Incidence, Causes, and Severity of High School Football Injuries on FieldTurf Versus Natural Grass

A 5-Year Prospective Study

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Background: Numerous injuries have been attributed to playing on artificial turf. Recently, FieldTurf was developed to duplicate the playing characteristics of natural grass. No long-term study has been conducted comparing game-related, high school football injuries between the 2 playing surfaces.

Hypothesis: High school athletes would not experience any difference in the incidence, causes, and severity of game-related injuries between FieldTurf and natural grass.

Study Design: Prospective cohort study.

Methods: A total of 8 high schools were evaluated over 5 competitive seasons for injury incidence, injury category, time of injury, injury time loss, player position, injury mechanism, primary type of injury, grade and anatomical location of injury, type of tissue injured, head and knee trauma, and environmental factors.

Results: Findings per 10 team games indicated total injury incidence rates of 15.2 (95% confidence interval, 13.7-16.4) versus 13.9 (95% confidence interval, 11.9-15.6). Minor injury incidence rates of 12.1 (95% confidence interval, 10.5-13.6) versus 10.7 (95% confidence interval, 8.7-12.7), substantial injury incidence rates of 1.9 (95% confidence interval, 1.4-2.6) versus 1.3 (95% confidence interval, 0.8-2.1), and severe injury incidence rates of 1.1 (95% confidence interval, 0.7-1.7) versus 1.9 (95% confidence interval 1.2-2.8) were documented on FieldTurf versus natural grass, respectively. Multivariate analyses indicated significant playing surface effects by injury time loss, injury mechanism, anatomical location of injury, and type of tissue injured. Higher incidences of 0-day time loss injuries, noncontact injuries, surface/epidermal injuries, muscle-related trauma, and injuries during higher temperatures were reported on FieldTurf. Higher incidences of 1- to 2-day time loss injuries, 22+ days time loss injuries, head and neural trauma, and ligament injuries were reported on natural grass.

Conclusions: Although similarities existed between FieldTurf and natural grass over a 5-year period of competitive play, both surfaces also exhibited unique injury patterns that warrant further investigation.

Keywords: artificial surface; knee; head; adolescent; environment

Over the past decades, numerous studies have attributed a greater risk and incidence of articular and concussive trauma to playing on artificial turf when compared to natural grass.[2,10,23,26,32,45,55,60] More recently, a new generation of synthetic surface called FieldTurf, which is composed of a polyethylene/polypropylene fiber blend stabilized with a graded silica sand and ground rubber infill, was developed to duplicate the playing characteristics of natural grass.

Although FieldTurf has been recommended as a viable option to natural grass in the prevention of injuries, research into the long-term effects of FieldTurf on injuries, during actual game conditions over several seasons of competition, has not been published in the scientific literature. With more than 1 million athletes playing high school football,[43] the rising number and cost of knee surgeries and rehabilitation alone reaching more than $1 billion each year,[16,22] coupled with the psychological trauma and setbacks in training typically experienced by athletes

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after a significant injury,[40] efforts to address ways to minimize predisposition to injury are warranted. Therefore, the purpose of this study was to quantify incidence, causes, and severity of game-related high school injuries on FieldTurf versus natural grass. It was hypothesized that high school athletes would not experience any difference in the incidence, causes, and severity of game-related injury between FieldTurf and natural grass.

MATERIALS AND METHODS

Population

A final total of 8 Texas high schools, classified as either 4A (900-1909 students) or 5A (1910+ students) by the University Interscholastic League governing body, were evaluated for game-related football injuries sustained while playing on both FieldTurf and natural grass during a 5-year period from year 1998 to 2002. The specific schools were selected based on availability of both playing surfaces during the competitive season, uniformity of sport skill level, and the presence of a full-time certified athletic training (ATC) staff, minimizing the potential for injury reporting bias.[13,56] The study initially started with 4 high schools over the first 4 years, resulting in an initial total of 165 seasonal and playoff games. An additional 4 high schools were added to the initial 4 schools in year 5, resulting in an additional 85 games. With the exception of deleting games played on other artificial surfaces (n = 10), selection bias was avoided by reporting all remaining games and subsequent injuries on either FieldTurf or natural grass. This resulted in a total of 240 games over the 5-year period played on either FieldTurf (n = 150) or natural grass (n = 90).

Two district stadiums using FieldTurf were used by all 8 schools. Both FieldTurf surfaces were installed within 3 years of each other and were considered new, high-quality surfaces by the ATCs. Different natural grass fields were used across the same geographical region, with similar quality and environmental influences. All teams, however, practiced on grass.

To quantify the history and potential influence of prior injuries, all athletes underwent preparticipation physical examinations under the care of an orthopaedic surgeon (B.S.B.). Criteria for exclusion included (1) any known preexisting congenital or developmental factor that predisposed an athlete to 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.[9,66]

Procedures

Based on paradigms suggested in prior research,[19,33,38,68] it was decided that a multifactorial approach that encompassed teams playing on both surfaces during the same time period, using a definitive but brief injury surveillance form, would provide several advantages. These include gaining a greater comparison of the nuances of each surface's influence on injury, avoiding limitations in data collection (eg, seasonal variation, subject randomization by surface), and minimizing difficulties in analyses and interpretation of findings that former studies have had.[2,51] For this prospective cohort study, a 2-sided, single-page injury surveillance form was developed based on prior criteria recommended and established in the literature (available as an appendix in the online version of this article at www.ajsm.org/cgi/content/32/7/1626/DC1).[28,33,41,44,46,50] The form includes the following: athletic identification number; athletic trainer; date of injury; athlete weight; school; type of playing surface; surface quality; surface age; temperature and humidity at game time; year/skill level of athlete; where the injury occurred; weather/field conditions; injury category; time period of injury; injury classification; injury time loss; position played at time of injury; injury situation; injury mechanism; personnel determining the injury; injury site location; principle body part; primary type of injury; grade of injury; occurrence of external bleeding; injury because of illegal action; head, eye, knee, shoulder, and thoracic/abdominal diagnosis; surgical intervention and time; and musculoskeletal, joint, or organ location of injury. The injury surveillance form was initially introduced to the high school ATCs at a preseason staff meeting to discuss and ensure face validity of the instrument. The form was then pretested during preseason practices and scrimmages to again quantify accuracy, comprehensiveness of information, and ease of application, and it was deemed adequate by ATCs and physicians.

The respective ATCs for each school were initially approached because of their daily interaction with the athletes and coaches during and after sport trauma and their expertise in injury recognition.[3,13] During a scheduled offseason meeting, 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.[51,56] After full explanation, all ATCs appeared enthusiastic and agreed to participate in the data collection without financial incentive. Informed consent was voluntarily obtained from the appropriate reporting staffs, and the study was conducted in accordance with the guidelines for use of human subjects as stipulated by the American College of Sports Medicine.[4]

All regular season conference and nonconference varsity games and postseason varsity playoff games were included. Injury data were recorded after game completion, with additional support from ATC notes to avoid lapse of memory leading to inaccuracy or response distortion.[51,68] All game-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 was deemed necessary. Any sport trauma that occurred toward the end of the competitive schedule was monitored beyond the player's specific season to determine date of recovery and functional return to play.[2,24]

Completed injury surveillance forms were either mailed or faxed to us within 3 working days after a game and were entered in the database before the next game. A follow-up telephone visit was used to obtain any additional information pertaining to any changes or additions in diagnosis, treatment, or time to return to play. To avoid the potential for on-the-field detection bias,[56] 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,[13,46,51] we attempted to define injury based on a combination of functional outcome, observation, and treatment.[13,24,46,50,64] A *reportable injury* was defined as any game-related football trauma that resulted in (1) an athlete missing all or part of a game, (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,[46,51] others have expressed a need to quantify and track these typically overlooked minor traumas to avoid underreporting of injury and to monitor those injuries that may turn into chronic or overuse problems.[14,28,41,69,71] Prior studies have also revealed that 42% to 60% of competitive trauma results in minimal time loss and medical cost.[52,68] Therefore, we felt that a definition that included functional outcome, observation, and treatment on all injuries would more clearly quantify the unique nuances or trauma observed with each playing surface and reduce the individual and player bias that allegedly influences injury reporting based solely on time loss.[51]

Injury time loss was based on the number of days absent from practice or game competition and was divided into 0, 1 to 2, 3 to 6, 7 to 9, 10 to 21, and 22 days or more of recovery time. Not surprisingly, a review of the literature revealed high subjectivity in the determination of what constitutes moderate or severe injury. Whereas any injury resulting in time loss of approximately 7 to 28 days has been considered moderate trauma and a time loss range of 21 to 28 days has been defined as severe,[35,68] others have defined severe injury as trauma resulting in ≥7 days of time loss.[6,28,33,42,48,54,59,62] Furthermore, what constitutes a moderate injury in one athlete (eg, elbow injury in an offensive lineman) may be considered severe when diagnosed in the throwing arm of a quarterback.[59,69] 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 22+ days of time loss as a *severe injury*. The delineation and subsequent analysis of minor, substantial, and severe injury primarily served to minimize potential time loss bias.[13,64]

Injury category was quantified by player-to-player collision, player-to-turf collision, injuries attributed to shoe-surface interaction during player contact, injuries attributed to shoe-surface interaction without player contact, and muscle-tendon–related overload. Time of injury by pregame and game quarter of play was documented to delineate the influence of fatigue over time from the potential surface influence on injury occurrence.[68,71]

Acute trauma was delineated from recurrent and overuse injury according to criteria previously published,[34,38,67] with acute trauma linked to an incidence that specifically occurred during a competitive game versus repetitive exposure resulting in symptoms and 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.[38,71]

To enhance optimal cell size and interpretation, the 23 player positions were condensed and analyzed by offense, defense, and special teams. *Mechanism of injury* was defined as occurring while a player was blocked above or below the waist, tackled above or below the waist, blocking, tackling, impacting with the playing surface, stepped on, fallen on or kicked, blocking a kick or punt, or sprinting or running with no player contact.

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 sprains, ligament tears, muscle strain/spasm, muscle tear, tendon strain, hyperextension, neural (burner, brachial plexus), subluxation/dislocation, and fracture (standard, epiphysial, avulsion, stress, osteochondral). Injuries were also defined according to grade (1, 2, or 3). Anatomical 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 concussion, hematoma, postconcussion and second-impact syndromes, neurological sequelae (eg, stingers/burners, transient quadriplegia), vascular or dental injury, or associated fractures, sprains, and strains.[9] Neural trauma was restricted to any injury involving only concussion, associated syndromes, and neurological sequelae. Because of growing concerns addressing excessive head and knee trauma in football,[9,10,13,22,27,31,51,53] these areas were specifically identified for further analyses (Table 1).

Although one study has associated a greater rate of injury with competing under dry surface conditions,[58] there has been a paucity of information on factors such as weather conditions and the effect of playing under surface conditions that influence injury frequency.[22,61,65] Therefore, environmental factors such as field conditions, temperature, and humidity were obtained before game time by each team's respective ATC and/or through the local airport climatic data center to ascertain the potential influence on injury from changes in weather throughout the season.[2]

Statistical Analyses

Because of variations in the frequency of injury within several categories potentiating inadequate cell size, statis-

TABLE 1
Frequency and Rate of Game-Related High School Football Injuries Between FieldTurf and Natural Grass by Head and Knee Trauma[a]

	FieldTurf				Natural Grass			
Variable	Number of Injuries	%	IRR	95% CI	Number of Injuries	%	IRR	95% CI
Head injury								
1° cerebral concussion	7	58.4	0.5	0.2-0.9	11	68.8	1.2	0.7-2.1
2° cerebral concussion	3	25.0	0.2	0.1-0.6	4	25.0	0.4	0.2-1.1
3° cerebral concussion	0	0.0	0.0	0.0-0.0	1	6.2	0.1	0.0-0.6
Posttraumatic headache	1	8.3	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0
Second-impact syndrome	1	8.3	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0
Concussion injuries combined	10	83.4	0.7	0.4-1.2	16	93.8	1.8	1.1-2.7
Knee injury								
Medial collateral	17	65.5	1.1	0.7-1.7	9	42.9	1.0	0.5-1.8
Lateral collateral	1	3.8	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0
Anterior cruciate	3	11.5	0.2	0.1-0.6	4	19.0	0.4	0.2-1.1
Posterior cruciate	0	0.0	0.0	0.0-0.0	1	4.8	0.1	0.0-0.6
ACL and associated tissue	3	11.5	0.2	0.1-0.6	5	23.8	0.6	0.2-1.2
Patellar tendon/syndrome	2	7.7	0.1	0.0-0.5	2	9.5	0.2	0.1-0.8
ACL injuries combined	6	23.0	0.4	0.2-0.8	9	42.8	1.0	0.5-1.8

[a]%, percentage of total injuries within each category that occurred on the specific playing surface; IRR, injury incidence rate = (number of injuries ÷ total number of injuries) × 10; CI, confidence interval.

tical power, and limitations on analysis, data were combined after the 5-year period based on prior recommendations in the literature.[33,46] This step resulted in the following categories: injury category, time of injury, injury classification, injury time loss, position played at time of injury, injury mechanism, injury site location, primary type of injury, grade of injury, anatomical location of injury, type of tissue injured, head diagnosis, knee diagnosis, and environmental factors. Tabular-frequency distributions were computed for data in each category using the Statistical Package for Social Sciences (version 10.0, SPSS Science Inc, Chicago, Ill) software. For ease of interpretation, the percentages of total injuries within each category that occurred on the specific playing surface were calculated, and 95% confidence intervals (95% CIs) were determined as described elsewhere.[57]

Because most high schools schedule a similar number of games each season, exposure to injury was defined in terms of team games, as previously recommended.[68] Using this definition, injury incidence rate (IRR) was expressed using (1) injuries per 10 team games = (number of injuries ÷ number of team games) × 10 and (2) injuries per team game = number of injuries ÷ number of team games.

To achieve a more thorough understanding beyond traditional frequency analyses and to eliminate the possibility of irrelevant sources of error,[37,38] data were numerically recoded, grouped by playing surface (FieldTurf, natural grass), and subjected to multivariate analyses of variance (MANOVAs) and Wilks' lambda criteria using general linear model procedures.[37] Data screening revealed no violations of multivariate normality, linearity, outliers, homogeneity of variance, multicollinearity, or singularity.[63] 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 squared means procedures were required because of the uneven number of observations on which to compare differences between variables. Statistical power analyses ($1 - \beta$; n size calculations) were performed and ranged from .063 to .814 at the P value selected to establish significance in this study.

RESULTS

Injury Incidence

A total of 240 high school games were evaluated for game-related football injuries sustained while playing on FieldTurf or natural grass during a 5-year period (Table 2). Overall, 150 (62.5%) team games were played on FieldTurf versus 90 (37.5%) team games played on natural grass. A total of 353 injuries were documented, with 228 (64.6%) occurring during play on FieldTurf as compared to 125 (35.4%) on natural grass.

When comparing IRRs between types of playing surface, injuries per 10 team games of 15.2 (95% CI, 13.2-16.4) versus 13.9 (95% CI, 11.9-15.6) and injuries per team game of 1.5 (95% CI, 1.0-2.2) versus 1.4 (95% CI, 0.8-2.3) were documented on FieldTurf versus natural grass, respectively. When comparing substantial IRRs (injuries requiring 7-21 days of injury rehabilitation) between type of playing surface, injuries per 10 team games of 1.9 (95% CI, 1.4-2.6) versus 1.3 (95% CI, 0.8-2.1) and injuries per team game of 0.19 (95% CI, 0.07-0.44) versus 0.13 (95% CI, 0.03-0.46) were documented on FieldTurf versus natural grass, respectively. When comparing severe IRRs (injuries

TABLE 2
Incidence of Game-Related High School Football Injuries Between FieldTurf and Natural Grass

Variable	FieldTurf	Natural Grass	Total/ Mean
Games evaluated			
Number of team games	150	90	240
Team games, %	62.5	37.5	100.0
All injuries			
Number of injuries	228	125	353
Injuries, %	64.6	35.4	100.0
Injuries per 10 team games[a]	15.2	13.9	14.7
Injuries per team game[b]	1.52	1.38	1.47
Minor injuries[c]			
Number of injuries	182	96	278
Injuries, %	65.0	35.0	100.0
Injuries per 10 team games	12.1	10.7	11.6
Injuries per team game	1.21	1.07	1.16
Substantial injuries			
Number of injuries	29	12	41
Injuries, %	70.7	29.3	100.0
Injuries per 10 team games	1.9	1.3	1.7
Injuries per team game	0.19	0.13	0.17
Severe injuries			
Number of injuries	17	17	34
Injuries, %	50.0	50.0	100.0
Injuries per 10 team games	1.1	1.9	1.4
Injuries per team game	0.11	0.19	0.14

[a]Injuries per 10 team games = (number of injuries ÷ number of team games) × 10.
[b]Injuries per team game = number of injuries ÷ number of team games.
[c]Minor injury = 0 to 6 days of injury time loss; substantial injury = 7 to 21 days of injury time loss; severe injury = 22 or more days of injury time loss.

requiring 22 or more days of injury rehabilitation) between type of playing surface, injuries per 10 team games of 1.1 (95% CI, 0.7-1.7) versus 1.9 (95% CI, 1.2-2.8) and injuries per team game of 0.11 (95% CI, 0.03-0.35) versus 0.19 (95% CI, 0.05-0.52) were documented on FieldTurf versus natural grass, respectively.

The majority of trauma comprised acute injuries on both FieldTurf (94.3%; IRR = 14.3; 95% CI, 12.8-15.6) and natural grass (94.4%; IRR = 13.0; 95% CI, 11.1-14.9). Only 11 of 228 (4.8%; IRR = 0.7; 95% CI, 0.4-1.3) injuries reported on FieldTurf and 7 of 125 (5.6%; IRR = 0.8; 95% CI, 0.4-1.5) reported on natural grass were classified as recurrent trauma. As expected, upperclassmen received the majority of trauma on both playing surfaces. On FieldTurf, 161 injuries occurred to seniors (70.6%; IRR = 10.7; 95% CI, 9.1-12.3), 61 to juniors (26.8%; IRR = 4.1; 95% CI, 3.3-4.9), and 6 to sophomores (2.6%; IRR = 0.4; 95% CI, 0.2-0.8). On natural grass, 82 injuries were reported among seniors (65.6%; IRR = 9.1; 95% CI, 8.3-9.5), 28 among juniors (22.4%; IRR = 3.1; 95% CI, 2.2-4.1), and 15 among sophomores (12.0%; IRR = 1.7; 95% CI, 1.0-2.6). No injuries were documented among freshman on either playing surface.

Injury Category

Multivariate analysis indicated no significant playing surface effect by injury category ($F_{4,348} = 1.582$; $P = .178$; $1 - \beta = 0.488$). As shown in Table 3, injury incidences between playing surfaces were similar across player-to-player collision ($P = .39$), player-to-turf collision ($P = .27$), injuries attributed to shoe-surface interaction during player contact ($P = .30$), and injuries attributed to shoe-surface interaction during no contact ($P = .33$). A higher incidence of muscle-tendon overload injuries ($P = .07$), however, was reported on FieldTurf (7.0%; IRR = 1.1; 95% CI, 0.7-1.7) as compared to natural grass (2.4%; IRR = 0.3; 95% CI, 0.1-0.9).

Time of Injury

No significant main effect between playing surface was observed across time of injury ($F_{1,231} = 0.111$; $P = .740$; $1 - \beta = 0.063$). IRRs (Table 3) for FieldTurf revealed that a limited number of injuries occurred during the pregame, increased from the first to second quarters, and remained steady throughout the third and fourth quarters. Records on natural grass, however, revealed that no injuries occurred during pregame, increased from the first to second quarters, but declined from the third to the fourth quarter of play.

Injury Time Loss

Findings indicated a significant playing surface effect by injury time loss ($F_{5,334} = 2.343$; $P = .041$; $1 - \beta = 0.749$), with subsequent post hoc analyses revealing a significantly greater rate of injuries ($P = .02$) resulting in 0-day time loss reported on FieldTurf (40.8%; IRR = 6.5; 95% CI, 5.7-7.2) when compared to natural grass (28.8%; IRR = 4.1; 95% CI, 3.2-5.1) but a higher incidence of injuries ($P = .04$) resulting in a 1- to 2-day time loss reported on natural grass (28.0%; IRR = 4.0; 95% CI, 3.0-5.0) versus FieldTurf (19.3%; IRR = 2.9; 95% CI, 2.3-3.7). There was also a greater incidence of injury ($P = .06$) resulting in 22 days or more time loss reported on natural grass (14.4%; IRR = 2.0; 95% CI, 1.3-2.9) when compared to FieldTurf (7.9%; IRR = 1.2; 95% CI, 0.8-1.8).

Position Played at Time of Injury

No significant playing surface effect by player position was observed ($F_{1,283} = 1.910$; $P = .168$; $1 - \beta = 0.281$). Although the incidences of injuries were similar across offensive and defensive positions, special teams play resulted in a higher number of injuries reported on FieldTurf (8.8%; IRR = 1.3; 95% CI, 0.98-2.0) versus natural grass (4.0%; IRR = 0.6; 95% CI, 0.2-1.2).

Injury Mechanism

A significant playing surface effect by injury mechanism was found ($F_{7,305} = 2.163$; $P = .037$; $1 - \beta = 0.814$), with post

TABLE 3
Frequency and Rate of Game-Related High School Football Injuries Between FieldTurf and Natural Grass by Category, Time, Severity, Player Position, and Mechanism[a]

Variable	FieldTurf				Natural Grass			
	Number of Injuries	%	IRR	95% CI	Number of Injuries	%	IRR	95% CI
Injury category								
Player-to-player collision	114	50.0	7.6	6.9-8.2	69	55.2	7.7	6.7-8.4
Player-to-turf collision	32	14.0	2.1	1.6-2.9	12	9.6	1.3	0.8-2.2
Shoe surface (contact)	61	26.8	4.1	3.3-4.9	40	32.0	4.4	3.5-5.5
Shoe surface (noncontact)	5	2.2	0.3	0.1-0.8	1	0.8	0.1	0.0-0.6
Muscle-tendon overload	16	7.0	1.1	0.7-1.7	3	2.4	0.3	0.1-0.9
Time of injury								
Pregame	4	1.8	0.3	0.1-0.7	0	0.0	0.0	0.0-0.0
First quarter	34	14.9	2.3	1.7-3.0	23	18.4	2.6	1.8-3.5
Second quarter	72	31.6	4.8	4.0-5.6	34	27.2	3.8	2.8-4.8
Third quarter	58	25.4	3.9	3.1-4.7	38	30.4	4.2	3.3-5.3
Fourth quarter	60	26.3	4.0	3.3-4.8	30	24.0	3.3	2.4-4.4
Injury time loss								
0 days	97	42.5	6.5	5.7-7.2[b]	37	29.6	4.1	3.2-5.1
1-2 days	44	19.3	2.9	2.3-3.7	36	28.8	4.0	3.0-5.0[c]
3-6 days	39	17.1	2.6	2.0-3.4	22	17.6	2.4	1.7-3.4
7-9 days	7	3.1	0.5	0.2-0.9	5	4.0	0.6	0.2-1.2
10-21 days	23	10.1	1.5	1.0-2.2	7	5.6	0.8	0.4-1.5
22 days or more	18	7.9	1.2	0.8-1.8	18	14.4	2.0	1.3-2.9
Position played at time of injury								
Offense	112	49.1	7.5	6.7-8.1	54	43.2	6.0	5.0-7.0
Defense	96	42.1	6.4	5.6-7.1	66	52.8	7.3	6.3-8.1
Special teams	20	8.8	1.3	0.9-2.0	5	4.0	0.6	0.2-1.2
Injury mechanism								
Blocked below waist	26	11.3	1.7	1.2-2.4	14	11.5	1.6	1.0-2.4
Blocked above waist	10	4.4	0.7	0.4-1.2	10	8.3	1.1	0.6-1.9
Tackling	46	20.0	3.1	2.4-3.8	35	28.1	3.9	2.9-4.9
Tackled below waist	25	10.8	1.7	1.2-2.3	13	10.4	1.4	0.9-2.3
Tackled above waist	20	8.8	1.3	0.9-2.0	20	15.6	2.2	1.5-3.2
Blocking	41	18.1	2.7	2.1-3.5	14	11.5	1.6	1.0-2.4
Impact with playing surface	26	11.3	1.7	1.2-2.4	13	10.4	1.4	0.9-2.3
Stepped on/fallen/kicked	19	8.3	1.3	0.8-1.9[d]	3	2.1	0.3	0.1-0.9
No contact/sprints/running	15	6.4	1.0	0.6-1.6[e]	3	2.1	0.3	0.1-0.9
Blocking a kick/punt	1	0.5	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0

[a] %, percentage of total injuries within each category that occurred on the specific playing surface; IRR, injury incidence rate = (number of injuries ÷ total number of injuries) × 10; CI, confidence interval.
[b] $P = .021$.
[c] $P = .040$.
[d] $P = .041$.
[e] $P = .036$.

hoc analyses indicating a higher incidence of noncontact/running/sprinting injuries ($P = .036$) reported on FieldTurf (6.4%; IRR = 1.0; 95% CI, 0.6-1.6) when compared to natural grass (2.1%; IRR = 0.3; 95% CI, 0.1-0.9). A higher incidence of injuries ($P = .041$) resulting from being stepped on, fallen on, or kicked was also reported during competition on FieldTurf (8.3%; IRR = 1.3; 95% CI, 0.8-1.9) than on natural grass (2.1%; IRR = 0.3; 95% CI, 0.1-0.9).

Primary Type of Injury

As shown in Table 4, differences in primary type of injury were noted between the two playing surfaces. A higher incidence of surface/epidermal injuries (5.8%; IRR = 0.9; 95% CI, 0.5-1.4) was reported on FieldTurf as compared to natural grass (0.8%; IRR = 0.1; 95% CI, 0.0-0.6). In addition, a higher incidence of muscle strains/spasms was also observed on FieldTurf (14.2%; IRR = 2.1; 95% CI, 1.6-2.9) than on natural grass (8.0%; IRR = 1.1; 95% CI, 0.6-1.9). Of special concern is the greater incidence of concussion observed during competition on natural grass (12.8%; IRR = 1.8; 95% CI, 1.1-2.7) when compared to competition on FieldTurf (4.4%; IRR = 0.7; 95% CI, 0.4-1.2), as well as a higher rate of ligament tears on the natural grass surface (7.2%; IRR = 1.0; 95% CI, 0.5-1.8) as opposed to FieldTurf (3.1%; IRR = 0.5; 95% CI, 0.2-0.9).

TABLE 4
Frequency and Rate of Game-Related High School Football Injuries Between FieldTurf and Natural Grass By Primary Type of Injury, Grade, Location, and Tissue Injured[a]

Variable	FieldTurf				Natural Grass			
	Number of Injuries	%	IRR	95% CI	Number of Injuries	%	IRR	95% CI
Primary type of injury								
Surface/epidermal	13	5.8	0.9	0.5-1.4	1	0.8	0.1	0.0-0.6
Contusion	58	25.2	3.9	3.1-4.7	30	24.0	3.3	2.4-4.4
Concussion	10	4.4	0.7	0.4-1.2	16	12.8	1.8	1.1-2.7
Inflammation	6	2.7	0.4	0.2-0.8	3	2.4	0.3	0.1-0.9
Ligament sprain	76	33.2	5.1	4.3-5.9	40	32.0	4.4	3.5-5.5
Ligament tear	7	3.1	0.5	0.2-0.9	9	7.2	1.0	0.5-1.8
Muscle strain/spasm	32	14.2	2.1	1.6-2.9	10	8.0	1.1	0.6-1.9
Muscle tear	1	0.4	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0
Tendon strain	2	0.9	0.1	0.0-0.5	0	0.0	0.0	0.0-0.0
Hyperextension	1	0.4	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0
Neural	5	2.2	0.3	0.1-0.8	5	4.0	0.6	0.2-1.2
Subluxation/dislocation	7	3.1	0.5	0.2-0.9	7	5.6	0.8	0.4-1.5
Fracture	10	4.4	0.7	0.4-1.2	4	3.2	0.4	0.2-1.1
Grade of injury								
First degree	88	38.6	5.9	5.1-6.6	49	39.2	5.4	4.4-6.4
Second degree	36	15.8	2.4	1.8-3.1	20	16.0	2.2	1.5-3.2
Third degree	18	7.9	1.2	0.8-1.8	16	12.8	1.8	1.1-2.7
Not applicable	86	37.7	5.7	4.9-6.5	40	32.0	4.4	3.5-5.5
Anatomical location of injury								
Cranial/cervical	23	10.1	1.5	1.0-2.2	24	19.2	2.7	1.9-3.7[b]
Upper extremity	64	28.1	4.3	3.5-5.1	29	23.2	3.2	2.3-4.2
Thoracic	18	7.9	1.2	0.8-1.8	8	6.4	0.9	0.5-1.7
Lower extremity	123	53.9	8.2	7.5-8.7	64	51.2	7.1	6.1-7.9
Type of tissue injured								
Bone	11	4.8	0.7	0.4-1.3	5	4.0	0.6	0.2-1.2
Joint	101	44.3	6.7	5.9-7.4	60	48.0	6.7	5.6-7.6
Muscle	82	35.9	5.5	4.7-6.2	36	28.8	4.0	3.0-5.0
Neural	17	7.5	1.1	0.7-1.7	21	16.8	2.3	1.6-3.3[c]
Other	17	7.5	1.1	0.7-1.7	3	2.4	0.3	0.1-0.9

[a]%, percentage of total injuries within each category that occurred on the specific playing surface; IRR, injury incidence rate = (number of injuries ÷ total number of injuries) × 10; CI, confidence interval.
[b]P = .009.
[c]P = .007.

Grade and Anatomical Location of Injury

As shown in Table 4, there were no significant playing surface effects by injury grade ($F_{3,221}$ = 1.171; P = .322; $1 - \beta$ = 0.313). Injury incidences between playing surfaces were similar across first-, second-, and third-degree injuries (Ps = .16-.62).

In regard to location of injury, a significant playing surface effect was observed ($F_{3,349}$ = 2.419; P = .046; $1 - \beta$ = 0.601), with a higher incidence of cranial/cervical trauma (P = .009) reported on natural grass (19.2%; IRR = 2.7; 95% CI, 1.9-3.7) compared to FieldTurf (10.1%; IRR = 1.5; 95% CI, 1.0-2.2). No significant differences in the incidence of upper extremity, thoracic, or lower extremity trauma were observed between playing surfaces (Ps = .25-.62).

Type of Tissue Injured

A significant playing surface effect was found by type of tissue injured ($F_{4,348}$ = 3.007; P = .018; $1 - \beta$ = 0.797). A higher incidence of neural injuries (16.8%; IRR = 2.3; 95% CI, 1.6-3.3; P = .007) was reported on natural grass versus FieldTurf (7.5%; IRR = 1.1; 95% CI, 0.7-1.7). Again, a higher incidence of muscle trauma was also observed on FieldTurf (35.9%; IRR = 5.5; 95% CI, 4.7-6.2) than on natural grass (28.8%; IRR = 4.0; 95% CI, 3.0-5.0).

Head and Knee Trauma

As shown in Table 1, a higher incidence of 1° cerebral concussions was reported on natural grass (68.8%; IRR = 1.2; 95% CI, 0.7-2.1) than on FieldTurf (58.4%; IRR = 0.5; 95% CI, 0.2-0.9), as well as total number of concussion injuries combined (natural grass: 93.8%; IRR = 1.8; 95% CI, 1.1-2.7; vs FieldTurf: 83.4%; IRR = 0.7; 95% CI, 0.4-1.2). Although no significant injury rates were found between playing surfaces across specific knee cases, a higher incidence of knee trauma was observed on natural grass (42.8%; IRR = 1.0; 95% CI, 0.5-1.8) than on FieldTurf (23.0%; IRR = 0.4; 95% CI, 0.2-0.8) when all ACL injuries were combined.

TABLE 5
Frequency and Rate of Game-Related High School Football Injuries Between FieldTurf and Natural Grass by Environmental Factors

	FieldTurf				Natural Grass			
Variable	Number of Injuries	%	IRR	95% CI	Number of Injuries	%	IRR	95% CI
Field conditions								
No precipitation/dry field	201	88.3	13.4	11.8-14.8	106	84.4	11.8	9.7-13.7
Rain	19	8.4	1.3	0.8-1.9	13	10.4	1.4	0.9-2.3
Snow	0	0.0	0.0	0.0-0.0	0	0.0	0.0	0.0-0.0
Sleet	0	0.0	0.0	0.0-0.0	0	0.0	0.0	0.0-0.0
No precipitation/wet field	8	3.3	0.5	0.3-1.0	6	5.2	0.7	0.3-1.4
Temperature, °F								
<40	3	1.2	0.2	0.1-0.6	0	0.0	0.0	0.0-0.0
40-49	10	4.2	0.7	0.4-1.2	21	16.9	2.3	1.6-3.3
50-59	31	13.8	2.1	1.5-2.8	11	8.5	1.2	0.7-2.1
60-69	41	18.0	2.7	2.1-3.5	30	23.7	3.3	2.4-4.4
70-79	46	20.3	3.1	2.4-3.8	55	44.1	6.1	5.1-7.1
80-89	78	34.1	5.2	4.4-6.0	4	3.4	0.4	0.2-1.1
90-99	18	7.8	1.2	0.8-1.8	4	3.4	0.4	0.2-1.1
>100	1	0.6	0.1	0.0-0.4	0	0.0	0.0	0.0-0.0
Cold days (≤69°F)	85	37.2	5.7	4.9-6.4	62	49.1	6.9	5.9-7.8
Hot days (≥70°F)	143	62.8	9.6	9.1-9.8	63	50.9	7.0	6.0-7.8
Humidity, %								
<40	125	55.0	8.3	7.7-8.8	55	44.0	6.1	5.1-7.1
40-49	18	8.0	1.2	0.8-1.8	32	26.0	3.6	2.6-4.6
50-59	10	4.3	0.7	0.4-1.2	3	2.0	0.3	0.1-0.9
60-69	27	11.7	1.8	1.3-2.5	3	2.0	0.3	0.1-0.9
70-79	17	7.4	1.1	0.7-1.7	5	4.0	0.6	0.2-1.2
80-89	16	6.8	1.1	0.7-1.7	0	0.0	0.0	0.0-0.0
90-99	4	1.9	0.3	0.1-0.7	7	6.0	0.8	0.4-1.5
100	11	4.9	0.7	0.4-1.3	20	16.0	2.2	1.5-3.2

[a]%, percentage of total injuries within each category that occurred on the specific playing surface; IRR, injury incidence rate = (number of injuries ÷ total number of injuries) × 10; CI, confidence interval.

Environmental Factors

The attempt to quantify weather conditions at time of injury revealed that the majority of injuries occurred during dry conditions, warm temperatures, and low humidity (see Table 5). Conditions of no precipitation (dry surface) were associated with 201 (88.3%) injuries on FieldTurf and 106 (84.4%) injuries on natural grass. Rain or wet field conditions were associated with 27 (11.7%) trauma cases on FieldTurf and 19 (15.6%) on natural grass. No injuries were reported during snow or sleet conditions.

Although no significant differences were noted between playing surfaces across temperature, interestingly, when analyzing data by cold days (eg, ≤69°F) as compared to hot days (eg, ≥70°F) as suggested by others,[48] a significantly higher incidence of injury was observed during hot days on FieldTurf (62.8%; IRR = 9.6; 95% CI, 9.1-9.8) as compared to natural grass (50.9%; IRR = 7.0; 95% CI, 6.0-7.8). On cold days, the incidence of injury was similar on both surfaces (FieldTurf: 37.2%; IRR = 5.7; 95% CI, 4.9-6.4; vs natural grass: 49.1%; IRR = 6.9; 95% CI, 5.9-7.8).

DISCUSSION

The purpose of this prospective cohort study was to quantify the incidence, causes, and severity of game-related high school football injuries on FieldTurf versus natural grass. It was hypothesized that high school athletes would not experience any difference in the incidence, causes, and severity of game-related injury between FieldTurf and natural grass. Although similarities did exist between FieldTurf and natural grass, significant and unique differences in sport trauma were observed between the two playing surfaces.

Injury Incidence

Over the 5-season study, the greater absolute number of injuries occurring on FieldTurf was primarily related to the increasing popularity resulting in a greater number of games played on the artificial surface. Overall, 353 game-related injuries, or 8.8 injuries per high school per season, were recorded among 8 high schools competing on both surfaces. This is consistent with the number of injuries observed in prior studies, ranging from 2.4 to 15.7 injuries per high school per season.[2,13,51] The incidence of acute injury (94.3%) was higher than reported in earlier studies, ranging from 72% to 84%.[44,52,53] The incidence of substantial trauma recorded in this study was also similar to the incidence of severe injury per high school per season reported elsewhere.[13] Although the large variation in injury definition among these studies prevents an accurate comparision,[46] 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 high school level of play.

In addition to acute injury, repetitive or recurrent trauma is considered a major contributor to future trauma.[19,24,71] The incidence of recurrent cases over 5 seasons in this study ranged from 4.8% on FieldTurf to 5.6% on natural grass, quite lower than the 13% to 17% of recurrent trauma reported in collegiate football, soccer, lacrosse, and professional soccer during a single season.[18,44,68] Whether recurrent trauma was observed over the same surface is not known. The increased interest but paucity of studies that address recurrent trauma prevents further discussion at the high school level of play.

The higher incidence of injury to upperclassmen on both surfaces is solely attributed to greater playing time and subsequent predisposition to injury typically observed at the varsity level of play, in which lower classmen receive limited playing time. With regard to foul play, the incidence (1.1%) of injury attributed to illegal action was negligible. This is similar to the 0.8% occurrence reported in National Collegiate Athletic Association football[44] but in contrast to the 25% to 62% reported among other youth, intercollegiate, and senior sports.[15,49,73-75]

The greater rate of overall injury documented on FieldTurf may be attributed to the high number of minor injuries (eg, abrasions, muscle strains, noncontact trauma) or influenced by the greater number of games or potential exposure to injury on FieldTurf over 5 competitive seasons. Despite the lower number of games played on natural grass, findings still clearly indicate a similar incidence of substantial injury cases documented on natural grass.

Injury Category

Results of this study indicate no significant differences between playing surfaces across injury categories. As previously described, however, there was a greater incidence of muscle-tendon overload injuries on FieldTurf. This may have been a function of faster play with the concomitant assistance of a more compliant, elastic surface than observed with natural grass.[24]

Time of Injury

It has been noted that with increasing fatigue over time, concomitant declines in available energy substrate and coordination predispose an athlete to injury.[68,71] The nonsignificant differences within and between playing surfaces in this study, however, indicated minimal influence on injury incidence from pregame through the fourth quarter of play. As previously noted, the acute differences in the composition and quality of surfaces may have influenced the type and severity of trauma but did not affect the time of injury observed over the 5-season period. Findings may also be reflective of the score and subsequent play calling of coaches.[2,7]

Injury Time Loss

The polyethylene/polypropylene nature of FieldTurf, although promoted as a nonabrasive surface with a natural earth feel, still resulted in a significantly greater incidence of minor injuries such as abrasions, contusions, and lacerations requiring 0 days of time loss. Findings also indicated, however, that a greater incidence of injuries ranging from 1 to 2 days of time loss and 22 days or more of time loss was associated with competing on natural grass. It should be noted that the majority of football fields in this region are typically of a resilient Bermuda grass blend that becomes dormant as temperatures drop and is supported by a mean annual rainfall of ≤18 inches and humidity of <40%. This playing surface is often overseeded with annual rye grass, adding minimal surface compliance and energy absorption with a high coefficient of restitution.[45] Previous research has documented a greater incidence of noncontact ACL injuries when competing on a dry surface.[22,58] Whether these findings with the natural grass surface are a function of decreasing turf quality with declining temperatures throughout the season, overuse because of increased multipurpose use, or simply the low rainfall and subsequent surface hardness is not clear and is beyond the control of this study.

Position Played at Time of Injury

The IRRs and subsequent multivariate analyses indicated no significant effect of playing surface on position played at the time of injury. The greater incidence of injuries during special teams play on FieldTurf, however, may be attributed to the faster, more consistent surface resulting in greater impact forces and concomitant trauma.[24,51] The similar incidence of injury among offensive and defensive players, however, is inconsistent with prior research indicating a greater incidence of trauma among offensive backs and numerous defensive positions.[30,43] Unfortunately at this time, the limited frequency of injury among some specific positions led to combining positions into either offense or defense, preventing further in-depth analyses and discussion of potential injury differences and position susceptibility that have been described by others.[19-21,30]

Injury Mechanism

The greater incidence of injuries from being stepped on, fallen on, or kicked while competing on FieldTurf (Table 3) as well as the higher incidence of noncontact, running, or sprinting injuries are related to the inherent nature of FieldTurf, which was proposed to combine the best of performance with safety. The more consistent artificial composition enhances the speed of the game but may also allow for greater opportunity for injury because of overextension and greater fatigue potential of muscles as players perform at a greater rate of acceleration, speed, and torque.[35,61] Although numerous other mechanisms may be at play,[19,33,35,39,71] risk factors repeatedly mentioned in the literature have included pivoting, change of direction, direct contact with an opposing player, deceleration, unfortunate mishaps (eg, piling on, moving pileup), and being jolted during an uncontrolled or compromised movement.[22,38] Others have identified equipment (eg, shoe/cleat design), the abrasive nature of artificial surfaces, and various anatomical and biomechanical influences.[2,5,6,22,30]

Primary Type of Injury

The greater incidence of surface/epidermal injuries and muscle strains/spasms documented on FieldTurf, as previously described, may be a result of greater velocity of play and fatigue potential.[35,39] The greater incidence of concussion and ligament tears on natural grass may be related to the shoe-surface traction usually associated with a harder, drier surface[47] and the inconsistent nature of natural grass in more arid regions of the country. Others have noted a similar incidence of ligament trauma on similar noncompliant surfaces.[22,58] Further investigation will be necessary to elucidate more definitive causes.

Grade and Anatomical Location of Injury

Although no significant playing surface effect was observed across injury grade (Table 4), the greater incidence of cranial/cervical trauma observed on natural grass may reflect the lower impact attenuation of the harder, drier surface. Interestingly, the incidence of concussion on both surfaces in this study was greater than cranial trauma previously reported among both high school and college athletes.[13,23,31,45,52,53,78] These findings are also in contrast to earlier studies indicating a lower concussion rate on natural grass when compared to the earlier generation of artificial surfaces.[23,45] The higher incidence of lower versus upper extremity trauma observed in this study was similar to earlier findings reported among high school and professional athletes.[6,12,13,24,51,52]

Type of Tissue Injured

The higher incidence of neural injuries reported on natural grass (Table 4) is consistent with prior work indicating an inverse relationship between a playing surface's energy absorbency or compliance and the degree of tissue trauma.[45,71] Although the coefficient of restitution or degree of rebound was not established in this study, the drier, noncompliant qualities of natural grass and its subsurface, when compared to the polyethylene/polypropylene/rubber composition of FieldTurf, seemed to result in minimal energy absorption at ground impact. The energy of impact is subsequently transferred back into the cranial/cervical region, increasing the potential for concussion.[71] Interestingly, cervical strains were more common on FieldTurf than on natural grass, although some have noted that cranial impact does not necessarily coincide with cervical trauma.[76] These strains, provoking similarities to whiplash, may be a function of the rubber-based surface, with further investigation needed to monitor this unique response not observed with natural grass.[71] The higher incidence of injury to muscle tissue on FieldTurf is reflective of the strains/spasms, as previously described.

Head and Knee Injuries

The greater incidence of first-degree and total concussions combined, as well as the greater incidence of ACL-involved trauma, further reiterates the level of severe trauma observed during competition on natural grass (Tables 1 and 2). Although this is in contrast to prior studies that indicated a higher incidence of severe injury on artificial surfaces,[2,10,23,26,32,45,55,60] the earlier findings may be a reflection of traditional synthetic materials as opposed to the newer generation of artificial surfaces being installed today.

Environmental Factors

Limited attention has been directed toward the potential influence of weather conditions on injury during competition.[2,22,24,48] The majority of play and injuries occurred during conditions of no precipitation and low humidity, therefore minimizing the opportunity to thoroughly ascertain possible influences under various field conditions. Of greater concern is the clinically significant increase in the incidence of injury on FieldTurf during temperatures ≥70°F when compared to cooler temperatures, similar to findings previously reported on artificial surfaces.[48] Although others have either indicated enhanced shoe-surface interaction potentiating articular trauma with increasing turf temperature[48,65] or reported greater frequency of knee trauma with higher temperatures,[47] overall, no significant environmental differences were observed between playing surfaces.

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 injury typically observed in high-collision team sports[8,38]; the strength and conditioning status of the athletes and variations in the type of equipment used[2,17,29,30,35,64]; weather conditions and variations in field conditions[2]; differences in postural/joint integrity, musculoskeletal structure, and biomechanics of movement[9,28,70,72]; coaching style and play calling[2,7,24,35]; quality of officiating and foul play[71]; player position and actual versus average time of exposure to injury[25,29,33]; sport skill level, intensity of play, and fatigue level at time of injury[9,23,33,36,64,70,71]; an athlete's ephemeral response to help seeking, injury, and subsequent pain[1,9,11,35,40,52]; player eligibility[2]; unreported congenital/developmental factors predisposing an athlete to additional injury[9,30,35,71,77]; or simply unforeseen mishap.[28,38] Also, there is always the opportunity for an injury to go unreported despite the comprehensive nature of any reporting system,[35] and although our study revealed significant and unique differences in injury causes, generalizability of the findings across the country may not be warranted because of varying environmental, field, and injury management conditions.

An initial concern of this study was that more games were played on FieldTurf but all practices were conducted on natural grass, which is commonplace in school districts sharing a stadium with multiple high schools. As evidenced by the findings, the additional time on natural grass during practice, however, did not seem to offer an advantage during games. Skewness of findings, however, remains a possibility, but it would be difficult to control uniformity of practice and game surface under the present situation in many school districts.

Key strengths of the study were the opportunity to follow several high schools during the 5-year period, which prevented seasonal injury fluctuations and individual team effect[2] and enhanced the ability to identify differences and trends in surface effect. In addition, the combined method of assessing functional outcome, 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.[11,28,56,68] The daily evaluation and follow-up telephone visits also increased the opportunity to quantify and track typically overlooked minor indices that often exacerbate into chronic or overuse problems.[11,28,68]

It must also be noted 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. The prospective cohort multivariate design, however, did enhance sample size, result in randomization of play on both surfaces, control for seasonal and team variation, and allow for greater insight into both significant and subtle differences between a new generation of artificial turf and natural grass.[2,39,51,71]

Finally, the lack of a universally accepted definition of sport injury will continue to be a challenge and subsequent influence on injury interpretation.[51] With the concomitant difficulty in subjectively determining a plethora of surface conditions and quality of natural grass,[2] any attempt to interpret the injury-surface interaction with any degree of accuracy will continue to pose concerns.

CONCLUSION

Although similarities did exist between FieldTurf and natural grass over a 5-year period of competitive play, there were significant differences in injury time loss, injury mechanism, anatomical location of injury, and type of tissue injured between playing surfaces. Both surfaces, from a statistical and clinical standpoint, also exhibited unique injury causes that need to be addressed to reduce the number of game-related, high school football injuries. The hypothesis that high school athletes would not experience any difference in the incidence, causes, and severity of game-related injury between FieldTurf and natural grass was not supported. It must be reiterated, however, that the findings of this study may only be generalizable to this level of competition. Because this study is still in the early stages, however, continued investigation is warranted.

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