

# An Analysis of Specific Lower Extremity Injury Rates on Grass and FieldTurf Playing Surfaces in National Football League Games

## 2000-2009 Seasons

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**Background:** Players in the National Football League (NFL) sustain injuries every season as the result of their participation. One factor associated with the rate of injury is the type of playing surface on which the players participate.

**Hypothesis:** There is no difference in the rate of knee sprains and ankle sprains during NFL games when comparing rates of those injuries during games played on natural grass surfaces with rates of those injuries during games played on the artificial surface FieldTurf.

**Study Design:** Descriptive epidemiology study.

**Methods:** The NFL records injury and exposure (ie, game) data as part of its injury surveillance system. During the 2000-2009 NFL seasons, there were 2680 games (5360 team games) played on grass or artificial surfaces. Specifically, 1356 team games were played on FieldTurf and 4004 team games were played on grass. We examined the 2000-2009 game-related injury data from those games as recorded by the injury surveillance system. The data included the injury diagnosis, the date of injury, and the surface at the time of injury. The injury data showed that 1528 knee sprains and 1503 ankle sprains occurred during those games. We calculated injury rates for knee sprains and ankle sprains—specifically, medial collateral ligament (MCL) sprains, anterior cruciate ligament (ACL) sprains, eversion ankle sprains, and inversion ankle sprains—using incidence density ratios (IDRs). We used a Poisson model and logistic regression odds ratios to validate the IDR analysis. A multivariate logistic regression model was used to adjust the odds ratio for weather conditions.

**Results:** The observed injury rate of knee sprains on FieldTurf was 22% (IDR = 1.22, 95% confidence interval [CI], 1.09-1.36) higher than on grass, and the injury rate of ankle sprains on FieldTurf was 22% (IDR = 1.22, 95% CI, 1.09-1.36) higher than on grass. These differences are statistically significant. Specifically, the observed injury rates of ACL sprains and eversion ankle sprains on FieldTurf surfaces were 67% ( $P < .001$ ) and 31% ( $P < .001$ ) higher than on grass surfaces and were statistically significant. The observed injury rates of MCL sprains and inversion ankle sprains were also not significantly higher on FieldTurf surfaces ( $P = .689$  and  $.390$ , respectively).

**Conclusion:** Injury rates for ACL sprains and eversion ankle sprains for NFL games played on FieldTurf were higher than rates for those injuries in games played on grass, and the differences were statistically significant.

**Keywords:** injury epidemiology; artificial surfaces; ankle sprains; knee sprains

For the past 3 decades, the sports and medical communities have examined the risk of injury associated with the sport of football. One constant issue of focus has been the comparison of injury rates associated with playing on grass surfaces with injury rates associated with playing on artificial surfaces.<sup>10,11,15,16,17,18</sup>

Artificial playing surfaces have been in use in National Football League (NFL) stadiums for more than 3 decades. The first artificial surface used in an NFL stadium was installed in the Houston Astrodome in late 1966.<sup>2</sup> This playing surface, called AstroTurf (Monsanto, Dalton, Georgia), consisted of a carpetlike mat installed over a layer of cushioning material laid over an asphalt base.<sup>19</sup> Over the years, the designers of this surface altered the design, first replacing the asphalt base with a combination of stone and earth and then with a fully permeable elastomeric layer of recycled rubber, polyurethane, and mineral aggregate. The

designers also modified the carpet layer to be less abrasive and more durable with more consistent traction.<sup>3</sup>

In the mid 1990s, artificial surface designers introduced a new generation of artificial playing surface into sports venues, so-called infill surfaces. Infill surfaces generally consist of long polyethylene fibers woven on a mat with spaces between the fibers that are filled with rubber particles or a combination of rubber and sand. Several surface design companies have introduced a number of different infill surfaces under various brand names, including, among others, FieldTurf (FieldTurf, Tarkett Sports North America, Montreal, Quebec, Canada), Momentum (Sportex, Kennewick, Georgia), and AstroTurf (General Sports Venue, Dalton, Georgia). Over the past 10 years, infill surfaces became popular in both the United States and Europe, especially in college and professional sports. As of the 2005 NFL season, all NFL stadiums had replaced the earlier generation artificial surfaces with either grass or infill surfaces.

Several research studies have presented findings that compared injury rates for natural surfaces with those for first- and second-generation artificial surfaces. Research efforts to date generally describe injury patterns in college and professional football in terms of injury rates for grass versus artificial surfaces under different types of playing conditions.<sup>4,8,9,15,17,18</sup> These studies used data derived from different types of injury surveillance projects with different definitions of reportable injury (in general, some variation of time loss from participation) and player exposure. In general, the studies identified the frequency of injury and a type of exposure, typically, a variation of playing session (eg, number of players, number of games/practices, or number of athlete exposures [1 athlete playing in a session]).<sup>10,11,14-16,17</sup> These studies examined injury rate differences as stratified by type of injury, participation session, weather, player position, player activity, and type of play<sup>4,10,11,16-18</sup> or sometimes through a combination of these variables.<sup>14</sup> Several of these studies found certain higher injury rates on the artificial surfaces compared with grass,<sup>15,16,17,18</sup> while 1 study identified no differences between the injury rates.<sup>6</sup> Among the studies that examined specific injuries, there was a common finding that the injury rates were higher on the artificial surface, although there is no consistency as to the statistical significance of these findings.

To date, 2 of the preceding studies have compared injury rates on grass to an infill surface (specifically, FieldTurf): 1 study that included data from high school football

and 1 study that included data from college football.<sup>10,11</sup> Injury rates among high school football players who sustained anterior cruciate ligament (ACL) injuries were found to be higher on grass than on FieldTurf surfaces.<sup>11</sup> For the college study, the ACL injury rates were higher on the grass than on the FieldTurf.<sup>10</sup> The authors point to their findings as a resource for the proposition that there are unique injury patterns on these surfaces in high school and college football and that these patterns warrant further investigation regarding procedures for prevention. In addition, their analyses identify specific variables for which the differences between the FieldTurf and grass surface data were statistically significant (eg, injury time-loss categories,<sup>10,11</sup> injury mechanism categories,<sup>11</sup> anatomic location of injury,<sup>10,11</sup> and type of tissue<sup>11</sup>).

### The NFL Experience

The NFL maintains an injury surveillance system to monitor, on a consistent basis, the type, frequency, and severity of injuries that occur for each team during an NFL season. Launched in 1980, the system records data including, but not limited to, the date of injury and date of return to play after the injury, the type of injury, the weather conditions for the game, and the type of field surface. Team-certified athletic trainers and physicians record the injury and exposure data on a day-to-day basis, including primary, and potentially secondary, diagnosis of injuries observed. Previous studies used data from the injury surveillance system to compare the NFL injury rates for older-generation artificial surfaces and grass surfaces.<sup>15,17,18</sup> These studies showed no statistically significant difference in the observed injury rates for knee sprains in general or for the more specific injuries of ACL sprains and medial collateral ligament (MCL) sprains.<sup>18</sup> One study found statistically significant higher observed injury rates for ankle sprains generally on the artificial surface and for eversion ankle sprains specifically.<sup>17</sup>

### METHODS

We examined injury rates for knee sprains (all reported), MCL sprains, ACL sprains, ankle sprains (all reported), eversion ankle sprains, and inversion ankle sprains in NFL games played on grass and FieldTurf surfaces during

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the 2000-2009 seasons. Specifically, we examined primary injury data from the NFL injury surveillance system as described previously. The NFL injury surveillance system uses the following operational definitions to ensure the collection of consistent information.

**Injury.** An injury is reportable when 1 or more of the following conditions exist: (1) any injury for which the player was removed from the session or missed 1 day after the injury; (2) any fracture, regardless of time loss; (3) any concussion, regardless of time loss; (4) any dental injury, regardless of time loss; and (5) any heat-related problem, regardless of time loss. For this study, primary injuries identified as knee sprains were abstracted from the injury surveillance system and selected for inclusion in the analysis. Among the knee sprains, MCL sprains and ACL sprains were examined. The MCL sprains represent the most frequent type of knee sprain, and the ACL sprains, while less frequent, are associated with the greatest amount of time lost from participation. If both MCL and ACL sprains occurred simultaneously, we considered the primary injury to be the ACL sprain. Similarly, primary injuries identified as ankle sprains were abstracted from the injury surveillance system. Within the ankle sprains, we identified inversion sprains (injuries to the anterior and posterior talofibular ligaments, calcaneofibular ligament, and lateral capsule) and eversion sprains (injuries to the anterior and posterior tibiofibular ligaments, interosseous ligament, deltoid ligament, and medial capsule) for analysis. The frequency of these 2 types of ankle sprains is similar. The time lost from participation differs with the ankle inversion injuries associated with days lost, while the eversion injuries are associated with weeks lost.

**Exposure.** The data used for the study included only game injuries; thus, the exposure variable for this study, as with other NFL studies, is a game. Each NFL game represents 2 team games, 1 contributed by each competing team (10 games = 20 team games). The team game represents a consistent level of playing exposure for the number of players on the field and the number of plays over a consistent period of play. For this reason, only game-related injuries were included in the analysis.

**Type of Surface.** During the 2000 NFL season, the Seattle Seahawks played the first NFL game on one of the new infill surfaces, specifically, a FieldTurf installation at the University of Washington. During the 2000 and 2001 seasons, the University of Washington facility had the only infill surface used for NFL games. Beginning with the 2002 season, NFL stadiums introduced more infill surfaces, and by the conclusion of the 2009 season, 14 of 32 NFL teams played in home stadiums that had a new-generation infill-playing surface, of which 10 (71%) were FieldTurf. The rest of the stadiums (18/32) have a grass surface, as the last NFL stadium with an older-generation artificial surface removed it after the 2004 season. Because the vast majority of games played on infill surfaces are on FieldTurf, we compared NFL injury rates associated only with FieldTurf with the NFL injury rates associated with grass playing surfaces.

**Weather Conditions.** Using data recorded by the NFL separate from the injury surveillance system, we also considered the weather conditions on the game day. Because of

the high variability of weather condition descriptions recorded, we grouped the weather data into categories of dry and wet (any reference to precipitation recorded on game day).

## Statistical Analysis

We used an incidence density ratio (IDR) analysis to evaluate the rates of knee and ankle sprain injuries on grass and FieldTurf playing surfaces. The IDR analysis divided each respective injury rate on FieldTurf by the injury rate on grass to create the IDR. In addition, we computed 95% confidence intervals (CIs) for the IDR.<sup>12,13</sup> When the IDR value is greater than 1, the observed injury rate is greater on FieldTurf than on grass; when the IDR value is less than 1, the observed injury rate is greater on grass than on FieldTurf. Similarly, 95% CIs for the IDR that do not include 1 reflect statistically significant differences between the 2 observed injury rates (with a 5% chance of error in this conclusion). If the calculated lower 95% confidence limit is greater than 1, then the observed injury rate on FieldTurf is greater than that on grass to a statistically significant degree; if the calculated upper 95% confidence limit is less than 1, then the observed injury rate on grass is greater than that on FieldTurf to a statistically significant degree. In addition, Bonferroni adjustments were made in the calculations to address the multiplicity issue associated with constructing multiple CIs.

We used several additional well-accepted methods of statistical analysis to validate the IDR findings on ACL sprains and eversion ankle sprains because they reflected statistically significant differences in the observed injury rates. To that end, because the knee and ankle sprain injuries included in the analysis represented approximately 20.7% (10.4% for knee sprains and 10.3% for ankle sprains) of the total number of injuries reported during NFL games in the 10-year study period, we used a Poisson modeling approach that considers the injuries as rare cases to estimate the injury rates<sup>5</sup> (see Appendix A, available in the online version of this article at <http://ajs.sagepub.com/supplemental>). We also evaluated the incidence data using an odds ratio (OR) approach that estimates the ratio of the odds of an injury occurring on FieldTurf to the odds of an injury occurring on grass (see Appendix B, available online). The odds of an event occurring is defined as the ratio of the probability that it occurs to the probability that it does not occur.<sup>7,20</sup> In addition, we used a multivariate logistic regression modeling approach to adjust the OR for the game time weather conditions (wet, dry; see Appendix C, available online). Finally, we used the Breslow and Day test procedure to validate the study's aggregation of the data from 2000-2009<sup>1</sup> (see Appendix D, available online). Online Appendix E summarizes these findings obtained through the different statistical modeling approaches.

## RESULTS

A review of the 2000-2009 NFL data show that there were 6612 team games played during that time. There were

TABLE 1  
Initial Analysis of Specific Lower Extremity Injury Rates per Team Game in the NFL<sup>a</sup>

	Knee Sprains			Ankle Sprains		
	All Reported	Knee, MCL	Knee, ACL	All Reported	Inversion	Eversion
Frequency of injury						
Number of injuries	1528	830	260	1503	631	734
Number of grass injuries	1082	615	166	1064	462	508
Number of FieldTurf injuries	446	215	94	439	169	226
Injury rates						
tTG	0.285	0.155	0.049	0.280	0.118	0.137
IR/TG (Grass)	0.270	0.154	0.041	0.266	0.115	0.127
IR/TG (FieldTurf)	0.329	0.159	0.069	0.324	0.125	0.167
IDR analysis						
IDR	1.22 <sup>b</sup>	1.03	1.67 <sup>b</sup>	1.22 <sup>b</sup>	1.08	1.31 <sup>b</sup>
95% CI	1.09-1.36	0.88-1.21	1.30-2.15	1.09-1.36	0.91-1.29	1.12-1.54
Z Statistic	3.5	0.4	4.03	3.49	0.86	3.42
P value	<.001	.689	<.001	<.001	.390	<.001
Multiplicity adjustments (6 intervals)						
99.167% CI	1.05-1.40	0.84-1.27	1.20-2.33	1.05-1.41	0.86-1.36	1.07-1.62

<sup>a</sup>MCL, medial collateral ligament; ACL, anterior cruciate ligament; IR/TG, Injury Rate/Team-Game; IDR, incidence density ratio; CI, confidence interval.

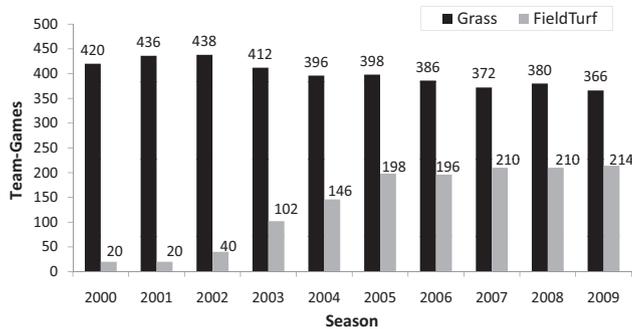


Figure 1. Frequency of team games by season.

4004 (60.6%) team games played on grass surfaces, 628 (9.5%) team games played on older-generation artificial surfaces, and 1980 (30.0%) team games played on infill playing surfaces. There were 1356 team games played on FieldTurf surfaces, representing 20.5% of total team games and 68.5% of team games played on infill surfaces (Figure 1).

The graph in Figure 2 displays the IDR and 95% CIs compared with an IDR of 1.0 (ie, no difference) for the different injury categories. Table 1 presents the observed knee and ankle sprain injury rates for NFL games played during the 2000-2009 seasons on grass and FieldTurf playing surfaces as well as the results of the IDR analysis. The data in Table 1 show the IDR for ACL sprains as 1.67 (95% CI, 1.30-2.15), which represents an injury rate on FieldTurf that is 67% higher than that on grass. The 95% CI does not include 1, and thus, the difference is statistically significant ( $P < .001$ ). The IDR for eversion ankle sprains is 1.31 (95% CI, 1.12-1.54), which represents an injury rate on FieldTurf that is 31% higher than that on grass, and this difference is also statistically significant ( $P < .001$ ).

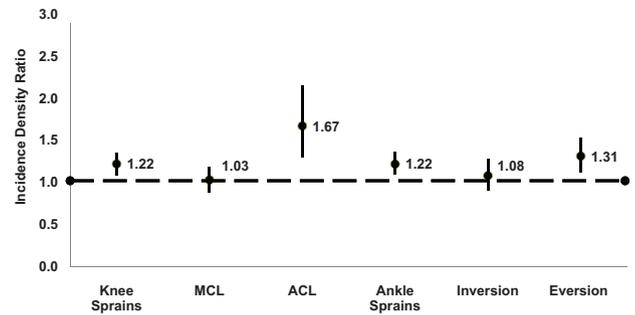


Figure 2. Incidence density ratio and 95% confidence intervals for FieldTurf/grass injury rates per team game.

Table 1 also shows higher observed injury rates on FieldTurf playing surfaces for MCL sprains and ankle inversion sprains, but the IDR calculations for these injuries of 1.03 (95% CI, 0.88-1.21) and 1.08 (95% CI, 0.91-1.29), respectively, show that while they are slightly higher (3% for MCL and 8% for inversion ankle sprains), they are not significantly different. A Bonferroni multiplicity adjustment for computing 6 CIs implies using a nominal confidence level of 99.167%. These adjusted CIs are also shown in Table 1 and confirm the statistical significance identified for the ACL injuries and eversion ankle sprains. Appendix E (available online) summarizes similar findings on ACL sprains and eversion ankle sprains obtained through other statistical modeling approaches—including a Poisson model, a logistic regression OR model, a multivariate logistic regression OR model, and a weighted OR analysis—and compares those findings to the IDR model. Online Appendices A through D present brief descriptions of these additional analyses, respectively.

## DISCUSSION

Many studies have been published comparing injury rates on playing surfaces. Some studies have found comparable rates on artificial surfaces and grass, while others have found differing rates on these surfaces. Generally, these studies have been performed by collecting data on a consistent cohort of athletes (eg, college football).<sup>8</sup> A common aspect of these studies is the grouping of injuries (eg, knee ligament sprains or ankle sprains). Grouping all injuries in broad categories alone, however, can limit the studies because the need for nonsurgical or surgical intervention and time loss from participation may vary based on the specific anatomic diagnosis.

One study evaluated the incidence of injury of college football players during games played on grass and FieldTurf and found no difference in respective injury rates when knee injuries were considered as a single group.<sup>10</sup> In our study, we focused on knee sprains rather than all knee injuries. In our evaluation of specific types of knee sprains, MCL and ACL sprains during NFL games, we found that the ACL sprains occurred at a significantly higher rate on FieldTurf surfaces, whereas there were no significant differences in rates of MCL sprains. In another study, the authors reported a higher incidence of ACL injuries in high school football players on grass compared with FieldTurf. In neither of these studies did the authors analyze ankle sprains in general or inversion and eversion injuries specifically.<sup>10,11</sup>

From our study, it is not possible to determine the cause of the higher incidence of eversion ankle and ACL sprains, and we do not purport to do so. The difference in the findings may relate to the mechanics of the injuries involved, but we can draw no such conclusions from our study. Further analysis is needed to identify possible contributing factors to the injuries studied (eg, the interactions between footwear and surface).

## CONCLUSION

We found statistically significant higher observed injury rates on FieldTurf than on grass for ACL sprains (67%) and eversion ankle sprains (31%) during games played in the NFL from 2000-2009. We did not find statistically significant higher injury observed rates for MCL sprains and inversion ankle sprains.

We recognized the importance of understanding other possible contributing factors and the mechanics of a particular injury and did not draw any conclusions related to the cause of the injuries analyzed. The statistical findings warrant additional analysis, and the addition of data from future NFL seasons will enhance the league's ability to examine other external factors.

The findings of this study are limited to an analysis of injuries that occurred during NFL games in the 2000-2009 seasons and to those injuries that occurred on either grass or FieldTurf surfaces installed in NFL stadiums. Further study is recommended to evaluate the injury rates

for other athletic populations and levels of football that participate on these playing surfaces.

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