Chapter

Playing Surface and Injury Risk: Artificial Turf Vs. Natural Grass

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Abstract

Artificial turf's developmental history spans 6 generations and includes design improvements that transformed an injury-inducing 1st generation field into a modern 3rd generation natural grass substitute. Artificial turf has become a widely adopted playing surface with a $2.7 billion United States Dollar (USD) valuation in North America. Turf's popularity is due to its increased functionality and decreased cost compared to natural grass that allows more sports to play on the surface for longer time periods with decreased maintenance costs. From a biomechanical perspective, artificial turf exhibits higher frictional coefficients than natural grass resulting in higher foot and ankle injury rates. Concussion rates on turf are decreased compared to natural grass due to lower G-max values on well-maintained artificial surfaces. Hip, knee, and overall injury rates are equivalent between the two surfaces except in specific populations including elite-level American football players that exhibit increased knee injury rates on artificial turf. Due to these tradeoffs, the authors suggest that athletic organizations with funding to support professional groundskeeping should consider investing in natural grass due to athlete preference and decreased injury risk. In contrast, organizations without sufficient funding for professional groundskeeping operations may consider investing in modern artificial turf due to its associated long-term benefits and decreased costs.

Keywords: artificial turf, synthetic turf, natural grass, sport fields, playing surfaces, comparative injury rates, lower extremity injuries, concussions

1. Introduction

1.1 The problem at large

Injury reduction studies and the strategies such studies create are important methods used to protect amateur and professional athletes worldwide. Through the process of identifying risk factors and taking steps to mitigate them, researchers and athletic administrators can take active roles in athlete safety. In the United States (US) alone, 2.6 million sports-related emergency room visits occur each year for patients in the 5–25 age range. Such injury rates account for significant financial and time costs for athletes and medical personnel, as US high-school athletics result in 500,000 medical visits, 30,000 hospitalizations, and $2 billion USD costs to the US healthcare system on average per year [1]. A study of North Carolina high school athletes demonstrated that injury-related expenses including medical costs, lost opportunity costs, and estimated impact on quality of life totaled an average of $10,432 USD per injury [2]. Due to the substantial impact of these athletic injuries at a personal and societal level, debates continue to occur regarding the specific equipment, protocols, and playing surfaces that will maximize player safety and minimize risk of injury. In this chapter, we compare athletic injury rates between artificial turf and natural grass playing surfaces. We set out to provide a concise summary and synthesis of the available literature, in hopes that this information may be useful to both medical providers and athletic administrators who are involved in the care of athletes across all levels of play.

1.2 History of artificial turf

The 1st artificial turf field was installed in 1966 in the Houston Astrodome in Houston, Texas [3]. Produced by Monsanto and named AstroTurf, this turf generation's design consisted of a thin nylon fiber woven carpet installed over top a compacted soil base [3, 4]. In 1969, 3 M produced its own but similar product, Tartan Turf, as a direct competitor to Astroturf which was subsequently installed that summer in the University of Michigan football stadium [4]. Both Astroturf and Tartan Turf are considered 1st generation turf fields due to their design and material commonalities. This 1st generation design was associated with common skin abrasions, ankle sprains due to the prevalent intersectional seams and high friction level of the woven carpet, and other injuries due to the non-forgiving solidity of the base material [3–9]. Because of these problems, the 2nd generation of artificial turf, Shag Turf, quickly evolved and came into use by 1976 [10, 11]. 2nd generation turf improved upon the prior design by adding a shock-absorbing rubber pad over the compacted soil and replacing the original carpet with vertically positioned polypropylene fibers supported in a silica-sand infill [3–7]. This design aided the athletic experience through providing a flatter and more routine playing surface that mimicked natural grass fields to a higher degree. Unfortunately, these fields exhibited a high propensity to cause serious abrasions to players, which significantly limited their adoption among American football and soccer organizations [3, 5, 7, 10–12]. This led to the genesis of 3rd generation artificial turf. First installed in a Pennsylvania high school in 1997, the design took cues from the 2nd generation but with a greater focus on athlete safety [3, 13]. Changes between the 2nd and 3rd generation included altering the fiber composition from polypropylene to polyethylene to decrease skin abrasions, increasing fiber length, and spreading the fibers laterally to rely more heavily on the infill material for structural support and to decrease surface hardness [3, 5, 14]. The infill material was made into a deeper layer and switched from silica sand to crumb rubber or a mixture of both elements, occasionally also combined with other infill materials such as different elastomers, polymers, and organic materials such as coconut fibers, cork, and ground walnut shells [3]. These changes were made to increase the shock absorbing properties of the playing surface to increase player safety and improve agility as well as ball handling characteristics. Technically, additional generations of turf exist but their validity remains debated. Companies have claimed development of 4th, 5th, and 6th generation artificial turf which all essentially build on the same principles of 3rd generation turf, but use specific materials or manufacturing processes that eliminate the need for rubber infill. These claims remain debated due to the notion that 4th, 5th, and 6th generation turf exist only as marketing ploys used by companies to promote their products as novel developments, when in reality their design borrows heavily from 3rd generation turf characteristics [15–17]. Currently, the authors are not aware of any major athletic regulatory bodies that recognize these designs as unique turf generations, making 3rd generation artificial turf the current industry standard for modern turf design.

Today, artificial turf's success is represented in its wide adoption at all levels and types of athletic competition. In North America alone in 2020, the total value of synthetic turf fields was estimated at $2.7 billion USD with a total area of 265 million square feet and 436 million pounds of infill material installed [18]. Out of 32 National Football League teams, 16 use turf fields across 14 stadiums [19]. With this high degree of use, comparison of injury risks between artificial turf and natural grass fields could provide applicable information that has the potential to effect millions of athletes every year.

1.3 Cost of artificial turf vs. grass injuries

Artificial turf is generally installed as a cost-saving, functional enhancement to athletic facilities for its ability to host multiple sports on the same field with minimal repair time and lower maintenance costs in comparison to natural grass fields. A common misconception surrounding artificial turf is its zero-maintenance nature. While artificial turf certainly has a lower maintenance cost than natural grass, it still requires a substantial level of upkeep to maintain the surface. Examples of such maintenance include debris removal, sanitation and disinfection, watering for heat dispersion, field hardness testing and infill replacement, rake sweeping and dragging to maintain proper fiber alignment and G-max value, snow removal in the winter, and regular certification checks to ensure maintenance is keeping the field within specification parameters [20, 21]. Even with these maintenance requirements and their associated costs, artificial turf still remains a significantly more cost effective option in the long term.

An analysis conducted by a field turf industry representative comparing the cost differential for an artificial versus natural grass 80,000 square foot field notes this cost disparity. Whereas artificial turf has considerably higher initial installation costs of $320,000 for base preparation and $400,000 for materials, maintenance costs of only $5000 per year significantly drop the long-term price compared to that of a natural grass field with costs of $150,000 for base preparation; $200,000 for materials; and $20,000 annual maintenance costs [6, 22]. Factoring in the significant increase in useable hours afforded by an artificial turf field, the 10-year average cost per hour of use for a turf field is estimated to be $25.74 whereas that of a natural grass field is over 3 times higher at $91.20 [6, 22]. Although these figures were sourced from turf industry representatives with potential for bias to promote the widespread adoption of turf, these analyses provide a general idea of possible financial savings associated with artificial playing surfaces.

1.4 Biomechanical factors

To understand and investigate the injuries associated with playing surface type, we must also understand the biomechanical factors at play that have a role in causing such injuries. At a base level, these factors can be split into two groups - intrinsic factors and extrinsic factors. Intrinsic factors pertain to the athlete and include body weight, velocity, acceleration, deceleration, angle of the athlete's foot and height before contact. Extrinsic factors pertain to variables outside of the athlete including cleat or shoe design, type of playing surface, and environmental aspects [6, 8]. Physics principles also play a role in athlete risk and safety through concepts such as coefficient of friction (COF), coefficient of release, coefficient of restitution and associated G-max value, and rotational stiffness (**Table 1**) [6, 8, 14, 24]. These principles and their impact on the athlete exist, for the most part, in the interaction between the playing surface and the athlete's footwear.

Athlete shoe or cleat choice plays a critical role in determining the biomechanical characteristics involved between the playing surface and their feet. As a general rule, cleats of any type exhibit higher COF, coefficient of release, and peak torque than their shoe counterparts when on an artificial turf surface [6, 27–31]. This concept is also applicable on grass surfaces, although the COF, coefficient of release, and peak torque values are decreased for each respective shoe type [28, 32, 33]. Comparatively, turf shoes, specifically designed to only be worn on old generation carpet-like turf, exhibit the highest COF and coefficient of release of any shoe-surface combination [34]. Longer length and larger diameter spikes on cleat bottoms also produce higher friction rates, torque rates, and rotational stiffness than cleats with shorter or narrower spikes [23]. Friction and torque are also further influenced by cleat layout. Cleat layouts with a higher concentration of spikes on forefoot exhibit higher torques on average compared to designs with more spikes on the hindfoot [35]. Aside from the cleat layout, cleat sole stiffness may also play an important role in athlete safety and performance. This role is currently poorly understood, as different studies have demonstrated both beneficial and adverse effects related to cleat sole stiffness with regard to injury risk [33, 36, 37]. These contradicting results are likely due to specific characteristics pertaining to specific athletes, sports, and playing surfaces [38].

Exogenous factors such as athlete weight, weather, and surface type may further alter the foot-playing surface relationship. A prior study has demonstrated that compressive load correlates with COF, coefficient of release, and rotational stiffness regardless of shoe type [39]. This result points to greater torques being generated by larger athletes that produce higher compressive loads and could have significance in injury rates pertaining to a particular sport with larger average athlete body size [34, 39]. Field conditions and surface type further complicate this relationship, as wet and slippery fields exhibit lower frictional coefficients compared to the same fields in a dry state. Similarly, artificial turf fields are typically associated with a higher COF than grass fields, although this may be dependent on field manufacturer and field maintenance practices [40, 41]. Furthermore, objects or debris such as twigs, cleat wraps, mud, or snow obscuring the cleat spikes and thus interrupting the cleat-surface interaction can drastically decrease frictional forces [27].

As a whole, the shoe-surface interface represents a highly dynamic relationship that involves multiple factors including the athlete, shoe, and surface itself, which aggregate to establish the frictional and torque forces incurred by the athlete at each moment of competition. Field designers choosing field materials and athletes choosing cleat designs must weigh the impact of their choices between their athletic performance and risk of injury. Increased shoe-surface friction is positively related to enhanced player performance but also increases the likelihood of injury due to an athlete's foot sticking to the surface and increasing probability of twisting knee or ankle injury [34, 42, 43].

Value	Definition
Coefficient of Friction (COF)	The linear relationship of force required to slide one surface across another. Relates to how much force is required for a planted foot to slip [6, 14]
Coefficient of Release (r)	$r = \frac{Force}{Weight}$ The constant relationship, relating to static friction, that describes the peak torque applied to the shoe-surface interface. Higher values associated with higher rates of injury [6, 23]
Coefficient of Restitution	The ability for a playing surface to absorb shock. This value represents the ratio of maximum deceleration experienced by the athlete during surface impact to the normal rate of gravitational acceleration [6, 24]. This value is especially pertinent to a field's concussion risk.
G-max Value	Represents the shock-absorbing characteristics of a playing surface. As G-max increases the shock absorbing performance of the playing surface decreases. In turf fields specifically, this value increases commensurate with the field's age [25]. Playing surfaces considered safe are limited to a maximum G-max of 200 g [6, 14, 24, 26]
Rotational Stiffness	The rate at which torque develops under rotation in the shoe-playing surface interface [6]

Table 1.
Playing surface biomechanical factors.

2. Injury risk of artificial turf vs. grass playing surfaces

2.1 Overall injury risk

To determine respective injury risk of artificial turf versus natural grass fields, we refer to the systematic review conducted by Gould et al. which investigated the matter. In this review, 53 total studies were included, 24 (45.3%) studied professional athletes with the remaining 29 (54.72%) studying amateurs. 27 (50.94%) examined both practices and games while 25 (47.2%) examined only games, and 1 (1.89%) examined only practices. 29 studies (54.72%) reported on new generation artificial turf, 14 (26.42%) on old-generation turf, and 10 (18.87%) studies did not specify turf generation [44].

Overall injury rate was evaluated in 32 of these studies with 17 (53.13%) finding no difference in injury rate between the playing surfaces, 12 (37.5%) finding a higher rate on artificial turf, and 3 (9.38%) finding a higher injury rate on natural grass though all 3 of these studies were funded by representatives of artificial turf manufacturers [44]. This data is summarized below in **Figure 1**.

Artificial turf generation is an important component in determining overall injury risk. Of the studies that disclosed the turf generation, 8 studies specifically compared early generation artificial turf to natural grass and 6 (75.00%) of these studies found early generation turf to produce higher overall injury rates than their grass counterparts. Comparatively, 18 studies compared new generation artificial turf to natural grass and 13 (72.22%) found no difference in injury rates between the playing surfaces [44]. This discrepancy in study results provides evidence of the safety improvements made by each artificial turf generation, as discussed previously.

The data as a whole suggest that rates of overall injury are similar when comparing natural grass to new generation artificial turf. However new generation turf is associated with higher rates of specific injuries for specific athlete populations, which will be discussed further in subsequent sections. Early generation artificial turf is associated with higher overall injury rates for most athletes, but these playing surfaces are now largely obsolete in North America.

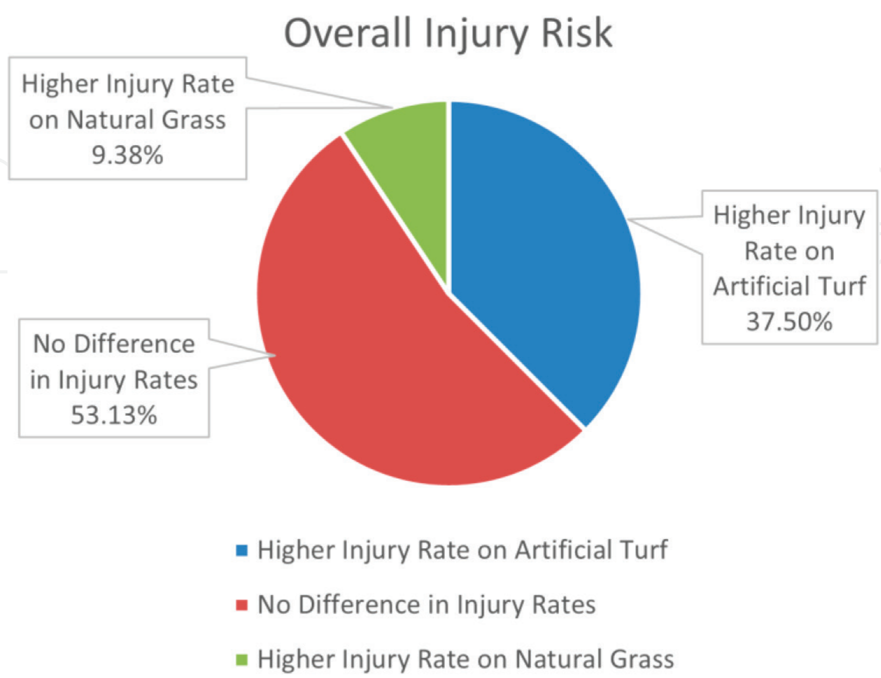

Figure 1.
Comparison of overall injury risk on artificial turf vs. natural grass.

2.2 Hip injury risk

Hip injury rate was evaluated in 13 studies with 11 (84.62%) finding no difference in hip injury rate between playing surfaces, 2 (15.38%) finding higher rates of injury on natural grass, and 0 studies finding higher rates of injury on artificial turf [44]. These results are summarized in **Figure 2** below. No studies examined injury rates on old generation artificial turf [44].

These results follow the trend of the overall injury rate in that the majority of studies find equivalent injury rates, in this case specifically pertaining to the hip, between modern 3rd generation artificial turf and natural grass fields.

2.3 Knee injury risk

Knee injury rate was evaluated in 32 studies with 19 (59.38%) finding no difference in injury rates between playing surface, 8 (25.00%) finding higher rates of injury on artificial turf, and 5 (15.63%) finding higher rates of knee injury on grass fields [44]. This data is summarized in **Figure 3**. Compared by artificial turf generation, 14/19 (73.68%) studies analyzing new generation turf found no difference in injury rates compared to grass while 4/7 (57.14%) studies analyzing old generation turf found an increased rate of knee injury on artificial surfaces [44].

Differences arose when comparing different sports to knee injury rates on each respective playing surface. Among studies involving soccer athletes, 14/16 (87.50%) found no difference between the playing surfaces. Comparatively, 8/14 (57.14%) studies examining American football found a higher rate of knee injury on artificial fields compared to grass [44]. Interestingly, 3 of the studies examining American football

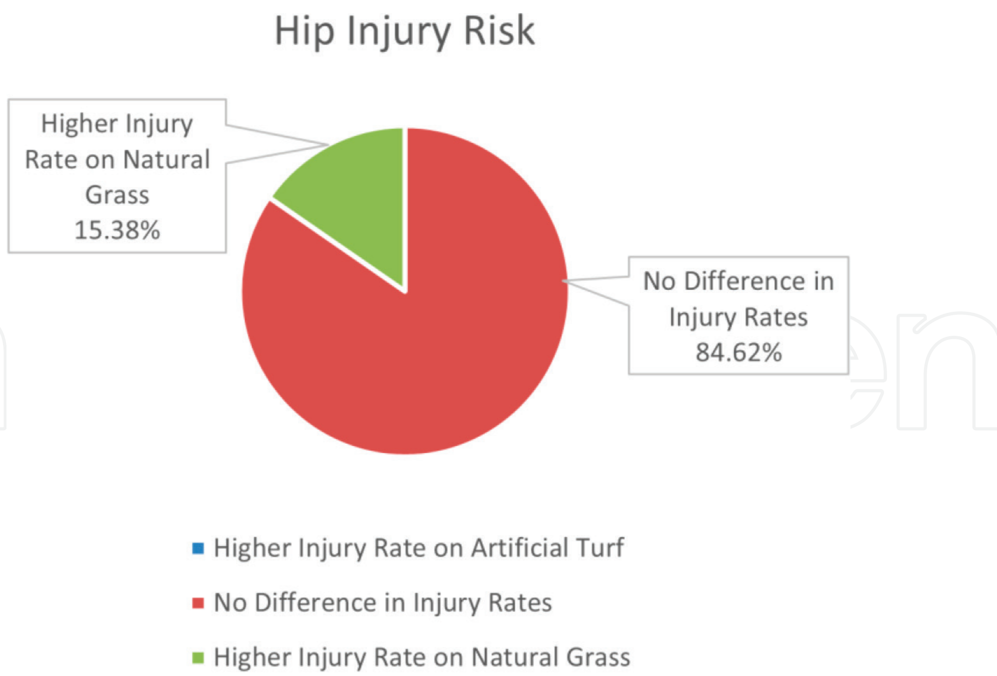

Figure 2.
Comparison of hip injury risk on artificial turf vs. natural grass.

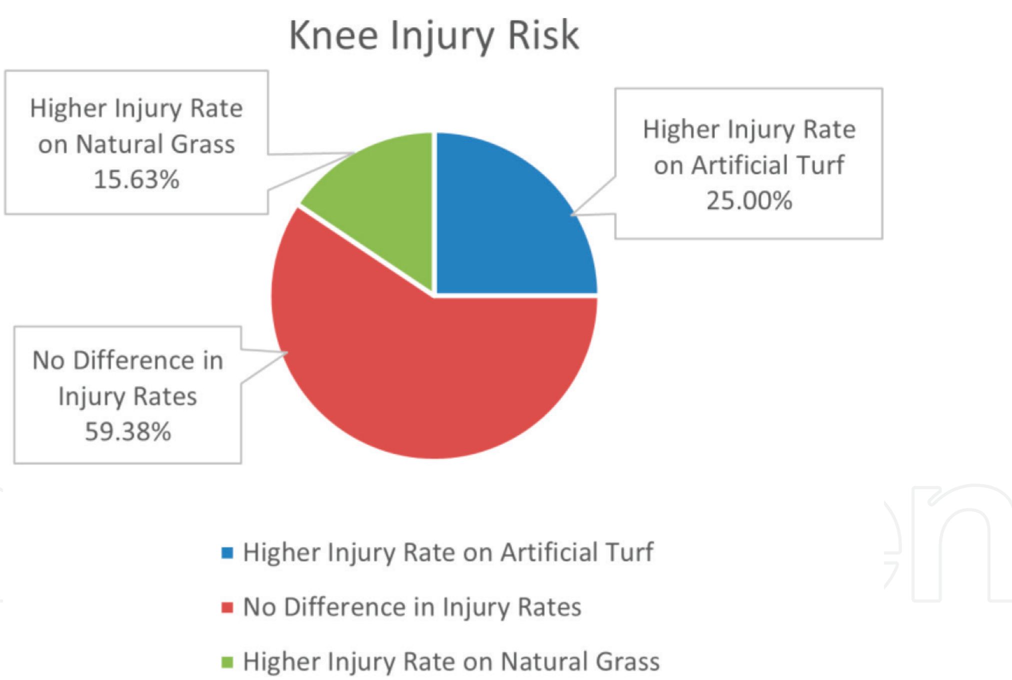

Figure 3.
Comparison of knee injury risk on artificial turf vs. natural grass.

involved new generation turf and still found a higher injury rate on the artificial surface compared to grass and all examined collegiate or professional American football players. This result stands in direct contrast to analyses covered in prior sections that showed no increased injury risk with modern turf designs. This finding may point to unknown factors that predispose elite American football players to higher knee injury risks on modern artificial turf surfaces that are not seen with other athlete types.

A possible explanation for American football players' elevated risk of knee injury follows the relationship between athlete size, applied force, and frictional coefficients. Elite American football players are typically large athletes with the average NFL cornerback weighing 193 pounds and linemen weighing 315 pounds or more [45]. Elite soccer players, in comparison, are notably smaller in stature. Measured at the 2018 FIFA World Cup, the lightest player in attendance weighed 130 pounds, the heaviest player weighed 218 pounds, and the average of the 736 players in attendance was 170 pounds [46]. This discrepancy in average athlete size may correlate to the differences in observed injury rates when viewed from a biomechanical perspective [39]. Frictional coefficients and peak torque correlate positively to applied force and thus increase in proportion to athlete size [39]. Larger football players would likely experience higher COF and torque than their smaller soccer counterparts, which could predispose them to knee injuries and therefore contribute to our described findings.

2.4 Foot and ankle injury risk

Foot and Ankle injury risk was evaluated in 25 total studies with 12 (48.00%) finding higher injury rates on artificial turf, 10 (40.00%) finding no difference in injury rates, and 3 (12.00%) finding higher injury rates on natural grass [44].

19 studies examined new-generation turf while 4 examined old generation turf. Of these studies, 9/19 (47.37%) new generation turf studies and 3/4 (75.00%) old generation turf studies found higher rates of foot and ankle injury on artificial turf compared to natural grass. This suggests that foot and ankle injury risk for all athletes on artificial turf is at least equivalent to and likely higher than rates on natural grass fields. This result is likely caused by higher COF and torque generation associated with artificial turf and is consistent with prior reviews of the topic (**Figure 4**) [44, 47–49].

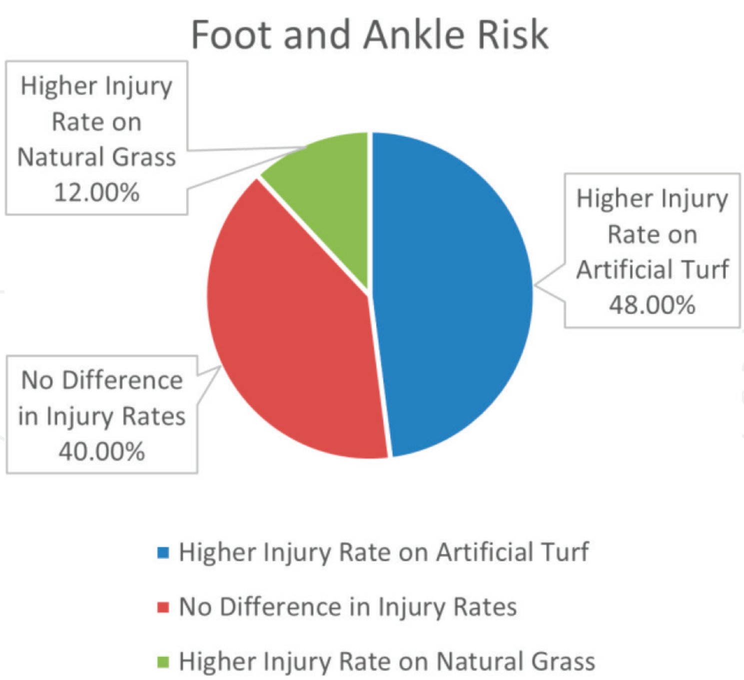

Figure 4.
Comparison of foot and ankle injury risk on artificial turf vs. natural grass.

2.5 Concussion and head injury risk

Sports-related concussion has recently become a relevant and popular research topic, with over 990 studies published in 2021 alone. Major American professional sports organizations have been at the forefront of concussion research funding and protocols, as the National Football League pledged 100 million dollars to research in 2016, and U.S. Soccer is actively testing concussion rule changes through August 2022 [50, 51]. Although there is no universal pathophysiologic definition for a concussion, it is caused by traumatic force to the head and results in immediate symptoms [52]. Therefore, variation in playing surface between artificial turf and natural grass is a logical factor to consider when determining concussion risk, particularly among contact sports where collision with playing surface may occur frequently.

A recent systematic review examined the rate ratio (RR)—ratio of the rate of injury per 1000 match playing hours on artificial turf divided by the rate of injury per 1000 match playing hours on natural grass—in soccer, American football, and rugby (**Table 2**) [53]. A rate ratio less than 1 indicates that there is a lower risk of concussion or head injury on artificial turf, whereas a rate ratio greater than 1 indicates that there is a greater risk of concussion or head injury on artificial turf. After examination of 69 observational studies to determine if they met inclusion criteria, there were a total of 12 studies published between 2004 and 2018 analyzed. Additional meta-analysis considered the subgroups of gender (male or female) and type of contact sport (soccer, American football, or rugby).

When data from all competitive contact sports is considered together, there is a lower rate of concussion or head injury on artificial turf compared to natural grass (RR = 0.89, 95% CI 0.77–1.04) [53]. In the eight studies that considered concussion only, the decreased rate of concussion on artificial turf was even more drastic (RR = 0.72, 95% CI 0.58–0.89) [53]. Together, these findings suggest that competitive contact sports on artificial turf are correlated with a reduced rate of concussion or head injury. However, it is important to consider differences in gender and sport type. For example, there was no difference in the rate of concussion or head injury on artificial turf compared to natural grass among female athletes (RR = 1.09, 95% CI 0.80–1.48) [53]. Moreover, both American football and rugby demonstrated a decreased risk of head injury or concussion on artificial turf compared to natural grass (RR = 0.72, 95% CI 0.54–0.96 and RR = 0.56, 95% CI 0.35–0.88 respectively), but soccer showed no statistical difference in rate of concussion or head injury between turf and grass (RR = 1.06, 95% CI 0.88–1.27) [53]. Whereas American football, rugby, and soccer are all considered contact sports, these data suggest that there may be more nuance in distinguishing head injury risk between contact sports. Grouping together soccer with American football and rugby for study may be problematic, as both American football and rugby regularly include violent collisions as part of the game. Although variation in the type of artificial turf should also be considered, a recent study analyzed injuries in 658 high school varsity football games and found no difference in concussion rate between artificial turf with a pad underlayer versus turf types without a pad underlayer [54].

The association of artificial turf with a reduced risk of concussion is still debated in the literature. In a survey of certified athletic trainers representing 17,459 high school and college football players, there was a disproportionately high rate of concussion and an increased risk of severe concussion among players on artificial turf compared to natural grass [55]. While less than 10% of athlete exposures were on artificial turf, almost 18% of concussions occurred on turf [55]. Moreover, 22% of head contacts on turf resulted in grade II concussions, compared to only 9% on grass, suggesting that turf-related concussions may be more severe than those occurring on grass [55]. An increased potential for

Total Number of Studies (concussion and head injury)	12
Total Number of Studies (concussion only)	8
Types of Sports	Soccer (8), American Football (2), Rugby (2)
Time Range	2004–2018
Overall Rate Ratio (concussion and head injury)	0.89, 95% CI 0.77–1.04
Overall Rate Ratio (concussion only)	0.72, 95% CI 0.58–0.89

Table 2.
Comparison of concussion and head injury risk on artificial turf vs. natural grass.

concussion on turf is supported by biomechanical factors as well, as some studies have identified higher rates of accelerometer deceleration and reduced impact attenuation on artificial turf (2558 m/s^2) compared to natural grass surfaces (2411 m/s^2) [56]. However, it is important to consider that these results are limited by the publication date of the study, as there have been significant advances in the technology of artificial turf in the last 22 years. This may influence the results toward a higher concussion rate on turf.

It is important to note that these conclusions regarding concussion and head injury are also limited by several other variables. In some sports and competitive environments, there have been substantial changes to the culture of head injury-reporting between 2000 and 2018. The type, maintenance, and temperature of both artificial turf and natural grass were also not accounted for in these study designs. Additionally, there were no studies considering American football at the professional level, so these results may not be applicable to the highest-level athletes. Finally, reported concussions may not be a result of playing surface type, as contact with the ball or other players may also result in head injury. Altogether, the most recent data suggest a greater risk of concussion on natural grass than artificial turf, but further research is warranted to draw a definitive conclusion on this topic.

3. Injury prevention strategies

3.1 Athlete-focused injury prevenion

Injury prevention is a multifactorial issue, as decreasing one category of injury risk can increase risk in other categories. This is seen with the injuries pertaining mostly to musculoskeletal categories versus surface contact injuries such as skin abrasions. Musculoskeletal injuries typically occur due to excess torque causing a locking effect on the foot [29–31, 42]. Surface contact injuries relate more to the opposite scenario in which too little grip on the field results in slipping and sliding on the surface. In this way, increasing or decreasing field friction in an attempt to decrease the rate of one type of injury may increase the incidence of a different type of injury.

Due to this scenario, a tradeoff must be considered. Athlete-focused strategies employed to decrease the rate of musculoskeletal injuries may include using cleat designs that minimize the torque placed on the lower extremities, such as cleats with spikes equally weighted in the forefoot and hindfoot or spike designs that decrease peak torque generation [30, 35]. Strategies to decrease surface contact injuries could include avoiding the use of cleat covers or any material that disrupts the shoe-surface interaction, as this can increase the risk of slipping during running and cutting movements [27, 42].

3.2 Playing surface-focused injury prevention

Injury prevention strategies focused on field design and maintenance must consider the same trade-offs described above. In general, field maintenance should be a primary focus to keep the playing surface as consistent as possible, so that athletes interact with the same surface characteristics every time. This consistency promotes both athletic performance and safety, as athletes can focus more on their sport and less on the field itself. This effect is magnified if field maintenance is lacking, as athletes are forced to play on foreign surfaces with unknown friction coefficients or, even worse, fields with different friction rates in different areas due to irregular maintenance practices.

To target specific injury rates, the strategies are similar to those discussed previously regarding augmenting specific physics principles. As a general rule, increasing field frictional coefficients will decrease field surface contact injury risk due to increased grip. However, joint injury risk may be increased in this scenario due to foot and lower limb trapping on the turf surface [27, 35, 42].

A unique factor in playing surface-focused injury prevention is the ability to protect against head and concussion injury risk. This is again accomplished with regular field maintenance, but with a focus on maintaining proper G-max values related to a field's coefficient of restitution [6, 14, 25, 26]. A safe value is typically considered below 200 G and acts as an effective way to increase athlete safety, without requiring the athlete to utilize additional equipment such as a helmet or head padding [24].

Weather changes also play a role in artificial surface properties and injury prevention, although their input is more difficult to control or mitigate. These changes may include extreme heat or cold as well as changing surface conditions with varying degrees of moisture. Depending on air conditions, artificial turf surface temperatures can be over 35 degrees Fahrenheit higher than those of a comparable natural grass field [57, 58]. Without proper preparation, such temperatures can result in diminished athletic performance and the potential for heat-related illness such as heat stroke or heat exhaustion [59]. In freezing conditions, the compacted soil sublayer in artificial turf can freeze resulting in a significantly harder surface which can increase surface contact injuries and concussions [60]. As discussed previously, environmental moisture also effects surface conditions through decreasing frictional coefficients and thus altering the foot-surface interface [27]. Some options to mitigate these concerns include indoor stadiums to maintain climate control or heated subsurface coils to minimize freeze effects [20, 61, 62].

3.3 Exercise strategies for injury prevention

Evidence-based exercise strategies allow physicians, athletic trainers, and other medical personnel to directly augment athletes' physical preparation in order to reduce the risk of injury. The FIFA 11+ Injury Prevention Program is an example of such a system that allows for medical personnel to advocate on behalf of their athletes [63, 64]. FIFA 11+ consists of a workout and warmup routine for athletes to complete several times a week, with the intention of better preparing their bodies for athletic competition and decreasing injuries. In trials, implementation of the routine was associated with a 30% reduction in non-contact injury rates among soccer athletes [63]. Such a program vetted by medical staff and supported by quantitative analysis provides a robust tool for team physicians to protect against common sports-associated injuries in a relatively straightforward and inexpensive manner. In the authors' opinion, the successful implementation of these types of programs should be a primary focus in the future. Whereas proven programs such as FIFA 11+ exist and are readily available, successfully convincing athletes to use them properly continues to be an issue. Studies of large athlete populations have found that as much as 89.3% of such populations use stretching for recovery but only 49.9% utilize such practices for pre-exercise routines, which account for the largest impact in injury prevention [65]. Maximizing the utilization of pre-exercise stretching and warmup routines would be expected to decrease the incidence of sports-related injuries and promote athlete safety moving forward.

4. Sources of bias

The validity of cost-effectiveness data and some injury studies have been impacted by industry bias and funding of private research. This presents in the form of industry-generated cost figures, which may be considered accurate in general, although the cost/benefit ratio between artificial turf and grass may be inflated to push consumers toward artificial playing surfaces. Similarly, 3 of the injury risk studies discussed in this chapter received direct funding from the artificial turf industry, and these studies consistently contradicted the majority of existing data, which does suggest some degree of study design bias in relation to funding sources. These potential biases manifested in the overall injury risk comparison, hip injury risk comparison, and foot and ankle injury risk comparison between artificial turf and natural grass [44]. Industry representatives have a vested interest in such studies, due to the financial opportunities afforded with positive research results in favor of artificial turf. A conscious effort should be made to remain aware of these studies and interpret the results in the context of these potential sources of bias.

5. Future research directions

Further research should be conducted on the biomechanical differences between modern generation turf and natural grass. Many studies included in this chapter compared early generations of artificial turf to natural grass. These investigations, if conducted again using solely modern artificial turf that mimics natural grass characteristics to a greater degree, may have found different results and more similarities between the two surfaces. Cleat design pertaining to sole stiffness should also be evaluated. At present, data in this area of study is ambiguous due to conflicting reports and should be further investigated to find the relationship between cleat stiffness, athletic performance, and injury risk [36, 37]. In addition, further studies are needed to address the gaps of understanding related to specific factors and how they interact with injury rates. Such studies may include the investigation of other sports such as field hockey and lacrosse, body mass, the use of headgear and helmets, level of athletic competition, and upper extremity injury rates. At present, comparative data in these areas are lacking and would certainly benefit from future study.

6. Conclusion

The comparison of artificial turf and natural grass suggests that injury rates are equivalent in most cases. Notable exceptions include higher rates of foot and ankle injuries in general, as well as higher knee injury rates among elite-level American football athletes, on artificial playing surfaces [44]. In contrast, concussion rates were found to be lower on artificial turf compared to natural grass. These data provide a strong indication of the importance of artificial field maintenance (specifically pertaining to G-max values) to maximize player protection and minimize the risk of field-related head injury [3, 6, 14, 20, 26]. Financial considerations suggest that artificial turf is an outstanding option for many athletic organizations, due to its low maintenance costs and higher degree of usability. Artificial fields may host a wide variety of sports that can share a single field, with a greater number of hours of use per year compared to natural grass fields [6, 22]. These factors must be weighed against the potential benefits of grass including lower musculoskeletal injury rates and an overwhelming athlete preference for a well-maintained natural grass surface, with surveys conducted by the National Football League Players Association (NFLPA) demonstrating that 69–72% of professional football players prefer natural grass to artificial turf [66–68]. Overall, the authors suggest that the use of artificial turf should be considered in organizations without adequate funding to support consistent, year-round professional grass groundskeeping. Alternatively, the authors advocate for the use of natural grass in well-funded athletic organizations (e.g. collegiate, professional), which possess appropriate funding to support professional maintenance protocols.

Conflict of interest

The authors declare no conflict of interest.

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