Lower Extremity Injury Rates on Artificial Turf Versus Natural Grass Playing Surfaces

A Systematic Review

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Background: No study has provided a comprehensive systematic review of sports injuries on artificial turf versus natural grass.

Purpose: To comprehensively examine the risk of overall injuries and multiple types of lower extremity injuries across all sports, all levels of competition, and on both old-generation and new-generation artificial turf.

Study Design: Systematic review; Level of evidence, 3.

Methods: A systematic review of the English-language literature was performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. All included articles compared overall injury rates or lower extremity (hip, knee, or foot and ankle) injury rates on artificial turf and natural grass. All sports, levels of competition, and turf types were included. Studies were excluded if they did not include overall injury rates or lower extremity injury rates. Because of the heterogeneity of the included studies, no attempt was made to aggregate risk ratios to conduct a quantitative meta-analysis.

Results: A total of 53 articles published between 1972 and 2020 were identified for study inclusion. Most studies on new-generation turf (13/18 articles) found similar overall injury rates between playing surfaces. When individual anatomic injury locations were analyzed, the greatest proportion of articles reported a higher foot and ankle injury rate on artificial turf compared with natural grass, both with old-generation (3/4 articles) and new-generation (9/19 articles) turf. Similar knee and hip injury rates were reported between playing surfaces for soccer athletes on new-generation turf, but football players, particularly those at high levels of competition, were more likely to sustain a knee injury on artificial turf than on natural grass.

Conclusion: The available body of literature suggests a higher rate of foot and ankle injuries on artificial turf, both old-generation and new-generation turf, compared with natural grass. High-quality studies also suggest that the rates of knee injuries and hip injuries are similar between playing surfaces, although elite-level football athletes may be more predisposed to knee injuries on artificial turf compared with natural grass. Only a few articles in the literature reported a higher overall injury rate on natural grass compared with artificial turf, and all of these studies received financial support from the artificial turf industry.

Keywords: artificial turf; natural grass; playing surfaces; injury risk; football; soccer

Since the installation of the first synthetic turf playing surface in 1966 at the Astrodome in Houston, Texas, artificial turf has emerged as a common alternative to natural grass at all levels of competition, from youth to professional. Compared with natural grass, artificial turf offers several potential advantages in terms of cost, durability, maintenance requirements, and multipurpose use.[14] However, concerns about athlete safety on artificial turf were raised as early as the 1970s, with the first reports of higher injury rates on artificial turf playing surfaces compared with natural grass.[1,5] Biomechanical evidence pertaining to the shoe-surface interface and foot-loading patterns has provided further support for concerns about artificial turf from a player health perspective.[31] Mechanical properties such as peak torque and rotational stiffness are thought to be substantially higher on artificial turf compared with natural grass, potentially leading to increased frictional forces between the foot and the playing surface that could predispose athletes to a higher risk of injuries.[6,9,29] Moreover, higher relative loads on the central forefoot and lesser toe areas on artificial turf have been demonstrated to cause greater foot inversion, which could potentially result in lateral ankle ligament injuries.[11,16,33]

The American Journal of Sports Medicine
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DOI: 10.1177/03635465211069562

However, the heterogeneity of study designs in the clinical literature has made it difficult to draw definitive conclusions with regard to the safety of artificial turf. Previous review articles on overall injury rates,[7,10,28,31,32] sport-specific injury rates,[25,30] and injury rates for a specific diagnosis, such as a concussion[21] or anterior cruciate ligament rupture,[4] are narrow in scope or narrative in format (nonsystematic). Given the presence of multiuse playing surfaces at the youth, high school, and collegiate levels, a more comprehensive overview of the literature may provide valuable information for sports medicine care providers and to athletic administrators. We are not aware of any systematic review that has examined comparative injury rates between artificial turf and natural grass including all sports, all levels of competition, and both old- and new-generation artificial turf types for a wide range of musculoskeletal diagnoses.

The objective of the present study was to conduct a systematic review comprehensively examining the comparative risk of lower extremity injuries on artificial turf and natural grass playing surfaces. It was not possible to aggregate risk ratios to conduct a quantitative meta-analysis because of the heterogeneity of the included studies with regard to sport, level of competition, artificial turf type, injury setting (ie, practice, game), and how injury incidence was reported. We performed a qualitative analysis of the literature on the overall injury risk and the risk of injuries to the foot and ankle, knee, and hip on artificial turf versus natural grass across all sports, levels of competition, injury settings, and types of artificial turf.

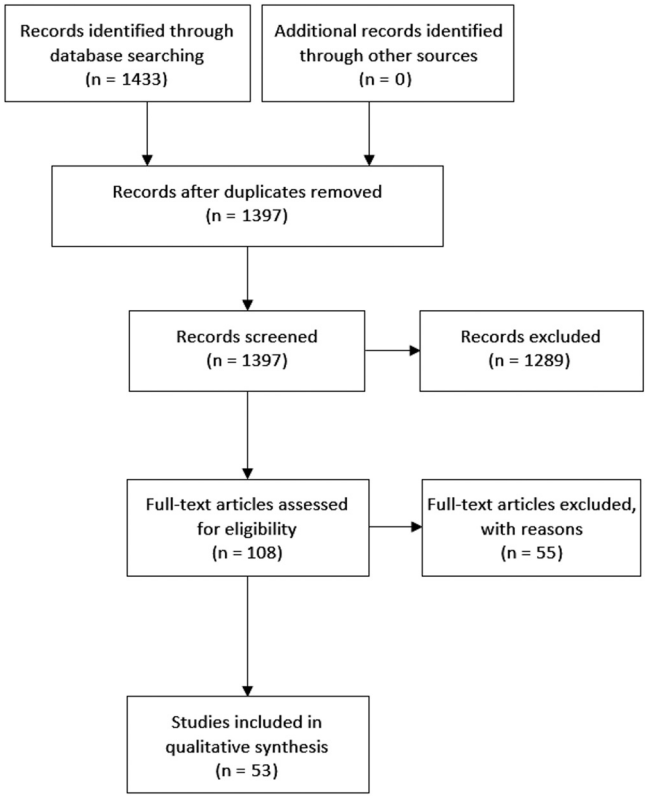

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram showing the identification of included studies.

METHODS

This systematic review was performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Figure 1).[19] A health sciences librarian developed the search strategy utilizing a combination of keywords and database-specific subject headings related to each concept including turf, grass, and injury. A search was conducted within PubMed, Embase (via Ovid), Web of Science Core Collection, and SPORTDiscus (via EBSCOhost) from inception to August 12, 2020. No limit regarding the year of publication was imposed. Non-English and nonhuman studies were excluded from the search, and duplicates were removed using EndNote X9 (Clarivate Analytics).

Articles were assessed for study eligibility by 2 reviewers, each of whom was blinded to the inclusion/exclusion decisions made by the other reviewer. The 2 reviewers, a senior orthopaedic surgery resident (H.P.G.) and an academic foot and ankle orthopaedic surgeon (G.P.G.), developed an algorithm for initial article screening, oversaw implementation with a team of premedical and medical students, and performed a detailed review of all included articles. In cases of a disagreement between the 2 reviewers, blinding was removed, and the eligibility of the article was determined by a group consensus, with the senior author (G.P.G.) making the final decision. Studies were included if they compared artificial turf and natural grass playing surfaces with regard to the rate of overall injuries or any type of lower extremity injuries, such as the hip, thigh, knee, lower leg, ankle, or foot. Pediatric and adult studies were included. Studies that reported only upper extremity, chest, abdomen, spine, or concussion injury rates were excluded. Only original research studies were included. Studies that reported only injury rates on artificial turf or natural grass without a direct comparison between the 2 playing surfaces were excluded. All abstracts and full-text

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Submitted July 21, 2021; accepted November 9, 2021.
One or more of the authors has declared the following potential conflict of interest or source of funding: G.P.G. has received royalties and payments for services other than consulting from Wright Medical Technology, consulting fees from Paragon 28, and hospitality payments from Supreme Orthopedic Systems. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

articles were stored in Rayyan QCRI,[22] which allowed blinding of each independent reviewer to the inclusion/exclusion decisions made by the other reviewer throughout the article assessment process.

Articles that met the eligibility criteria underwent data extraction for study design (prospective, retrospective, randomized controlled trial, cohort, case-control), level of evidence (1-5), cohort selection process (ad hoc, systematic), sport (football, soccer, other), level of competition (professional, amateur), injury setting (practice, game, practice and game), number of athletic seasons, and turf type (old generation, new generation, not reported). Specific injury information was also extracted from each article, including athlete exposures, number of practices/games, number of injuries, injury diagnoses, and injury mechanisms. Study funding sources were also considered.

Articles that did not state the level of evidence were independently graded for level of evidence by the same 2 blinded reviewers. Level 1 articles included high-quality randomized controlled trials, level 2 articles included lower quality randomized controlled trials and prospective cohort studies, and level 3 articles included retrospective cohort and case-control studies. Studies that did not exclude eligible athletes and used predefined enrollment criteria (eg, entire division, entire conference, entire league) were classified as using systematic cohort selection. Studies were classified as using ad hoc cohort selection if the study excluded some eligible athletes and if the participants were not enrolled according to predefined criteria (eg, athletes from several teams were included, but there was no stated rationale for inclusion). Articles were defined as industry funded if the authors received financial support for the research from a company that produces, sells, or distributes artificial turf.

RESULTS

Characteristics of Included Studies

Details of the literature search strategy are summarized in Figure 1. A total of 53 studies met inclusion criteria (see Appendix). Article publication dates ranged from 1972 to 2020. Of the 53 studies, 33 (62.3%) were prospective, and 20 (37.7%) were retrospective. The most common study design was cohort studies (n = 36; 67.9%), followed by case-control studies (n = 15; 28.3%). Randomized controlled trials accounted for only 2 (3.8%) of the included studies. All studies were rated level of evidence ≥3, with almost all articles classified as either level 2 or 3 (n = 51; 96.2%) (Figure 2).

The 3 (5.7%) industry-funded studies were published by the same author with research funding from 1 artificial turf company (Figure 3).

Systematic cohort selection was used in 21 studies (39.6%), and ad hoc cohort selection was used in 32 studies (60.4%). A total of 24 articles (45.3%) examined football, 22 articles (41.5%) studied soccer, and 1 article (1.9%) studied both football and soccer. Rugby (n = 4; 7.5%), ultimate Frisbee (n = 1; 1.9%), and field hockey (n = 1; 1.9%) comprised the remaining 6 articles (Figure 4).

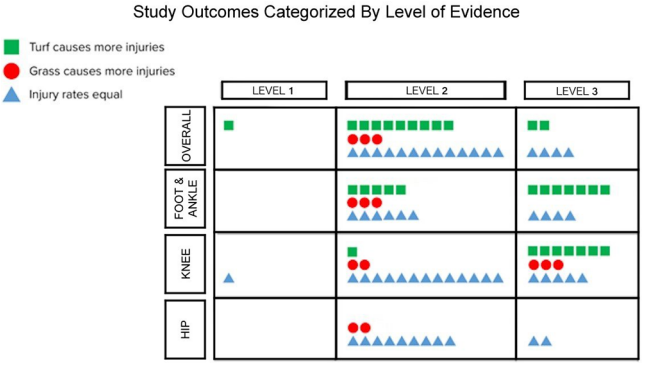

Figure 2. Diagram showing the conclusion of each article with regard to injury rates on artificial turf and natural grass, with articles classified by level of evidence.

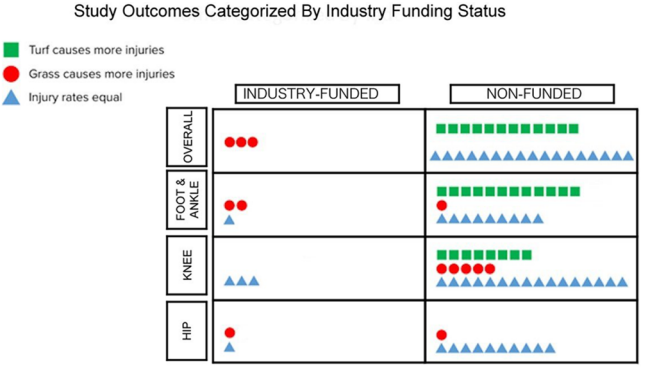

Figure 3. Diagram showing the conclusion of each article with regard to injury rates on artificial turf and natural grass, with articles classified by industry funding status.

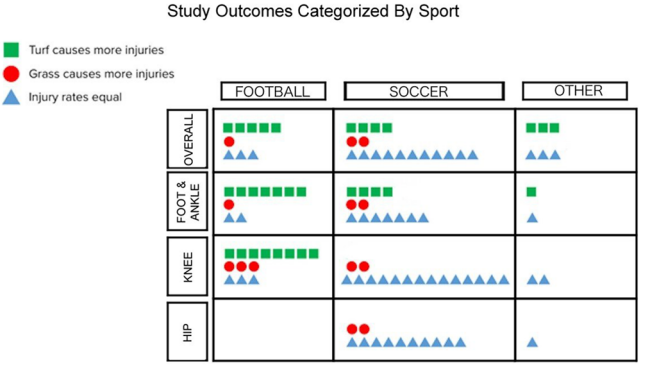

Figure 4. Diagram showing the conclusion of each article with regard to injury rates on artificial turf and natural grass, with articles classified by sport.

Competition level was divided equally between professional (n = 24; 45.3%) and amateur (n = 29; 54.7%) (Figure 5).

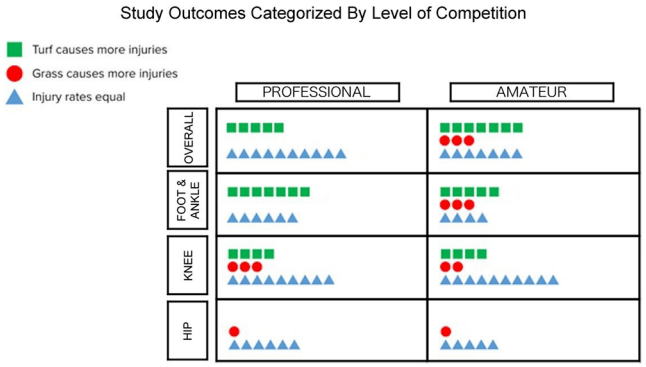

Figure 5. Diagram showing the conclusion of each article with regard to injury rates on artificial turf and natural grass, with articles classified by level of competition.

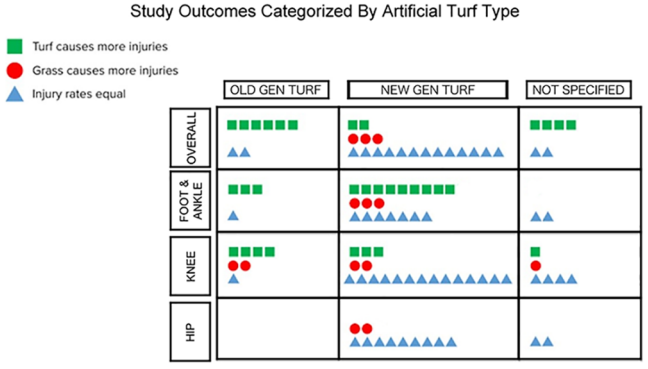

Figure 6. Diagram showing the conclusion of each article with regard to injury rates on artificial turf and natural grass, with articles classified by artificial turf type. Gen, generation.

The included studies were evenly split between those that examined both games and practices (n = 27; 50.9%) and those that examined only games (n = 25; 47.2%), whereas the 1 remaining study (1.9%) examined only practices. The included studies tracked injury data over a median of 3 seasons (interquartile range, 1-5). A total of 29 articles (54.7%) reported on new-generation artificial turf, 14 articles (26.4%) reported on old-generation artificial turf, and 10 articles (18.9%) did not report the type of artificial turf (Figure 6).

Overall Injury Rate

Of the 32 articles that compared overall injury rates on artificial turf and natural grass, over half (17/32; 53.1%) reported no difference in overall injury rates between the 2 playing surfaces, 12 (37.5%) reported a higher overall injury rate on artificial turf, and 3 (9.4%) reported a higher overall injury rate on natural grass. Although 6 of 8 articles (75.0%) that examined overall injury rates on old-generation turf reported a higher risk of injuries on artificial turf, 13 of 18 articles (72.2%) that examined overall injury rates on new-generation turf reported no difference between playing surfaces. A higher overall injury rate on natural grass was reported by 3 articles (9.4%), all of which utilized ad hoc cohort selection and were the only included studies that were industry funded.

Foot and Ankle Injury Rate

A total of 25 articles compared foot and ankle injury rates on artificial turf and natural grass. The greatest proportion of these studies (12/25; 48.0%) reported a higher rate of foot and ankle injuries on artificial turf than natural grass, whereas 10 (40.0%) found no difference in foot and ankle injury rates between playing surfaces, and 3 (12.0%) reported a higher foot and ankle injury rate on natural grass. Of these 3 studies, 2 (66.7%) utilized ad hoc cohort selection and were industry funded. Although a relatively high proportion of studies that reported on new-generation turf (9/19; 47.4%) found a higher risk of foot and ankle injury on artificial turf, that finding was even more frequently reported in earlier articles that examined old-generation turf (3/4; 75.0%).

Knee Injury Rate

A total of 32 articles compared knee injury rates on artificial turf and natural grass. Over half of these studies (19/32; 59.4%) found no difference in knee injury rates between artificial turf and natural grass, whereas 8 studies (25.0%) reported a higher knee injury rate on artificial turf, and 5 studies (15.6%) reported a higher knee injury rate on natural grass. Over two-thirds of articles (14/19; 73.7%) that examined knee injury rates on new-generation turf reported no difference in knee injury rates between the 2 playing surfaces, compared with a majority of studies (4/7; 57.1%) that reported a higher knee injury rate on old-generation turf compared with natural grass. A majority of articles (14/16; 87.5%) reported no difference in knee injury rates among soccer athletes, and 8 of 14 articles (57.1%) examining football athletes reported a higher knee injury rate on artificial turf. All 3 of the industry-funded studies reported no difference in knee injury rate between the two playing surfaces.

Hip Injury Rate

A total of 13 articles compared hip injury rates on artificial turf and natural grass. Of these studies, 11 (84.6%) reported no difference in hip injury rates between playing surfaces, while the remaining 2 studies (15.4%) reported a higher hip injury rate on natural grass. Of the 2 studies that found a higher risk of hip injuries on natural grass, both utilized ad hoc cohort selection, and 1 (50.0%) received industry funding. None of the included articles reported hip injury rates in football athletes, and none examined old-generation turf.

DISCUSSION

Although the heterogeneity of the available literature precludes a quantitative meta-analysis, this qualitative

systematic review of study outcomes suggests that the rates of overall injuries, hip injuries, and knee injuries are similar between playing surfaces. Earlier studies suggested a greater risk of these types of injuries on old-generation turf, but more recent data note an equivalent injury risk on new-generation turf compared with natural grass for most athletes. Foot and ankle injury rates are a notable exception to this trend in that the risk of foot and ankle injuries has remained higher on new-generation turf compared with natural grass, though still less than that on old-generation turf. These conclusions were not affected by the conflicting findings of the 3 included studies that received financial support from the artificial turf industry.

A majority of the included studies in this systematic review utilized ad hoc cohort selection, which raises concerns about the study design. Study cohorts that are defined in an ad hoc manner introduce the possibility of bias because of differences that may exist between individual athletic programs with regard to injury-reporting tendencies. Although some teams may consistently and accurately report athletes' injuries, others may tend to underreport injuries whether because of inadequate documentation or underlying cultural elements that discourage athletes and medical personnel from disclosing injuries when they occur. These issues are of particular concern at the youth and high school levels in which many schools are unable to employ a full-time athletic trainer or arrange sideline physician coverage at sporting events.[15,23] The potential effect of differences in injury-reporting practices can be diminished by studying predefined groups of athletes or athletic teams that are not created solely for the purpose of the study. For instance, including entire divisions or leagues may have less potential for bias than studying an ad hoc collection of teams that are selected by the study investigator. Studies sponsored by the National Football League provide an ideal model for avoiding this problem by utilizing comprehensive, standardized injury reporting and including all teams in the league.[12,16]

Among the 32 articles that compared overall injury rates, a slight majority reported no difference in the injury risk between playing surfaces. Although one-third of articles reported a higher overall injury rate on artificial turf, half of these studies[1,2,5,13,24,27] utilized first- and second-generation turf types that are now considered obsolete. Thus, whereas a higher overall injury rate might have existed on earlier generations of artificial turf, the more recent literature indicates that this risk has been ameliorated with the widespread adoption of new-generation turf since it was developed in the late 1990s.

There were 3 outlier articles that found a higher overall injury rate on natural grass compared with new-generation turf.[17-19] These studies all utilized ad hoc cohort selection and thus had a high inherent risk of bias, a concern acknowledged by the author himself. All 3 studies were also supported by turf industry funding. Our results with regard to the overall injury rate coincide with the findings of previous narrative reviews,[7,31] which also concluded that the risk of overall injuries appears to be similar between artificial turf and natural grass.

Of the 25 included articles that examined foot and ankle injury rates in isolation, the greatest proportion found a higher foot and ankle injury rate on artificial turf, and this trend persisted when studies examining new-generation turf were analyzed separately. Only 3 articles[17,19,26] reported a higher risk of foot and ankle injuries on natural grass, 2 of which utilized ad hoc cohort selection and received artificial turf industry funding.[17,19] Thus, the literature appears to support the conclusion that the risk of foot and ankle injuries is at least equivalent between playing surfaces and may be higher on artificial turf. These findings are consistent with previous narrative reviews that have concluded a higher risk of foot and ankle injuries on artificial turf.[28,31,32]

The literature results are heterogeneous regarding the potential association between playing surface and knee injury. Although half of all articles reported no difference in knee injury rates between playing surfaces, some articles found a higher knee injury rate on artificial turf, and others found a higher knee injury rate on natural grass. Analysis of the studies that utilized new-generation artificial turf revealed a higher proportion of these articles that found no difference in knee injury rates. Interestingly, all 3 of the articles reporting a higher knee injury rate on new-generation artificial turf[8,12,16] were conducted among football players at the collegiate or professional level, suggesting that there may be unique factors in the elite football population that predispose these athletes to a higher risk of knee injuries on artificial turf compared with natural grass. These findings correspond with the results of a previous systematic review that reported a higher risk of anterior cruciate ligament ruptures on artificial turf for football players but not for soccer players.[4] Taken together, the whole body of relevant literature suggests that the risk of knee injuries is similar on artificial turf and natural grass for most athletes but that football players, particularly those at high levels of competition, may be more likely to sustain a knee injury on artificial turf than natural grass.

Relatively few articles in the literature have compared hip injury rates on artificial turf and natural grass. Of these 13 studies, the majority found no difference in hip injury rates between playing surfaces, whereas only 2 articles cited a higher risk of hip injuries on natural grass. Consistent with observations in overall injuries and foot and ankle injuries, both of the articles that reported a higher hip injury rate on natural grass utilized ad hoc cohort selection, and 1 of the 2 studies[3,19] was funded by the artificial turf industry.[19] The only study not funded by the turf industry that found a higher hip injury rate on natural grass was a prospective cohort investigation that examined injury rates in a small ad hoc group of the Saudi National Team soccer players that yielded a very low number of injuries.[3] The findings of this systematic review appear to indicate that the risk of hip injuries is comparable between artificial turf and natural grass.

There were several limitations to this systematic review. The wide variability in study methods, particularly in terms of how athlete exposures were reported, made it

impossible to perform a quantitative meta-analysis using aggregate risk ratios. Our systematic review design was unable to account for the fact that the underlying injury rates among different sports, levels of competition, and injury settings may be inherently different. Similarly, our methods did not permit the assessment of other variables that may affect injury rates such as differences in turf composition, athletic footwear, and field conditions. No restrictions were made in terms of study quality, and no formal weighting process was performed, thereby limiting our ability to differentiate the more reliable injury data from the less reliable data among the included articles. For these reasons, our systematic review should be interpreted as a global snapshot of the literature, and our findings are not intended to replace the interpretation of high-quality individual studies that focus on specific athletic populations with specific types of injuries.

CONCLUSION

The available body of literature suggests a higher rate of foot and ankle injuries on artificial turf compared with natural grass on both old- and new-generation turf. High-quality studies also suggest that the rates of knee injuries and hip injuries are similar between playing surfaces, although elite-level football athletes may be more predisposed to knee injuries on artificial turf compared with natural grass. Only a few articles in the literature reported a higher overall injury rate on natural grass compared with artificial turf, and all of these studies received financial support from the artificial turf industry.

ACKNOWLEDGMENT

The authors thank Lyn Camire Jones, MA, ELS, of the Department of Orthopaedic Surgery, MedStar Union Memorial Hospital, for editorial assistance and C. Scott Dorris, MLIS, AHIP, for assistance in performing the literature search.

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