that unplanned movements result in significantly higher external knee abduction and tibial internal rotation, increasing the frequency of knee injuries (Giesche et al. 2021). These findings can be applied to ankle injuries in the NFL, where contact is frequent and can force athletes into injury-prone positions on a non-deformable playing surface, such as slit-film turf, leading to subsequent injury.

This data contrasts with the common belief that synthetic turf leads to a higher incidence of non-contact injuries. For instance, Mack et al. found that synthetic turf was associated with a 16% increase in lower extremity injuries compared to natural turf in NFL athletes, particularly for non-contact injuries (Mack, Hershman, Anderson, et al. 2019). Similarly, Gould et al. reported higher rates of foot and ankle injuries on artificial turf across various sports (Gould et al. 2023). An analysis by Williams et al. aligns more closely with the findings of this study, revealing no clear pattern in the incidence rate ratio for soccer injuries on artificial turf versus natural grass and highlighting the complexities of the issue (Williams, Hume, and Kara 2011). Injury prevalence changes based on age and gender of athlete, level of play, and if the injury was during a match or training (Williams, Hume, and Kara 2011). Some cohorts saw advantages or disadvantages based on the specific location of the injury; collegiate female soccer players benefited from training on artificial turf when focusing on the knee whereas professional male soccer players had an increased incidence of knee injuries while playing matches on artificial playing surfaces (Williams, Hume, and Kara 2011). Similarly, Ekstrand et al. saw no difference in injury incidence on artificial turf or grass when intra-cohort analysis was performed, save for ankle sprains which reached significant levels on artificial turf compared to grass (Ekstrand, Timpka, and Hagglund 2006). Unlike the comparative cohort designs in prior studies, the present analysis was limited

to a single-sport, single-league cohort, which restricts direct comparison. However, within this focused population, we identified a modest but noteworthy association between player age and MOI, suggesting that younger athletes may be more susceptible to non-contact injuries.

Meyers et al. conducted a long-term study comparing match-related injuries in collegiate soccer and found that FieldTurf (a monofilament turf) is, in many cases, safer than natural grass, with significantly lower total injury incidence rates and less trauma on FieldTurf (Meyers 2017, 2013). Conversely, Cousins et al. found that synthetic surfaces increased match injury incidence in elite rugby union players, with a significant effect on both contact and non-contact injuries (Cousins et al. 2022). Kent et al. used the Biocore Elite Athlete Shoe Turf Tester (BEAST) device to show that the torque on the LE on synthetic turf can be at least 225 Newton-meters, well above the 130-150 Newton-Meter threshold that is expected to mitigate injury (Kent, Yoder, O'Cain, et al. 2021). Additionally, Mack et al. showed a 16% increase in injury rate on artificial turf when compared to natural grass (Mack, Hershman, Anderson, et al. 2019). Moreover, Livesay et al. demonstrated that peak torque was significantly higher on artificial surfaces compared to natural grass, with the lowest torque observed when a grass shoe was used on a grass surface ($p < .0001$) (Livesay, Reda, and Nauman 2006). These findings suggest that natural grass may present a lower risk of torque-related injuries compared to artificial playing surfaces (Ekstrand, Timpka, and Hagglund 2006). Our findings add nuance to the ongoing debate about the safety of synthetic turf versus natural grass. While Meyers et al. reported lower overall injury rates on FieldTurf in collegiate soccer, and Livesay et al. demonstrated biomechanical advantages of natural grass in reducing torque-related stress, our results suggest that the relationship between surface type and injury mechanism is highly context-dependent. Specifically, while we found that injuries on slit-film turf were more commonly due to contact, non-contact injuries were more prevalent on natural grass. These findings contrast with reports such as those by Cousins et al., who noted increased non-contact injury risk on synthetic surfaces in elite rugby. Taken together, our NFL-focused analysis highlights that injury patterns may not be universally generalizable across sports and underscores the need for sport- and surface-specific injury surveillance and prevention strategies.

The statistical analysis revealed significant differences in injury distribution across playing surfaces and a significant association between playing surface and MOI. However, no significant differences were observed when comparing injuries on grass versus MFDF turf or MFDF versus slit turf. A significant association was found between grass and slit turf. These results indicate that playing surface influences MOI, but not as previously expected. Injuries occurred more frequently on grass compared to slit turf, while no differences were observed between other surfaces. Numerous studies have shown that artificial playing surfaces predisposes athletes to injuries, especially in those who play American football (Hershman, Anderson, Bergfeld, et al. 2012; Mack, Hershman, Anderson, et al. 2019; Mack, Kent, Coughlin, et al. 2020). This trend is observed regardless of the type of turf used in the NFL, including monofilament, dual-fiber, and slit-film. This risk has garnered attention from the National Football League Players Association (NFLPA) to seek the banning of synthetic turf, particularly the slit-film variant. Slit-film is considered the most dangerous subtype of artificial turf due to its webbed nature which can prevent disengagement between the foot and surface (Tretter 2022). Further research is needed to confirm these findings and better understand the relationship between MOI and playing surface.

While the study suggests that synthetic turf may not be as hazardous as commonly believed, particularly for non-contact injuries, it is essential to consider the broader body of evidence indicating higher injury rates on synthetic surfaces. This is especially important for high school and college athletic programs, as they are more likely to use turf. Programs would like to balance cost-effectiveness with limiting injury risks for their own and opposing athletes, and this study in conjunction with others makes it difficult to make a clear-cut decision. The data from this study shows that slit-film turf does not lead to more injuries compared to grass, which can provide more evidence behind programs opting for turf utilization. Furthermore, this would make stadium design and maintenance of the field more feasible. Turf is much easier to upkeep compared to natural grass, which would add another reason for programs and stadiums to implement this field surface.

It is also important to acknowledge the considerable increase in injuries in later stages of play compared to earlier periods. The results reveal a notable increase in injuries during the fourth quarter (41%) compared to more even distributions in the first (17.9%), second (21.8%), and third (19.2%) quarters, suggesting that fatigue may contribute to the higher injury rate late in the game. These results are consistent with an article by Verschueren et al. which states that athletes who experience acute fatigue can show a decrease in single leg posture, increasing the risk of foot and ankle injuries (Verschueren, Tassignon, De Pauw, et al. 2020). Postural instability in fatigued athletes is further exacerbated by a history of ankle injuries, which leads to high risk of reinjury (Steib et al. 2013). In a study by Steib et al., participants' single leg performance were measured before and after being fatigued. The results showed that fatigue significantly impacted static and dynamic control in

patients with history of ankle injury (Steib et al. 2013). Collectively, these studies are consistent with the findings of the current study.

Another important factor to consider is the susceptibility to reinjury after prior injury. It's difficult to ascertain whether a previous injury is directly correlated to the injuries documented, but it is reasonable to assume it could influence reinjury. In a systematic review studying ACL reinjury in young athletes post reconstruction, the secondary ACL reinjury rate was 20% (Wiggins et al. 2016). Furthermore, there was a 30 to 40 times greater risk of ACL injury compared to uninjured adolescents (Wiggins et al. 2016). This can be applied to NFL players as they constantly battle injuries week to week but may not be indicated on the injury report. This leads to susceptibility to injuries that are not well documented, making it difficult to correlate between new injuries and aggravation of previous injuries. In this study, reinjury was not captured due to this lack of documentation and inconsistency in tracking.

CONCLUSION

This study has several limitations. It relied on retrospective video analysis and publicly available NFL injury reports, which may introduce classification bias and underreport less severe injuries. If this was the case, it would put the athletes at an increased risk of re-aggravating the injury or picking up a new one altogether. Variability in team reporting practices could also affect data consistency. Important confounding variables, such as cleat type, field maintenance, player biomechanics, and fatigue, were not controlled. The sample size was limited to one season and league, restricting generalizability. Additionally, the study lacked biomechanical testing and access to medical records, limiting insights into injury severity and mechanisms. Furthermore, although the NFL sets the policies on reporting injuries, it is not feasible to assume all teams strictly follow it as expected. The classification of injury mechanisms was performed by human reviewers, and because injuries did not occur under identical circumstances, some variability in grading and interpretation is possible. These factors may act as confounders and potentially influence the incidence of non-contact knee injuries.

This study analyzed the relationship between playing surface type and non-contact ankle and foot injuries in the NFL during the 2022-2023 season. While turf surfaces, particularly slit-film turf, have been widely criticized for increasing injury risk, our findings suggest a more complex relationship between surface type and injury mechanism. Our initial hypothesis, that slit-film turf would have the highest rate of non-contact ankle and foot injuries, was not supported by the data. These findings highlight the need for further research across multiple seasons to confirm trends and account for additional variables such as player biomechanics, prior injuries, and variations in turf composition. While artificial surfaces may not inherently increase non-contact injury risk as previously assumed, they could contribute to a higher incidence of direct contact injuries related to surface rigidity. Future research should integrate

biomechanical data, player tracking, shoe type, and surface traction analysis to better understand injury mechanisms. A multi-season study considering cleat design, player position, and environmental factors could further refine recommendations for field design and player safety.

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