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Review Article

Cleat-surface Interface and Lower Extremity Injuries

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Abstract

Non-contact injuries with playing surfaces occurring from applied player impact and frictional forces are a major source of lower extremity injuries in competitive sports. Artificial playing surfaces are a common alternative to natural grass surfaces; however, these surfaces are associated with player injury as well. The purpose of this manuscript is to explore the existing literature on the relationship between cleat surface interface and lower extremity injuries in athletes and the importance of proper playing surface conditions alongside proper cleat selection to optimize injury prevention and athletic performance. As artificial turf has become more advanced, studies have shown the rates of lower extremity injuries of the knee, ankle, and foot have decreased to be more similar to the rate of injury on natural grass. However, foot and ankle injury rates remain significantly higher on artificial turf. Furthermore, certain studies continue to demonstrate an increased rate of knee injuries in football players, suggesting that significant performance differences still exist between artificial turf and natural grass. Future studies warrant focusing on ways to improve the cleat-surface interface of new-generation turf, emphasizing proper cleat selection, and playing surface conditions for injury prevention thus optimizing athletic performance.

Introduction

Lower extremity injuries are common in a variety of competitive sports and are a significant concern among athletes. With increasing rates of athletic participation comes increasing rates of injury, therefore need for injury prevention is pivotal [1,2]. Player safety can be affected by the surface on which they are playing and the type of shoes they are wearing. Non-contact injuries, which can occur due to impact or frictional forces applied when an athlete comes in contact with the playing surface can be quite frustrating for athletes. Artificial playing surfaces have become a common alternative to natural grass and were created to increase the durability and versatility of an athlete's playing surface. Astroturf is composed of monofilament knitted nylon fibers and was the first synthetic playing surface developed in the 1960s. These surfaces initially lacked padding, causing turf burn and high bounce due to lack of impact of absorption, therefore shock absorbing pads were added to decrease friction [1]. In the 1970s, second-generation playing surfaces with fibers made of longer, softer polyethylene spaced further apart were developed that were softer and more natural for play [3]. In the 1990s, third-generation artificial surfaces (FieldTurf) emerged, which more closely replicated natural grass with increased fiber length and density, including a base layer of sand and rubberized particles [4,5]. However, after a rash of injuries that were anecdotally attributed to artificial turf, starting in the 1970s, multiple studies focused on examining the impact of the cleat-surface interface on sports injuries. These studies identified the interaction between an athlete's cleats and the playing surface as a critical factor affecting biomechanics, traction, stability, and force distribution, all of which can significantly increase the risk of injury [6]. This chapter delves into the existing literature on the relationship between cleat surface interface, specifically natural surface vs. artificial turf, and lower extremity injuries in athletes, highlighting the importance of proper cleat selection and playing surface conditions for injury prevention and optimization of athletic performance.

Biomechanics

The biomechanics of the cleat-surface interface plays a crucial role in an athlete's performance and injury risk [7]. One must consider the type of material and interactions of the two surfaces that come in contact with athletes: the playing surface and the cleat. Based on the structure, mechanics, and manipulation of the two surfaces, the same mode of non-contact insult may lead to different injury patterns depending on the interactions at play. Injuries can be due to 1) intrinsic factors including endurance, ligamentous stability, body weight, velocity, acceleration, deceleration, foot angle, and height before contact, or 2) extrinsic factors including protective equipment, environmental factors, and playing surfaces [5]. It is well demonstrated that factors that influence torque at the shoe-surface interface include the type of surface [8], the material of the heel and toe of the playing shoe, and the weight and stance of the player [9]. The coefficient of friction varies with each playing surface as it is a linear relationship between the force required to slide one surface against another. Another important factor to consider at this interface is the coefficient of release, which is based on the peak torque that develops at the shoe-surface interface and represents the shock absorbance ability of a surface [10,11]. The rate at which torque develops under rotation at the interface is known as rotational stiffness [12]. Past studies have shown that there is a direct relationship between the difference in frictional properties of these two contact surfaces and the incidence of injury, specifically with low frictional resistance causing slipping and excessive frictional resistance causing sticking, both resulting in injury [13]. A study by Cawley, et al. analyzed the interaction between different types of playing surfaces (natural grass and synthetic turf) and athletic shoes (turf, court, molded cleat, or traditional cleat), specifically measuring translational resistance and rotational torque of the shoe-surface interface. This study found that natural grass generated higher peak moments than turf for cleated shoes, suggesting a significant difference between surfaces [14]. Based on the aforementioned studies, we now know that players experience different rotational torque on different surfaces.

Cleat-surface rotational traction (the traction that resists rotation of the shoe during pivoting movements) has also been shown to have an impact on athlete performance and rate of injury. In the past, we have seen that artificial surfaces with infill, (sand or rubber pellets that simulate the dirt in natural grass) have greater rotational traction than in natural grass [15,16]. However, as technology has improved over time, more recent studies show that third-generation turf traction coefficients are not significantly higher and should not be considered hazardous with regard to excessive traction. This suggests that although new-generation surfaces and cleats have addressed the drawbacks of artificial turf concerning traction, they have yet to solve the disparities in rotational torque. Surfaces, lack the ability to release a cleat in a potentially injurious overload scenario and consequently generate significantly higher shear force and torque on the knee, ankle, and foot leading to injury. For example, football turf with sand/rubber infill has significantly higher rotational torque than natural grass [17]. This means that when a player maneuvers on an artificial surface, they experience much greater rotational force translated through their lower extremity than they would on a natural grass surface. Additionally, traditional artificial turfs have the ability to deform and can control peak torque because cleats may not be fully engaged [10]. Torque also changes with cleat type: blade cleats are associated with significantly higher rotational torques than studs on both natural grass and turf with infill [17]. These higher rotational torques between the sole of the shoe and the playing surface have been correlated with torsional injuries of the lower limb and knee.

In regards to the shoe, the cleat configuration, number and size of cleats, and sole and cleat material are especially of interest [3,5]. For example, shoes with more cleats on the heel than forefoot have lower torques [9]. Furthermore, a study by Queen et al. showed that small cleats had the lowest plantar pressures on the foot, suggesting that small cleats could potentially decrease the incidence of metatarsal stress fractures [18,19].

Knee injuries

These biomechanical differences in the cleat-surface interface may impact the occurrence of knee injuries during competition. Approximately 70% of ACL sports injuries occur in a non-contact manner including rapid changing of direction, falls, or sudden stops while running. The force that stresses the knee in a plane that does not coincide with normal joint motion when the foot is fixed leads to injury if the force is greater than the elastic integrity of the structure experiencing stress [11]. Specifically, studies have shown that playing on surfaces that cause increased sliding conditions leads to less knee pain and that twisting injuries to the knee are more directly a result of resistance to rotation rather than excessive foot fixation [14]. Knee injuries are primarily ligamentous and vary from minor sprains to season-ending tears that require operative management. Previous studies looking at older-generation artificial turf (first and second) reported a higher knee injury rate compared with natural grass [20]. This correlates with cadaver models showing that cleats on natural grass produced less strain in the Anterior Collateral Ligament (ACL) in response to an axial load and internal rotation than artificial turf [21]. However, more recent studies show that with new-generation turf, there's no significant difference in knee injury rates [22,23]. In soccer players, studies have found no difference in injury rates between playing surfaces [20]. One exception, interestingly, is those conducted among high-level football players, both collegiate and professional, that did find an increase in knee injuries in new-generation turf compared to natural grass. This suggests that football players are more likely to sustain a knee injury on new-generation artificial turf compared to natural grass and could be explained by planting and pivoting movements specific to football [24-26].

Foot and ankle injuries

Foot and ankle injuries sustained in sports commonly encompass ligament or tendon injuries as well as fractures. It has been demonstrated that lesser toe areas on artificial turf and higher relative loads on the central forefoot could lead to increased foot inversion leading to potential lateral ankle ligament injuries [27-29]. In contrast to knee injuries, where the data is more mixed, literature over time has consistently proven an increased rate of foot and ankle injuries sustained on artificial turf compared to natural grass [20,23,30,31]. While injuries have decreased as advancements have been made in artificial turf, the disparities in injury rates compared to natural grass have persisted. These studies found no significant differences between females and males in the injuries. In a meta-analysis of the articles published between 1972 and 2020 that comprehensively examined the risk of overall injuries across all artificial turf and natural grass, a higher proportion of foot and ankle injuries were on artificial turf compared to natural grass [20]. Based on these findings, it appears the biomechanical differences between artificial turf and the shoe-surface interface influence foot and ankle injuries.

Authors' perspective and recommendations

The author's current sports medicine practice involves the care of athletes both on and off the field. Based on current published data along with first-hand experience, patients are counseled on the decreased injury risk with appropriate cleat-surface interface. It is critical to match the aggressiveness of the cleat with the quality of the grass or turf, the length of the grass or turf, and the weather conditions on the field. To avoid injuries, the cleat should not be overly aggressive for the surface. Sport-specific standard cleats should be worn on grass surfaces in most instances. There are some very high-quality fields where the grass is shorter and softer, therefore, turf shoes may potentially be worn on that field if it is dry. On a wet and muddy surface, more aggressive cleats should be used to allow the foot to plant safely on the ground and avoid sliding which could cause potential injuries to the knee and ankle. The authors' perspective on indoor short turf surfaces would be to use either flat sport-specific footwear or turf shoes. It is important to take the time with athletes, their parents, and coaches to review the shoes (1-3 pairs, cleats, turfs, indoor flat footwear, trainers, etc.) that they will need for their season.

Conclusion

The introduction of artificial turf and its widespread popularity increased lower extremity injuries in competitive athletes. As technology improved and new generation artificial turf developed, the rates of lower extremity injuries of the knee, ankle, and foot have decreased to be more similar to the rate of injury on natural grass, however, foot and ankle injury rates remain significantly higher on artificial turf. Certain studies still show an increased rate of knee injuries in football players, suggesting that significant performance differences still exist between artificial turf and natural grass. This chapter highlighted the biomechanical differences in the cleat-surface interface between artificial and natural grass. More work is to be done to better simulate natural grass with artificial turf. Future research should focus on ways to improve the cleat-surface interface of new-generation turf, emphasizing proper cleat selection and playing surface conditions for injury prevention and optimizing athletic performance.

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