## Incidence, Mechanisms, and Severity of Match-Related Collegiate Men's Soccer Injuries on FieldTurf and Natural Grass Surfaces: A 6-Year Prospective Study


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# Incidence, Mechanisms, and Severity of Match-Related Collegiate Men's Soccer Injuries on FieldTurf and Natural Grass Surfaces

## A 6-Year Prospective Study

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**Background:** Numerous injuries have been attributed to playing on artificial turf. More recently, newer generations of artificial turf have been developed to duplicate the playing characteristics of natural grass. Although artificial turf has been deemed safer than natural grass in some studies, few long-term studies have been conducted comparing match-related collegiate soccer injuries between the 2 playing surfaces.

**Hypothesis:** Collegiate male soccer athletes do not experience any difference in the incidence, mechanisms, or severity of match-related injuries between FieldTurf and natural grass.

**Study Design:** Cohort study; Level of evidence, 2.

**Methods:** Male soccer athletes from 11 universities were evaluated over 6 seasons. Demographic features and predictors included player position, cleat design, player weight, turf age, and environmental factors. Outcomes of interest included injury incidence, injury category, time loss, injury mechanism and situation, type of injury, injury grade and anatomic location, injury severity, head and lower extremity trauma, and elective medical procedures. All match-related injuries were evaluated by the attending head athletic trainer and team physicians on site and subsequently in the physician's office when further follow-up and treatment were deemed necessary. In sum, 765 collegiate games were evaluated for match-related soccer injuries sustained on FieldTurf or natural grass during 6 seasons.

**Results:** Overall, 380 team games (49.7%) were played on FieldTurf versus 385 team games (50.3%) played on natural grass. A total of 722 injuries were documented, with 268 (37.1%) occurring on FieldTurf and 454 (62.9%) on natural grass. Multivariate analysis per 10 team games indicated a significant playing surface effect: $F_{2,720} = 7.260$, $P = .001$. A significantly lower total injury incidence rate (IIR) of 7.1 (95% CI, 6.6-7.5) versus 11.8 (95% CI, 11.3-12.2; $P < .0001$) and lower rate of substantial injuries, 0.7 (95% CI, 0.5-1.0) versus 1.9 (95% CI, 1.5-2.3; $P < .03$), were documented on FieldTurf versus natural grass, respectively. Analyses also indicated significantly less trauma on FieldTurf when comparing injury category, time loss, player position, injury mechanism and situation, injuries under various environmental conditions, cleat design, turf age, anatomic location, and elective medical procedures. No significant difference ($F_{11,710} = 0.822$, $P = .618$) between surfaces by knee injury was observed, with the majority of knee injuries involving patellar tendinopathies/syndromes followed by medial collateral ligament injuries on both surfaces.

**Conclusion:** Although similarities existed between FieldTurf and natural grass during competitive match play, FieldTurf is, in many cases, safer than natural grass when comparing injuries in collegiate men's soccer. The findings of this study, however, may not be generalizable to other levels of competition or to other artificial surfaces.

**Keywords:** artificial surface; knee; head; trauma

For over 40 years, a greater risk and incidence of articular and concussive trauma have been attributed to playing on artificial turf when compared with natural grass.[12,21] Over the past 2 decades, newer generations of artificial surfaces were developed to duplicate the playing characteristics of natural grass. The first artificial turf infill system composed of a polyethylene grass fiber blend stabilized with graded silica sand and cryogenically ground rubber infill, FieldTurf, set the standard for subsequent artificial grass playing surfaces used today. Although FieldTurf has been recommended as a practical option to natural grass

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in the prevention of American football and collegiate women's soccer injuries,[27-29] minimal research has been conducted comparing match-related collegiate men's soccer injuries between the 2 playing surfaces over several seasons of competition.[6,10]

More than 1 million athletes play competitive soccer in the United States.[32,33] The number of injuries is rising, and their cost of treatment and rehabilitation is reaching into the millions of dollars each year.[31,46] Coupled with this is the psychological trauma and setbacks in training and the potential for long-term degenerative changes typically experienced by athletes after a significant injury.[1,30,52] As such, efforts to address ways to minimize the predisposition to injuries are warranted.[4] Therefore, the purpose of this study was to quantify the incidence, mechanisms, and severity of match-related collegiate men's soccer injuries on FieldTurf and natural grass. It was hypothesized that collegiate male athletes would not experience differences in the incidence, mechanisms, and severity of match-related injuries between FieldTurf and natural grass.

## METHODS

### Population

A total of 11 universities, classified as Division IA by the National Collegiate Athletic Association, were evaluated for match-related collegiate men's soccer injuries sustained while playing on both FieldTurf and natural grass during a 6-year period during the years from 2007 to 2012. The specific schools were selected based on the availability of both playing surfaces during the competitive season, uniformity of sport skill level, and presence of full-time certified athletic training (ATC) staff, minimizing the potential for injury-reporting bias.[4,27,29,40] This resulted in a total of 765 matches over the 6-year period played on either FieldTurf (n = 380) or natural grass (n = 385).

To quantify prior injuries and their potential influence, all athletes underwent preparticipation physical examinations under the care of their respective team physician/orthopaedic surgeon. Criteria for exclusion included (1) any known preexisting congenital or developmental factor that predisposed an athlete to a potential injury and (2) the acknowledgment, complaint, or observed evidence of any medical or orthopaedic problem severe enough to compromise an athlete's performance or endanger his health as determined by self-response, medical history, and interview.[27,29]

### Procedures

On the basis of paradigms suggested in prior research,[1,22,26,50] it was decided that a multifactorial approach that encompassed teams playing on both surfaces during the same time period, using definitive but brief injury surveillance, would provide several advantages. These include gaining a greater comparison of the nuances of each surface's influence on injuries, avoiding limitations in data collection (eg, seasonal variation, participant randomization by surface), and minimizing difficulties in analyses and interpretation of findings that former studies have had.[1,39] For this prospective cohort study, a previously developed 2-sided, single-page injury surveillance form was used based on prior criteria recommended and previously described in the literature.[15,22,27,28,35] The form includes the following: athletic identification number; athletic trainer; date of injury; athlete weight; university; type of playing surface; surface quality; surface age; temperature at match time; cleat design; year/skill level of athlete; where the injury occurred; weather/field conditions; injury category; injury classification; injury time loss; position played at time of injury; injury mechanism; injury situation; personnel determining the injury; injury site location; principal body part; primary type of injury; grade of injury; occurrence of external bleeding; injury because of illegal action; head, knee, shoulder, and thoracic/abdominal diagnosis; elective imaging and surgical procedures; and musculoskeletal, joint, or organ location of injury.

The injury surveillance form was initially emailed to the head ATCs during the preceding summer before the start of the soccer season. At this time, we provided all ATCs with an overview of the purpose, procedures, benefits, time demands, and importance of the study. They were also provided with copies of the injury surveillance form and detailed instructions for completion to avoid the potential for performance and detection biases.[6,39,40] After a full explanation, all ATCs agreed to participate in data collection. Informed consent was voluntarily obtained from the appropriate reporting staff, institutional review board permission was granted, and the study was conducted in accordance with the guidelines for the use of human participants. Continual communication was maintained to discuss potential concerns and to ensure the accuracy of data collection, comprehensiveness of information, and ease of application.

All regular-season conference and nonconference matches and postseason tournament matches were included. Injury data were recorded after match completion, with additional support from ATC notes to avoid lapses in memory that may lead to inaccuracy or response distortion.[39,50] All match-related injuries were evaluated by the attending head athletic trainer and team physicians on site and subsequently in the physician's office when further follow-up and treatment were deemed necessary. Any sport trauma that occurred toward the end of the competitive schedule was monitored beyond the player's specific season to determine the date of recovery and functional return to play.[4,6,27]

Completed injury surveillance forms were faxed to us within 7 working days after a match and were entered in

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the database before the next week. A follow-up telephone call was made to obtain any additional information pertaining to any changes or additions in the diagnosis, treatment, or time to return to play. To avoid the potential for on-the-field detection bias,[28,40] a single-blind outcome approach was maintained throughout the study period, with total data collection, compilation, and analyses limited to the data coordinator.

## Definitions

Although any definition of injury and level of trauma lacks universal agreement and has its shortcomings,[1,18,35,39] we defined an injury based on a combination of functional outcomes, observation, and treatment.[27,28,35] A "reportable injury" was defined as any game-related soccer trauma that resulted in (1) an athlete missing all or part of a match, (2) time away from competition, (3) any injury reported or treated by the athletic trainer or physician, and (4) all cranial/cervical trauma reported. Although some authors have recommended omitting minor injuries,[35,39] others have expressed a need to quantify and track these typically overlooked minor traumas to avoid underreporting of injuries and to monitor those injuries that may turn into chronic or overuse problems.[5,15,16,28,53] Prior studies have also revealed that 42% to 60% of competitive trauma results in minimal time loss and medical cost.[29,50] Therefore, we felt that a definition that included functional outcomes, observation, and treatment on all injuries would more clearly quantify the unique nuances or trauma observed with each playing surface and reduce the trainer/physician and player biases that allegedly influence injury reporting based solely on time loss.[27,39]

Injury time loss was based on the number of days absent from practice or match competition and was divided into 0, 1 to 2, 3 to 6, 7 to 9, 10 to 21, and $\geq$22 days of recovery time. Not surprisingly, a review of the literature revealed high subjectivity in the determination of what constitutes a moderate or severe injury. Whereas any injury resulting in a time loss of approximately 7 to 28 days has been considered moderate trauma and a time loss of 21 to 28 days has been defined as severe,[6,50] others have defined a severe injury as trauma resulting in $\geq$7 days of time loss.[15,22,37] Furthermore, what constitutes a moderate injury in one athlete (eg, elbow injury in a midfielder) may be considered severe when diagnosed in the throwing arm of a goalkeeper.[2,53] Therefore, we chose to define any trauma that required 0 to 6 days of time loss as a "minor injury," an injury that required 7 to 21 days of time loss resulting in the athlete being unable to return to play at the same competitive level as a "substantial injury," and trauma that required $\geq$22 days of time loss as a "severe injury."[27-29] The delineation and subsequent analysis of minor, substantial, and severe injuries are similar to earlier criteria established in soccer[14,28,38] and primarily served to minimize potential time-loss bias.[27]

Injury category was quantified by player-to-player collision, player-to-turf collision, player-to-ball impact, player-to-object collision, injuries attributed to shoe-surface interaction during player contact, injuries attributed to shoe-surface interaction without player contact, and muscle-tendon–related overload.[4,27] Regarding injury classification, "acute trauma" was delineated from recurrent and overuse injuries according to criteria previously published,[24,27] with acute trauma linked to an incidence that specifically occurred during a competitive match versus "repetitive exposure," which resulted in symptoms and an injury to the same location during the season (recurrent). An "overuse injury" was defined as repetitive exposure resulting in trauma and sequelae with no definitive onset.[28]

To enhance optimal cell size and interpretation, player positions were condensed and analyzed by offense and defense as well as analyzed individually (goalkeeper, center back/sweeper/libero, fullback, wingback, defensive mid-anchorman, attacking midfielder, wide midfielder, winger, center striker, dual/deep-lying striker). "Mechanism of injury" was defined as occurring while a player was dribbling/shielding; heading; passing/receiving a pass; shooting; attempting a slide tackle; being tackled from the side/behind; blocking a shot/pass; scrambling for a loose ball; goalkeeping; making contact with the playing surface; being stepped on, fallen on, or kicked; sprinting/running/jumping with no player contact; or suffering from heat illness or overuse. "Injury situation" was defined as trauma occurring during a specific play or event such as a warm-up; kickoff; offensive direct play; possession buildup; offensive counterattack; defensive high pressure, middle pressure, or low pressure; kicks (penalty, corner, direct, indirect); dropped ball; or throw-in.

To optimize analyses, "primary type of injury" was combined into the following categories: surface/epidermal (abrasion, laceration, puncture wound), contusion, concussion, inflammation (bursitis, tendinitis, fasciitis, synovitis, capsulitis, apophysitis), ligament sprain, ligament tear, muscle-tendon strain/spasm/tear, cartilage tear, hyperextension, neural (burner, brachial plexus), subluxation/dislocation, and fracture (standard, epiphyseal, avulsion, stress, osteochondral). Injuries were also defined according to grade (1, 2, or 3).

Because of increasing concerns of rising medical costs,[31] the potential for long-term articular changes,[1,52] and the perceived higher incidence of articular trauma while playing on artificial turf,[54] elective imaging procedures (computed tomography, magnetic resonance imaging, radiography, ultrasound) and the number of in-season and postseason surgical procedures were documented. "Anatomic location of injury" was combined from 40 physical areas and analyzed by cranial/cervical, upper extremity, thoracic, and lower extremity trauma and further analyzed by type of tissue injured (bone, joint, muscle, neural, other). "Cranial/cervical trauma" included grade 1 to 3 concussions; hematomas; postconcussions and second-impact syndromes; neurological sequelae (eg, stingers/burners, transient quadriplegia); vascular or dental injuries; or associated fractures, sprains, and strains.[27,28] "Neural trauma" was restricted to any injury involving only concussions, associated syndromes, and neurological sequelae. Because of growing concerns addressing excessive head, knee, and lower extremity trauma in sport,[31,39] these areas were specifically identified for further analyses.

TABLE 1
Incidence of Match-Related Collegiate Men's Soccer Injuries Between FieldTurf and Natural Grass Surfaces[a]

| Variable | FieldTurf | Natural Grass | Total or Mean |
|---|---|---|---|
| Matches evaluated, n (%) | 380 (49.7) | 385 (50.3) | 765 (100.0) |
| All injuries | | | |
| n (%) | 268 (37.1) | 454 (62.9) | 722 (100.0)[b] |
| IIR (95% CI) | 7.1 (6.6-7.5) | 11.8 (11.3-12.2) | 9.4 |
| Minor injuries | | | |
| n (%) | 234 (87.3) | 370 (81.5) | 604 (83.7)[c] |
| IIR (95% CI) | 6.2 (5.7-6.6) | 9.6 (9.4-9.8) | 7.9 |
| Substantial injuries | | | |
| n (%) | 26 (9.7) | 72 (15.9) | 98 (13.6)[d] |
| IIR (95% CI) | 0.7 (0.5-1.0) | 1.9 (1.5-2.3) | 1.3 |
| Severe injuries | | | |
| n (%) | 8 (3.0) | 12 (2.6) | 20 (2.8) |
| IIR (95% CI) | 0.2 (0.1-0.4) | 0.3 (0.2-0.5) | 0.3 |

[a]Wilks λ for severity of injury ($F_{2,720}$ = 7.260, $P$ = .001). Injury incidence rate (IIR) = (*number of injuries/number of team matches*) × 10. Minor injury = 0-6 days of injury time loss; substantial injury = 7-21 days of injury time loss; severe injury = ≥22 days of injury time loss.
[b]$P < .0001$.
[c]$P < .04$.
[d]$P < .03$.

Because studies have indicated a variation in peak pressure, torque, and in-shoe foot loading patterns resulting from the shoe-surface interaction,[9,23,51] the type of cleat design (studded removable cleats, combination of molded conical with either cleats or blades) and player weight (121-140, 141-160, 161-180, 181-200, and >200 lb) were documented. In addition, there has been minimal information on factors such as weather conditions and the effect of playing under surface conditions that influence injury frequency.[28,29,36] Therefore, environmental factors such as field conditions and temperature were obtained before match time by each team's respective ATC and/or through the local airport climatic data center to ascertain the potential influence on injuries from changes in weather throughout the season.[27] Finally, based on injury concerns from the wear and tear and aging of artificial surfaces, data on turf age (new, 1-3, 4-7, and ≥8 years) were gathered for surface comparison, an area not previously documented in the literature in men's collegiate soccer.

## Statistical Analyses

Tabular frequency distributions were computed for data in each category using the Statistical Package for the Social Sciences software (version 10.0; SPSS Inc). Because most universities schedule a similar number of matches each season, exposure to injuries was defined in terms of team matches, as previously recommended.[27-29,50] Using this definition, the injury incidence rate (IIR) was expressed using injuries per 10 team matches: (*number of injuries/number of team matches*) × 10. When appropriate, the denominator was adjusted to reflect the number of athletes playing in each specific cleat type as well as the number of matches played in adverse weather conditions or on a dry field. The 95% CIs for IIRs were determined as described elsewhere.[48]

To achieve a more thorough understanding beyond traditional frequency analyses and to eliminate the possibility of irrelevant sources of error,[26,48] after the season, data were numerically recoded, grouped by playing surface (FieldTurf, natural grass), and subjected to multivariate analyses of variance and the Wilks λ criteria using general linear model procedures.[27,48] Data screening was conducted to ensure no violations of multivariate normality, linearity, outliers, homogeneity of variance, multicollinearity, or singularity.[48] When significant main effects were observed, univariate post hoc procedures were performed within each dependent variable based on the total percentage of injuries reported on each playing surface. An experiment-wise type I error rate of 0.05 was established a priori, and least squares mean procedures were required because of the uneven number of observations on which to compare differences between variables.

## RESULTS

A total of 765 collegiate matches were evaluated for game-related soccer injuries sustained while playing on FieldTurf or natural grass during the 2007 to 2012 seasons (Table 1). Overall, 380 (49.7%) team matches were played on FieldTurf versus 385 (50.3%) team matches played on natural grass. A total of 722 injuries were documented, with multivariate analysis indicating a significant playing surface effect across the level of injury ($F_{2,720}$ = 7.260, $P$ = .001). Post hoc analysis indicated that a significantly lower incidence of total injuries ($P < .0001$), minor injuries ($P < .04$), and substantial injuries ($P < .03$) were documented on FieldTurf than reported on natural grass.

The majority of trauma comprised acute injuries, with significantly fewer ($P < .0001$) injuries reported on FieldTurf (IIR, 5.9; 95% CI, 5.4-6.4) than on natural grass (IIR, 11.0; 95% CI, 10.7-11.4). Only 44 of 268 (IIR, 1.1; 95% CI, 0.8-1.7) injuries reported on FieldTurf and 30 of 454 (IIR, 0.8; 95% CI, 0.5-1.2) injuries reported on natural

TABLE 2
Frequency and Rate of Match-Related Collegiate Men's Soccer Injuries Between FieldTurf and Natural Grass Surfaces by Head and Knee Trauma[a]

| | FieldTurf (n = 380) | | Natural Grass (n = 385) | |
|---|---|---|---|---|
| Variable | n | IIR (95% CI) | n | IIR (95% CI) |
| Head injury | | | | |
| Concussion | | | | |
| First degree | 12 | 0.3 (0.2-0.5) | 23 | 0.6 (0.4-0.9) |
| Second degree | 2 | 0.1 (0.0-0.2) | 8 | 0.2 (0.1-0.4) |
| Third degree | 0 | 0.0 (0.0-0.0) | 0 | 0.0 (0.0-0.0) |
| Posttraumatic headache | 4 | 0.1 (0.0-0.3) | 4 | 0.1 (0.0-0.3) |
| Postconcussion syndrome | 0 | 0.0 (0.0-0.0) | 2 | 0.1 (0.0-0.2) |
| Epistaxis | 9 | 0.2 (0.1-0.4) | 18 | 0.5 (0.3-0.7) |
| Concussion injuries combined | 14 | 0.4 (0.2-0.6) | 31 | 0.8 (0.6-1.1) |
| Knee injury | | | | |
| Medial collateral ligament | 4 | 0.1 (0.0-0.3) | 4 | 0.1 (0.0-0.3) |
| Lateral collateral ligament | 0 | 0.0 (0.0-0.0) | 2 | 0.1 (0.0-0.2) |
| ACL | 0 | 0.0 (0.0-0.0) | 1 | 0.0 (0.0-0.1) |
| ACL and associated tissue | 1 | 0.0 (0.0-0.1) | 1 | 0.0 (0.0-0.1) |
| PCL and associated tissue | 1 | 0.0 (0.0-0.1) | 4 | 0.1 (0.0-0.3) |
| Arcuate-popliteal complex | 0 | 0.0 (0.0-0.0) | 2 | 0.1 (0.0-0.2) |
| Lateral/medial meniscus | 1 | 0.0 (0.0-0.1) | 0 | 0.0 (0.0-0.0) |
| Patellar tendinopathies/syndromes | 5 | 0.1 (0.1-0.3) | 9 | 0.2 (0.1-0.4) |
| ACL injuries combined | 1 | 0.0 (0.0-0.1) | 2 | 0.1 (0.0-0.2) |

[a]Wilks λ for head injury ($F_{5,716}$ = 0.580, $P$ = .716) and knee injury ($F_{11,710}$ = 0.822, $P$ = .618). Injury incidence rate (IIR) = (*number of injuries/number of team matches*) × 10. ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

grass were classified as recurrent trauma or complications from a prior injury.

## Head and Knee Trauma

As shown in Table 2, there was no significant main effect ($F_{5,716}$ = 0.580, $P$ = .716) between surfaces by head injury when combined by all sources of trauma. A similar nonsignificant main effect ($F_{11,710}$ = 0.822, $P$ = .618) between surfaces by knee injury was also observed. The majority of knee trauma involved patellar tendinopathies/syndromes, followed by medial collateral ligament injuries on both surfaces.

## Injury Category and Injury Time Loss

As shown in Table 3, multivariate analysis indicated no significant playing surface effect by injury category ($F_{6,715}$ = 1.085, $P$ = .370). With regard to injury time loss, however, findings indicated a significant playing surface effect ($F_{5,716}$ = 3.075, $P$ = .009), with subsequent post hoc analyses (Table 3) revealing a significantly lower ($P$ < .02) incidence of injuries resulting in 0-day time loss, 1- to 2-day time loss, and 7- to 9-day time loss reported on FieldTurf versus natural grass.

## Position Played at Time of Injury

There was a significant playing surface effect by overall player position, that is, offense and defense ($F_{1,719}$ = 3.254, $P$ = .039) (Table 3). Post hoc analyses indicated a lower ($P$ < .05) incidence of both defensive and offensive injuries reported on FieldTurf when compared with natural grass.

Multivariate analysis also indicated a significant main effect by specific position ($F_{11,710}$ = 2.794, $P$ = .001), with a significantly lower ($P$ < .001) incidence of injuries to center back/sweeper/libero athletes on the defensive side when competing on FieldTurf versus natural grass. Offensively, a significantly lower incidence of trauma ($P$ < .02) was experienced by midfielder positions combined, center strikers, and striker positions combined while playing on FieldTurf when compared with natural grass.

## Environmental Factors

The attempt to quantify environmental conditions at the time of injury revealed that the majority of injuries occurred during dry weather (see Appendix Table A1, available online). With regard to field conditions, there was a significant main effect ($F_{2,719}$ = 2.705, $P$ = .030) between surfaces, with a significantly lower incidence of injuries on FieldTurf versus natural grass during no precipitation/dry field conditions ($P$ < .02), during rainy conditions ($P$ < .05), during no precipitation/wet field conditions ($P$ < .05), and during all adverse weather conditions combined ($P$ < .01).

When analyzing data by cold days (ie, ≤69°F) as compared with hot days (ie, ≥70°F) as suggested by others,[26-29] there was a significant main effect ($F_{1,720}$ = 14.125, $P$ = .0001) between surfaces by environment temperature. Post hoc analyses indicated a significantly lower incidence of injuries

TABLE 3
Frequency and Rate of Match-Related Collegiate Men's Soccer Injuries Between FieldTurf and Natural Grass Surfaces by Injury Category, Injury Time Loss, and Player Position[a]

| | FieldTurf (n = 380) | | Natural Grass (n = 385) | |
|---|---|---|---|---|
| Variable | n | IIR (95% CI) | n | IIR (95% CI) |
| Injury category | | | | |
| Player-to-player collision | 111 | 2.9 (2.5-3.4) | 206 | 5.4 (4.9-5.8) |
| Player-to-turf collision | 30 | 0.8 (0.6-1.1) | 42 | 1.1 (0.8-1.4) |
| Player-to-ball/object impact | 14 | 0.4 (0.2-0.6) | 27 | 0.7 (0.5-1.0) |
| Shoe surface (contact) | 51 | 1.3 (1.0-1.7) | 88 | 2.3 (1.9-2.7) |
| Shoe surface (noncontact) | 16 | 0.4 (0.3-0.7) | 34 | 0.9 (0.6-1.2) |
| Muscle-tendon overload | 46 | 1.2 (0.9-1.6) | 57 | 1.5 (1.2-1.9) |
| Injury time loss, d | | | | |
| 0 | 122 | 3.2 (2.8-3.7) | 165 | 4.3 (3.8-4.8)[b] |
| 1-2 | 55 | 1.4 (1.1-1.8) | 130 | 3.4 (2.9-3.9)[b] |
| 3-6 | 57 | 1.5 (1.2-1.9) | 76 | 2.0 (1.6-2.4) |
| 7-9 | 16 | 0.4 (0.3-0.7) | 52 | 1.4 (1.0-1.7)[b] |
| 10-21 | 10 | 0.3 (0.1-0.5) | 19 | 0.5 (0.3-0.8) |
| ≥22 | 8 | 0.2 (0.1-0.4) | 12 | 0.3 (0.2-0.5) |
| Position played at time of injury | | | | |
| Defense | 131 | 3.5 (3.0-4.0) | 241 | 6.3 (5.8-6.7)[c] |
| Goalkeeper | 18 | 0.5 (0.3-0.7) | 32 | 0.8 (0.6-1.2) |
| Center back/sweeper/libero | 39 | 1.0 (0.8-1.4) | 110 | 2.9 (2.4-3.3)[d] |
| Fullback | 22 | 0.6 (0.4-0.9) | 42 | 1.1 (0.8-1.4) |
| Wingback | 29 | 0.8 (0.5-1.1) | 25 | 0.6 (0.4-0.9) |
| Midanchorman | 23 | 0.6 (0.4-0.9) | 32 | 0.8 (0.6-1.2) |
| Offense | 137 | 3.6 (3.1-4.1) | 213 | 5.5 (5.0-6.0)[c] |
| Attacking midfielder | 52 | 1.4 (1.1-1.8) | 58 | 1.5 (1.2-1.9) |
| Wide midfielder | 34 | 0.9 (0.6-1.2) | 49 | 1.3 (1.0-1.6) |
| Winger | 7 | 0.2 (0.1-0.4) | 15 | 0.4 (0.2-0.6) |
| Center striker | 23 | 0.6 (0.4-0.9) | 66 | 1.7 (1.4-2.1)[b] |
| Dual/deep-lying striker | 21 | 0.6 (0.4-0.8) | 25 | 0.6 (0.4-0.9) |

[a]Wilks λ for injury category ($F_{6,715}$ = 1.085, $P$ = .370), injury time loss ($F_{5,716}$ = 3.075, $P$ = .009), overall position played at time of injury ($F_{1,719}$ = 3.254, $P$ = .039), and skill position played at time of injury ($F_{11,710}$ = 2.794, $P$ = .001). Injury incidence rate (IIR) = (*number of injuries/number of team matches*) × 10.
[b]$P < .02$.
[c]$P < .05$.
[d]$P < .001$.

($P < .0001$) reported on FieldTurf versus natural grass on both cold days and hot days.

## Cleat Design and Player Weight

The effect of the type of shoe-surface interface with the playing surface has become an increasing concern within the medical community. The results of this investigation indicated a significant main effect ($F_{5,716}$ = 37.633, $P$ = .0001) between surfaces by cleat design (see Appendix Table A2, available online), with a significantly lower incidence of injuries ($P < .0001$) reported while wearing studded removable cleats on FieldTurf when compared with natural grass. No significant injury differences were observed among players wearing either a combination of a molded conical/cleat design or a combination of molded conical/blade design. When addressing the anecdotal concerns on the influence of player weight on cleat release and the concomitant potential for injuries, the findings indicated no significant main effect ($F_{4,717}$ = 0.504, $P$ = .733) between surfaces by player weight (see Appendix Table A2).

## Age of Playing Surface

As existing artificial surfaces continue to mature, there have been concerns as to the influence of the age of the playing surface on injuries. In this study, there was a significant main effect ($F_{3,718}$ = 27.576, $P$ = .0001) by age of playing surface (see Appendix Table A2). The findings indicated a significantly lower incidence of injuries ($P < .02$) documented on new FieldTurf surfaces as compared with new natural grass. The findings also indicated a significantly lower number of injuries ($P < .0001$) for FieldTurf used for ≥8 years versus natural grass but no significant injury incidence between playing surfaces on moderately aged surfaces (ie, used for 1-3 or 4-7 years).

### Injury Mechanism and Situation

As shown in Appendix Table A3 (available online), a significant main effect was observed ($F_{19,702}$ = 2.224, $P$ = .002) between surfaces by injury mechanism, with significantly fewer injuries documented while tackled from the side or behind ($P < .002$) and while goalkeeping ($P < .05$) on FieldTurf when compared with natural grass. A similar significant main effect was noted ($F_{10,711}$ = 1.921, $P$ = .040) between surfaces by injury situation. The findings indicated a significantly lower ($P < .05$) incidence of injuries attributed to offensive direct plays, defensive high pressure situations, and defensive middle pressure situations while competing on FieldTurf versus natural grass.

### Primary Type of Injury and Injury Grade

As shown in Appendix Table A4 (available online), a significant main effect ($F_{14,707}$ = 2.112, $P$ = .010) by primary type of injury was noted between the 2 surfaces, with post hoc analyses indicating a significantly lower incidence of surface/epidermal injuries ($P < .05$) and contusions ($P < .001$) reported on FieldTurf versus natural grass. The findings revealed no significant differences in ligament, cartilage, and muscle trauma combined while playing on FieldTurf as compared with natural grass as well as no significant main effect ($F_{2,719}$ = 1.977, $P$ = .139) between surfaces by injury grade.

### Elective Imaging/Surgical Procedures

There was a significant main effect ($F_{3,177}$ = 5.445, $P$ = .001) by elective medical care (see Appendix Table A4). Post hoc analyses indicated a significantly lower incidence of radiographs ($P < .01$) ordered after injuries on FieldTurf than reported on natural grass as well as a significantly lower incidence of total elective imaging and surgical procedures combined ($P < .0001$) after injuries on FieldTurf versus natural grass.

### Anatomic Location and Type of Tissue Injured

The findings also indicated a significant playing surface effect ($F_{3,718}$ = 5.792, $P$ = .001) by anatomic/regional location of injury, with post hoc analyses indicating a significantly lower incidence ($P < .01$) of cranial/cervical trauma and lower extremity injuries while playing on FieldTurf versus natural grass. The results, however, did not indicate a significant surface effect ($F_{4,717}$ = 1.644, $P$ = .161) by type of tissue injured.

Consistent with the regional location of trauma, a significant playing surface effect ($F_{34,687}$ = 2.248, $P$ = .0001) was observed across the specific location of body trauma (see Appendix Table A5, available online). The findings indicated a significantly lower incidence of nonconcussive head ($P < .05$), facial/chin/jaw ($P < .008$), pelvis/hip/buttock ($P < .0001$), upper leg ($P < .05$), and heel/Achilles tendon ($P < .05$) trauma reported on FieldTurf when compared with playing on natural grass.

When analyzing by specific lower extremity trauma (see Appendix Table A6, available online), there was no significant playing surface effect by specific joint injured ($F_{16,704}$ = 1.400, $P$ = .135), nor was there a significant playing surface effect ($F_{8,713}$ = 0.219, $P$ = .988) by specific muscle trauma.

## DISCUSSION

The purpose of this prospective cohort study was to quantify the incidence, mechanisms, and severity of match-related collegiate men's soccer injuries on FieldTurf versus natural grass. It was hypothesized that collegiate male athletes would not experience any difference in the incidence, mechanisms, and severity of match-related injuries between FieldTurf and natural grass. Although similarities did exist between FieldTurf and natural grass, numerous differences in sport trauma were observed between the 2 playing surfaces.

### Injury Incidence

Over the 6-season study, the number of match-related injuries, or 10.9 injuries per university per season, is consistent with the number of injuries observed in prior studies, ranging from 2.4 to 15.7 injuries per school per season.[2,27-29,39] The incidence of acute injuries (83.6%) was similar to findings in earlier studies, ranging from 71% to 94%.[6,26-28,32] The overall incidence of substantial and severe trauma recorded in this study is also consistent with prior seasonal trauma reported on soccer[5,28] but substantially lower than observed in professional female soccer.[8] Although the large variation in injury definitions among these studies prevents an accurate comparison, both the total number and the number of minor, substantial, and severe injuries recorded in this study still reflect the typical level of trauma observed at the collegiate level of play. The lower overall incidence of trauma on FieldTurf is consistent with prior studies in collegiate football and women's soccer[27,28] but is in contrast to other findings between surfaces in elite soccer,[6,7] which may be reflective of assessing injuries on single versus multiple artificial infill surface systems, level of play, and distinct differences in experience when comparing elite to collegiate players.

In addition to acute injuries, repetitive or recurrent trauma is considered a major contributor to future trauma.[27] The incidence of recurrent injuries on FieldTurf in this study was similar to recurrent trauma reported in other studies in high-contact field sports, whereas recurrent injuries on natural grass were lower than previously documented.[10,27-29,47] Whether recurrent trauma was observed over the same type of artificial infill surface in all studies is not known. The paucity of studies, despite increased interest, that address recurrent trauma prevents further discussion at the collegiate level of play.

With regard to foul play, the incidence (28.5%) of injuries attributed to illegal actions was not unexpected. This is higher than the 0.5% to 5.7% occurrence reported in collegiate and high school football,[12,27,29,32] is twice as high as documented in collegiate women's soccer,[28] but is consistent with the 23% to 62% reported in professional female soccer and other intercollegiate and senior sports.[5,8,37]

## Head and Knee Trauma

Although there were no significant differences in head or knee trauma between the 2 surfaces, when compared with other high-contact field sports,[27-29] the greater incidence of concussion injuries combined on natural grass is a concern and further reiterates the overall level of potential head trauma observed during collegiate soccer competition (Table 2).[3,16,28] Consistent with prior studies,[10,11] however, a minimal number of head traumas (13%) was attributed directly to player-turf impact in this study. With the prevalence of head trauma with subsequent posttraumatic conditions taking center stage in sport, other factors need to be considered besides playing surface.

The nonsignificant playing surface effect on the incidence of knee trauma is consistent with the incidence of joint derangement on both surfaces in prior studies in women's collegiate and elite-level soccer.[4,6,28] Although there is no clear consensus, the high incidence of patellar tendinopathies/syndromes reported on both surfaces in this study is consistent with earlier findings and may be attributed to several factors independent of the playing surface.[13,28] These include weak knee extension strength, overuse, inadequate patellar tracking, lower extremity malalignment, or simply not monitoring and addressing training regimen responses to minimize the aforementioned factors during the season.[13,19,55] The low incidence of anterior cruciate ligament trauma in this study may be reflective of the less aggressive level of play when compared with professional/elite athletes. Continued efforts to delineate the physical influence from the playing surface effect in the incidence of knee trauma are warranted.

## Injury Category and Injury Time Loss

The nonsignificant difference between playing surfaces across injury categories is consistent with studies indicating similar findings between artificial and natural grass surfaces in soccer and football.[5,10,27,28] As similarly noted when discussing the severity of injury, the significantly lower incidence of substantial injuries requiring 7 to 21 days of time loss on FieldTurf versus natural grass is consistent with prior injuries documented in collegiate women's soccer competing on this specific artificial turf surface[28] but is in contrast to findings assessing injuries among elite athletes across various artificial infill systems combined.[6,7] Whether these findings with the natural grass surface are a function of decreasing turf quality with high temperatures and low moisture content,[36,49] lower surface compliance and a higher coefficient of restitution observed after noncontact injuries on natural grass,[37] excessive wear because of multipurpose use,[49] or simply the lack of resiliency of natural grass as the season progresses is not clear and is beyond the scope of this study.

## Position Played at Time of Injury

When grouped by generalized positions, that is, offense and defense, the significant effect of playing surface at the time of injury is consistent with prior studies indicating a greater incidence of injuries among offensive positions while competing on natural grass surfaces[27,29] but is in contrast to other findings in collegiate women's soccer,[28] which may simply reflect the greater physicality observed in men's soccer competition.

When assessing specific skill positions in this study, the results are consistent with earlier studies reporting a greater incidence of trauma among midfielders, followed by strikers and goalkeepers, reflective of the degree of continual participation of midfielders and the imminent, close-contact, high-velocity peril that comes with the striker position during a match.[11,28] The findings of this study similarly indicated a significantly greater incidence of trauma across midfielders as well as a significant 2-fold increase in injuries among strikers particularly when competing on natural grass. The 3-fold increase in injuries among center back/sweeper/libero positions, however, was not observed in women's collegiate soccer,[28] again attributed to greater physicality in the men's game. Unfortunately, at this time, the limited frequency of injuries among most player positions in this study prevented further in-depth analyses and a discussion of potential injury differences and position susceptibility.

## Environmental Factors

Limited attention has been directed toward the potential influence of weather conditions on injuries during competition.[12,27-29,36] The majority of matches and injuries in this study occurred during conditions of no precipitation, therefore minimizing the opportunity to thoroughly ascertain possible influences under various field conditions. The significantly lower incidence of injuries on FieldTurf during play on wet fields, as well as all adverse conditions combined, may reflect the more consistent surface that FieldTurf provides during inclement weather. The significantly lower incidence of injuries on FieldTurf when temperatures remained $\geq$70°F is consistent with trauma observed in collegiate football and women's soccer[27,28] but is in contrast to prior findings previously reported on other surfaces,[29,36] although those surfaces were either an earlier type of artificial turf or natural surface under drier conditions when compared with today's highly managed collegiate grass surfaces.

Contrary to prior studies on original artificial turf surfaces, the significantly greater incidence of injuries during hot days on natural grass supports prior findings that indicated enhanced shoe-surface interaction potentiating articular trauma with increasing surface temperature as well as reports of a greater frequency of knee trauma with higher temperatures.[28,36] From a safety standpoint, the natural grass findings are of clinical concern and warrant further investigation.[45]

## Cleat Design and Player Weight

With the exception of studded removable cleats, the majority of cleat designs associated with injuries in this study did not reflect a significant shoe-surface influence. This is consistent with prior work assessing in-shoe foot loading patterns during maximal sprint efforts in male high school athletes.[9] The significantly lower incidence of trauma on FieldTurf while wearing studded cleats may reflect a more optimal cleat release on this type of artificial turf infill system during both linear and rotational movements when compared with blade or strictly removable cleat patterns.

The overall nonsignificant influence of player weight on either playing surface, at this time, does not support anecdotal concerns of player weight on cleat release and potentiating injuries. In summary, more studies are warranted to quantify the interaction of cleat design, player weight, and playing surface on injuries.[9,28]

## Age of Playing Surface

Limited information has been provided in the literature concerning the influence of playing surface age on injuries[27-29,36] primarily because of the limited but growing number of newer generations of artificial surfaces being installed as well as the challenges of delineating various interactions on natural grass surfaces under continual transition and various management systems.[45] The significantly lower incidence of injuries reported on newly installed FieldTurf surfaces, when compared with new natural grass fields, is consistent with prior summaries pointing to less opportunities for trauma with greater surface uniformity and optimal vertical deformation, shock absorption, and rotational resistance.[1,27,28,55]

The significantly lower number of injuries reported on $\geq$8-year-old FieldTurf may be a reflection of the consistent surface quality of FieldTurf over time as well as the decreasing quality of natural grass as the season progresses.[28,49] Further analyses as to factors contributing to surface age and sport trauma may more firmly establish these observations.

## Injury Mechanism and Situation

Prior authors have surmised that the more consistent artificial composition enhances the speed of the game,[2,27,29] but others have suggested a greater opportunity for injuries because of overextension and a greater potential for muscle fatigue on artificial turf from greater rates of acceleration, in-shoe loading patterns, and torque during pivoting, change of direction, direct contact with an opposing player, deceleration, unfortunate mishaps, or being jolted during an uncontrolled or compromised movement.[9,24] The significantly lower incidence of injuries attributed to being tackled from the side or behind, during goalkeeping duties, and during direct play and middle to high pressure situations documented on FieldTurf in this study, however, did not confirm these claims and supports the use of this type of artificial turf infill system for competitive play.

## Primary Type of Injury and Injury Grade

With the exception of a significantly lower number of minor surface/epidermal and contusion injuries documented on FieldTurf, we found no other surface effect on the primary type of trauma in this study. This is consistent with earlier injury observations in collegiate women's soccer.[28] Other studies, however, have found a lower incidence of lower extremity strains on artificial turf,[7,27] which may be related to the lower shoe-surface traction usually associated with a more consistent, compliant surface.[27] Although others have reported greater shoe-surface peak torque and rotational stiffness with artificial surfaces,[23,51] these studies were conducted under noncompetitive laboratory conditions utilizing traditional mechanical simulations that lacked environmental variability, player contact, and anatomic and neuromuscular complexities during actual sport performance, thus limiting the comparison to on-the-field sport activity.[17,18] Further investigation into the biomechanics of the shoe-surface interaction beyond the laboratory setting will be necessary to elucidate more definitive causes.

The nonsignificant incidence of trauma across the grade of injury between surfaces (see Appendix Table A4) is consistent with findings on similar surfaces during high school football and soccer competitions[29,44] but is in contrast to trauma documented in collegiate football and women's soccer.[27,28] Equivocal findings between studies may reflect the varying levels of play and the degree of speed, power, and subsequent impact trauma observed across these sports.[2,27]

## Elective Imaging and Surgical Procedures

With increasing health care costs and equivocal sport injury findings, surprisingly, the tracking of elective imaging and surgical procedures has been limited in prior injury risk studies.[28] In addition, injury findings have been too generic in lieu of definitive diagnoses, thus limiting the effect of these studies in minimizing the future predisposition to injuries.

The higher incidence of posttraumatic imaging procedures, as well as total procedures combined, that are required after injuries while playing on natural grass is not in juxtaposition with suggestions of more serious injuries on artificial surface[54] and reveals a greater level of trauma than reported in collegiate women's soccer.[28] The future reporting of explicit diagnoses after injuries, as well as documenting medical procedures beyond the playing field, would add pertinent insight on the incidence and severity of trauma across various surfaces.

## Anatomic Location, Type of Tissue, and Lower Extremity Injury

Regarding the anatomic location and specific location of body trauma (see Appendix Tables A4 and A5), the significant differences between playing surfaces are in contrast to earlier studies addressing cranial/cervical, upper extremity, and thoracic trauma at the collegiate level of play.[7,27,28] The significantly lower incidence of lower extremity injuries on FieldTurf in this study, however, was also similar to previous reports among collegiate athletes[27] but is in contrast to earlier findings indicating no significant differences between surfaces.[7,10,44] The differences in results may be reflective of the various artificial infill surfaces studied or simply the type of sport.[2,6] Of greater concern is the significantly greater incidence of facial and cervical injuries reported among athletes competing on natural grass in a sport in which craniofacial and mouthguard protection is typically absent, which needs to be addressed.

Although others have reported a greater incidence of ankle sprains combining data derived from 8 to 12 different brands of artificial turf,[6,7] significant surface differences in ankle trauma were not confirmed in this study (see Appendix Table A6). The differences in outcomes may be a result of the prior studies not controlling for the length and time of collection or variation in the turf type or quality, which are methodological concerns that may have benefited from further analyses.

## Limitations

There were several potential limitations to the study that may have influenced the type and number of injuries reported. These included the inability to determine and control the inherent random variation in injuries typically observed in high-collision team sports[2,26,27]; the strength and conditioning status of the athletes and variations in the type of equipment used[1,2,15,20,24,34]; the weather conditions and variation in field conditions[27,29,55]; the differences in postural/joint integrity, musculoskeletal structure, and biomechanics of movement[1,20,25,42,43]; the time of year[7,20]; the coaching style and experience and player management[1,2,12,17,24,25]; the quality of officiating and foul play[1,27,51]; the player's position and actual versus average time to exposure to injury[2,15,17]; the sport skill level, intensity of play, and fatigue level at the time of injury[4,17,20,41]; the athlete's ephemeral response to the risk potential, injury, and subsequent pain[1,23,25,30,39]; the unreported congenital/developmental factors predisposing an athlete to additional injuries[1,2,20,24,42,44]; or simply any unforeseen mishap.[2,26,29] Also, there is always the opportunity for an injury to go unreported despite the comprehensive nature of any reporting system.[2,6,24] Finally, a systematic error could have potentially influenced findings as a result of a team or teams with a home field of either FieldTurf or natural grass with relatively fewer injuries based on the aforementioned limitations (eg, coaching style, physical conditioning) or a medical professional's own view of what constitutes an injury, resulting in a lower number of injuries reported.

Key strengths of the study included the opportunity to follow several as well as identical universities competing at a high level during the 6-year period. This prevented confounding interteam seasonal injury fluctuations and individual team effects, which enhanced the ability to identify differences and trends in the surface effect.[6,10] In addition, this is one of only 2 studies on injury risk factors in soccer that has addressed elective imaging and surgical procedures on both surfaces as well as cleat design and age of the playing surfaces at the time of injury.[28] Finally, the combined method of assessing functional outcomes, time loss, direct observation, and treatment records, as well as the daily interactions of ATCs and players evaluated in this study, minimized the potential for transfer bias and unreported injuries throughout the season.[27,29] The daily evaluation and follow-up telephone calls also increased the opportunity to quantify and track typically overlooked minor injuries that often evolve into chronic or overuse problems.[6,27,50]

Note that the percentage of influence from risk factors other than simply surface type cannot be overlooked. Because of the inherent challenges of collecting data on multiple indices and on numerous teams and players over an extended period of time, the degree of influence from these risk factors remains a limitation that can only be acknowledged at this time.[6,17,26] The prospective cohort multivariate design did enhance the sample size, result in randomization of play on both surfaces, control for seasonal and team variations, and allow for greater insight into both significant and subtle differences between a new generation of artificial turf and natural grass.

Finally, the lack of a universally accepted definition of a sport injury will continue to be a challenge and a subsequent influence on injury interpretation.[13,27,35] With the concomitant difficulty in subjectively determining a plethora of surface conditions and quality of natural grass,[27,35] any attempt to interpret the injury-surface interaction with any degree of accuracy will continue to pose concerns.

# CONCLUSION

Although numerous similarities did exist between FieldTurf and natural grass over the 6-year period of competitive match play, there were significant differences in injury incidence, severity of injury, injury time loss, injuries across player position, injuries under various field conditions and temperatures, cleat design, age of playing surface, injury mechanism and situation, elective imaging/surgical procedures, and anatomic location of body trauma. No significant differences in head or lower extremity trauma, however, were observed between playing surfaces. Both surfaces, from a statistical and clinical standpoint, exhibited unique injury causes that need to be addressed to reduce the number of match-related collegiate men's soccer injuries. The hypothesis that collegiate male athletes would not experience any difference in the incidence, mechanisms, and severity of match-related injuries between FieldTurf and natural grass was only partially supported. In conclusion, FieldTurf is, in many cases, safer than natural grass when comparing injuries in collegiate men's soccer. The findings of this study, however, may not be generalizable to other levels of competition or to other artificial surfaces.

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