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The Effects of Artificial Turf on the Performance of Soccer Players and Evaluating the Risk Factors Compared to Natural Grass

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Abstract

The global popularity of soccer has led to widespread tendency towards this sport. Because of the convenience of using artificial surfaces, the rapid growth of using these surfaces led to concerns about the declining performance of the players. The aim of this comprehensive review is to study the difference between the performance of players on different playing surfaces and the risk factors for use of artificial turf compared to natural grass. A literature search of valid scientific databases such as Science Direct, PubMed and Jstor by searching keywords was performed. In total, more than 6,000 articles were retrieved. After the preliminary selection process, the final analysis was performed on a total of 76 articles.

Results: Mechanical properties of artificial grass have a significant effect on the average time of sprinting, the best time of sprinting and maximum speed. The numbers of sliding tackles on artificial turf were lower compared to natural grass. Artificial turfs exposed hardness, elasticity and high friction. The characteristics of artificial grass have changed over time and increased the probability of injuries. There was no significant difference between the overall risks of acute injuries in soccer players performing on artificial turf compared to natural grass. The amateur, young and female soccer players had rated lower injuries on artificial grass. But the rate of injuries in elite soccer players were higher on artificial grass and hence they are not found of playing on such playing surfaces.

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Introduction

Soccer is a very popular sport all over the world with various actions such as change of direction, starts, stops, jumps and kicks[1]. The number of people who played soccer in 2007 was 265 millions2. Since more than four percent of the world's population engage in this sport3, providing appropriate facilities is crucial. Proper sporting surfaces are among the most important equipment. Various factors, including the shock absorbance, friction, and the energy loss are considered for selection of playing surfaces. Among these factors, the shock absorbance is considered as a key factor in preventing injuries[4]. In recent years, artificial grass has become a trusted alternative for natural grass for many sports, especially in soccer. Despite the fact that different sports often have unique requirements, Complex system of artificial turfs has proved to be well able to catch up with the special requirements of various sports[5].

The use of third generation artificial grass is officially accepted by FIFA and UEFA in international tournaments. However, there are concerns that some of the mechanical properties of artificial sports-surfaces may be associated with acute and chronic sports injuries[6,7]. Potential mechanisms for different patterns of injuries on artificial turf compared to natural grass include: torque, rotational stiffness, interaction of surface and shoes, shock absorption[9]. In this review article, the articles are sorted in the following areas: artificial grass surface infrastructure, user security and the player's performance[8].

The use of artificial turf has provided different operating conditions compared to natural grass such as speeding up and increasing the bounces of the ball and various impacts on player movement pattern. The performance qualities of soccer players during exercise and competition on the synthetic turfs are affected by low shock absorbance and high surface temperature. This would lead to injuries, particularly of the lower extremities. The purpose of this study is to review the literature and studies on the impact of artificial turf on the soccer players' performance, the nature of the risk factors and injuries compared to those of natural grass surfaces in order to minimize the injuries and achieve maximum benefits of training and competition on these types of surfaces.

Methods and Materials

Comprehensive search was undertaken from September 2016 to February 2017 through valid scientific databases such as Science Direct, PubMed and Jstor by searching keywords such as "soccer", "playing surface", "artificial turf", "natural grass" and "artificial turf risk factors". Articles published from 1975 to 2016 were selected.. Afterwards, the title and abstracts of articles were reviewed. Non-English articles, repetitive topics, studies on non-human samples, simulation, measurement tools of mechanical properties and articles with the purpose of treatment and rehabilitation were excluded. The selection criteria were as follows: (1) studies comparing artificial and natural turf, (2) articles related to the mechanical properties of artificial surfaces for soccer, and (3) studies of mechanisms or risk factors of injuries on artificial turf and comparison of their rate and nature with those of natural grass. Afterwards, the bibliographies of the selected articles were observed to select and add additional articles that may have not been detected through the preliminary search.

Results

The database search yielded about 6000 articles relevant to the objectives of this article. After the preliminary selection process and addition of further papers based on the bibliography of the initial articles, a total of 76 papers were chosen and reviewed. The process of search, selection and extraction of the papers is depicted in Figure 1.

The literature dedicated to the impact of

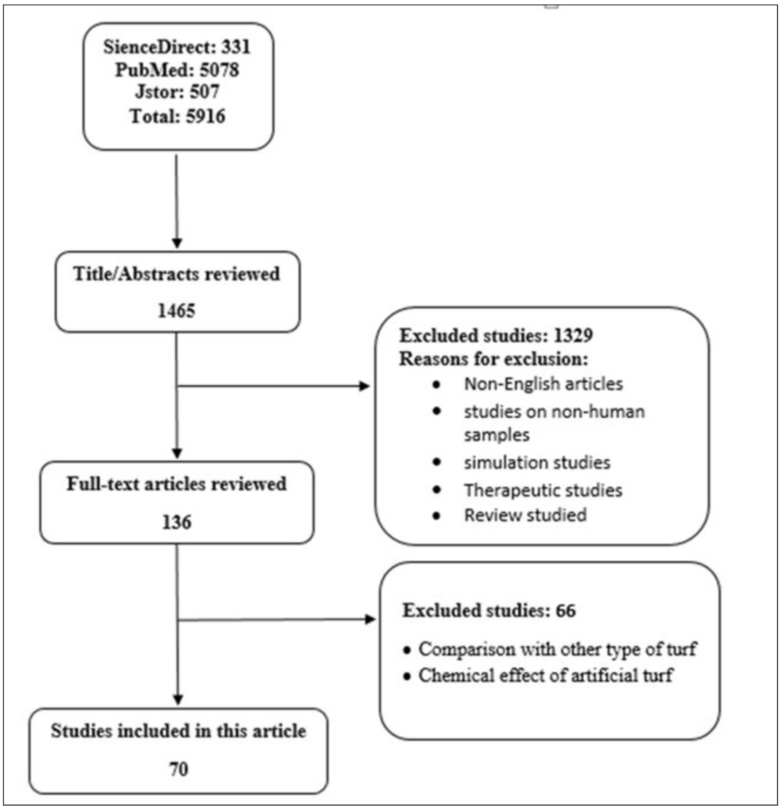

Figure 1. Articles selection process used in this study

artificial grass on the performance of players include investigations on shock absorption, hardness, friction, impacts on the ball (change in the ball's rolling resistance[9] and rebound factor[10]), rotational traction resistance[11], maximum impact[12], movement patterns[13] and technical ability[14]. The risk factors associated with injury on artificial turf can be divided into two groups: internal factors and external factors. The first group is in direct association with the properties of artificial turf and includes hardness, surface traction, infill material, thickness and length of fibers; while the second group includes environmental factors (e.g. weather conditions, grass surface temperatures), factors related to sports equipment (e.g. surface-shoe interaction (shock absorption, traction and friction), and shoe characteristics (height and number of studs). Many studies have investigated the nature and incidence of injury on artificial turf as compared to natural grass.

This study first reviews the literature pertaining to the effect of playing surface on the performance of players, and then assesses the results of articles in relation to the risk factors affecting the incidence of injury on artificial turf.

The impact of artificial turf on the performance of players

Shock absorption and surface hardness

Artificial turf has lower shock absorption than natural grass, so switching the training from natural grass to artificial grass can be uncomfortable and lead to more foot pain in young soccer players[15]. Running, jumping and landing is affected by the hardness of the artificial grass. Furthermore, as time passes, the layers of infill material become compressed[16], and water-induced degradation hardens the shock absorption layers [9]. As Table 1 shows, Fleming *et al* (2013) found that on harder surfaces, players can produce larger peak push-off force and therefore significantly higher plantar-flexion torque. On softer surfaces however, players can make faster changes in acceleration and produce greater force[11]. A survey by Poulos *et al* (2014) on professional soccer players reported that hardness of artificial turf is one of the causes of injury[17], but a study by Rennie *et al* (2016) on the impact of hardness of playing surface on the probability of injuries did not find sufficient evidence in support of this hypothesis[18].

Friction

Friction performs a major role in players' ability to make fast changes in direction, but too much friction can impose excessive force on bones, muscles and joints[19]. Andreasson *et al* (1986) found that the torque generated between the shoe and the playing surface during sudden stops and changes in direction is a cause of injury in the ligaments of knee and ankle. On the artificial turf, this torque depends somewhat on the surface friction force[20]. A study by Bonstingl *et al* (1975) on the torque created on artificial turf found that heavy

Table 1. Summary of studies on the impact of artificial turf on the performance of players

Study	***Subject***	***Level of Performance***	***Methods***	***Results***
Andersson et al *(2008)*	Sex, Age	Elite	Evaluation of movement pattern and technics with Motion Analyzer	no difference in terms of running activities and technical performance; less sliding tackles and more short passes on artificial turf
Clarke et al *(2010)*	72 Male 21 Female	-	SERG impact hammer	As the penetration of boot increases, the traction increase; on artificial turf the stud provided low traction.
Fleming et al *(2013)*	6 different cleat	Elite	Cutting maneuver, sprint and 180º turn, jump-head-land	Frontal plane moments and ground reaction forces were increased in softer and higher traction surfaces.
McGhie et al *(2013)*	16 Men	-	-	Different artificial turfs had different transitional traction. Traction decreased on Long fiber with high thickness infill
Nédélec et al *(2013)*	22 Men	Elite		The reduction in maximum torque of hamstrings immediately, 24 hours and 48 hours after the test was higher on natural grass.
Poulos et al *(2014)*	13 Men	Elite	Cutting maneuver	1. more stiffness, 2. Higher friction, 3. Higher metabolic cost
Sa ́nchez et al *(2014)*	99 Men	Amateur	Conditioning test and Isokinetic	Players feel more comfortable on harder and stiffer systems
Tay et al *(2015)*	18 Men	-	-	Turfs that have no infill have the highest friction, and those with full gravel or rubber infill have equally lower friction

weight players suffer more torque than lighter weight players, and the magnitude of this torque when the foot is in full contact with the ground is 70% more than when only parts of the fingers are in touch with the ground[21].

A study by Tay *et al* (2015) (Table 1) on the effects of infills and fibers of artificial turf on tits friction behavior reported that a foot rotating on the artificial turf either compresses its infills or pulls them toward outer side of the foot; both of these processes elongate the fiber and increase surface friction, which makes the movement of players and the ball more difficult[22]. Villwock *et al* (2009) also agreed with this argument and reported that fiber type and size and amount of infill material have significant impact on the frictional behavior of artificial sports surfaces[22,23]. Orchard (2002) showed that the surface-shoe friction is often positively correlated with surface hardness, dryness, grass cover and fiber density, length of shoe studs, and speed of the game. He stated that the use of surface-shoe traction reduction solutions such as watering and softening the pitch, playing during winter, using natural grass, and wearing shoes with short studs may reduce the likelihood of injury[24].

McLaren et al (2012) studied the performance degradation of artificial turf with age and found that the friction effect is associated with interaction between skin abrasion and ball resistance. He reported that growth of moss and algae on the surface reduces the surface-shoe friction and makes the surface slippery; and that the ball roll distance is affected by bending resistance, friction, and orientation of the fibers[9]. Tay *et al* (2015) reported that artificial sports surfaces that have no infill have the highest friction, and those with full gravel or rubber infill have equally lower friction[22]. In a survey conducted by Poulos *et al* (2014) on professional soccer players, they cited the high friction as the second most important cause of injury on artificial turfs[17].

Traction and rolling resistance

Traction is a key parameter for measuring comfort, performance and risk of injury[25]. Soccer movements require high transitional traction between shoe and surface[26]. Many studies have shown that torque and traction experienced by the lower limb joints are greater on artificial turf than on natural grass[27,28]. Also, a study by Drakos et al (2010) on the effect of shoe-surface interaction on the traction applied on the anterior cruciate ligament (ACL) for four different combinations of artificial grass, natural grass and shoes concluded that the least amount of traction in ACL occurs in combination of cleats and natural grass[28]. Fleming *et al* (2013) showed the surface hardness and rotational traction resistance affect the dynamics of human movement; and that during turning and stopping maneuvers, softer surfaces with higher traction increase the torque of frontal plane as well as ground reaction forces during mid-stance[11]. A biomechanical analysis by McGhie *et al* (2013) on shoe-surface traction on third generation artificial grass found that different types of artificial grass exhibit different translational traction properties. As Table.1 shows, they found that traction of long grass with more infill is more than other types of artificial grass, but in general, all combinations of artificial grass and shoes have a significantly high traction, to which players must get accustomed[29].

A comparison of different types of artificial grass by Sa´nchez *et al* (2014) showed that pitches that have a lower rotational traction (asphalt sub-base without elastic layers) allow players to score a higher total time in the Repeated Sprint Ability test than pitches with average rotational traction (compressed gravel sub-base without elastic layers and compressed gravel sub-base with elastic layers)[30]; however, pitch must also provide adequate translational traction during acceleration, deceleration and fast changes in directions to prevent slipping[31]. Frederick (1993), Shorten *et al* (2003) and Villwock *et al* (2009) also showed that rotational traction is associated with injury and a combination of high translational traction and low rotational traction is desirable for sports surfaces[31-33]. The biomechanical analysis of McGhie (2014) on shock absorption and traction of third-generation artificial turfs also showed that high traction of artificial turfs in comparison to natural grass make the athletes playing on these surfaces more prone to injury[34].

Maximum impact

The ability of a surface to withstand the movements is directly related to its impact absorption properties[32,35]. Theoretically, the thicker is the surface, the greater is the contact time, and so the more distributed is the impact force[34]. Therefore, thickness and amount of infill used in artificial turf affect its impact absorption properties[36,37]. Clarke *et al* (2010) used a mechanical traction measurement tool to evaluate the penetration and traction performance of soccer shoes on natural and artificial grass. The results showed that the third generation artificial turfs have a higher maximum impact force and lower deformation peaks, meaning that they are much harder than natural grass[14]. McGhie (2013) reported that the peak impact during running and stopping maneuvers is significantly higher in recreational synthetic turfs than professional sports turfs. In addition, it was found that the shoes with traditional rounded studs cause a higher peak impact during running and cutting maneuvers than the professional shoes for synthetic turfs, and bladed cleats[12].

Movement patterns and technical ability

A study conducted by Brito *et al* (2012) on movement patterns on several different surfaces reported that distance covered on asphalt is highest and artificial grass holds the second rank by a narrow margin. Also, the number of high-intensity runs on asphalt was higher than artificial turf[38]. Nédélec *et al* (2013) studied the recovery kinetics of physical performance and scores of participants performing certain soccer exercises on natural and artificial grass. The study of physical fitness tests including squat jump, 6-second sprint on non-motorized treadmill, counter-movement jump, and isokinetic eccentric hamstring assessment showed that the reduction in maximum torque of hamstrings immediately, 24 hours and 48 hours after the test was higher on natural grass than on artificial grass. Also, the rate of decline in squat jump performances, 48 hours after the test, was significantly lower on natural grass than on the artificial grass. But there was no significant difference in sprint performances. The results of countermovement jump also showed no significant difference in terms of time and surface interaction, and no difference in terms of fatigue or delay in recovery[39]. Brito *et al* (2012) also reported that the jump performance after playing on artificial turf, asphalt and gravel was lower than before the game; but there was no difference in sprint performance before and after the game[38]. Sa´nchez *et al* (2014) showed that mechanical properties of the pitch have a significant impact on the mean time of sprinting, the best time of sprinting, and the average maximum speed[30].

A study conducted by Strutzenberger *et al* (2014) on the performance of 30 ° and 60 ° cutting maneuvers on third-generation artificial turf and natural grass found less knee valgus and internal rotation on artificial turf, which reflects the reduced risk of knee injury. This data highlights the fact that artificial grass is not worse than natural grass and can potentially reduce the risk of knee injuries. It was also stated that on artificial grass, ankle joint experience increased dorsiflexion and inversion when foot strikes the ground. Another major impact was reported to be the increased ankle inversion and external rotation during the weight acceptance phase[40].

Dragoo *et al* (2010) found that pitch properties can affect the speed and style of play[41]. Andersson *et al* (2008) also evaluated the movement patterns, ball skills and impressions of elite Swedish soccer players in matches played on artificial turf and natural grass. Their results showed no difference in terms of total distance traveled, high intensity runs, number of sprints, standing tackles or heading between matches played on artificial turf and natural grass. However, the number of sliding tackles was higher on natural grass, and the number of short passes and midfield-to-midfield passes was higher on artificial turf[42]. More details in this regard are provided in Table 1.

In a survey conducted using a 0-10 scale (in which 0 represented the absolute superiority of artificial turf, 10 represented the absolute superiority of natural grass, and 5 represented equal quality), male soccer players expressed very negative opinions about artificial grass (8.3) and cited poorer ball control and the need for greater physical effort as its disadvantages. However, female soccer players believed that there is no difference between natural grass and artificial turf in terms of ball control, ball movement and physical effort[42].

Ford *et al* (2006) showed that there is a different between load patterns within the shoe when it is used on natural grass and artificial turf. They gauged the pressure distribution inside the shoes and found that, in comparison to natural grass, artificial turf imposes significantly higher peak pressure in the center of the forefoot but significantly lesser pressure on fingers. Therefore, playing surface has a significant impact on the plantar loading during sports activities[43].

Risk factors associated with the use of artificial turf

Internal risk factors

Internal factors associated with the occurrence of injuries on artificial turf are related to material, installation and maintenance of turf. The difference in turf performance is mainly due to factors such as age and method of installation rather than infill material[44]. A study by Jan-Kieft (2009) on long-term performance of 50 artificial turf pitches showed that as the artificial turfs with rubber infill age, they become harder, their performance worsens, and cause the ball to move faster[45]. McLaren (2014) also reported that as the artificial turfs age their fibers become more fragile; with reduction in height of fibers, the amount of infill material that it can support decreases, so system becomes unsafe and it must then be replaced[10]. It was also found that hard/dry pitches increase the probability of injury[46].

Cheng *et al* (2014) studied the environmental and health impacts of artificial turf and reported that most concerns in regards to artificial turfs is about their filler materials, which are mostly made of scrap rubber. These rubbers can contain large amounts of organic and heavy metal contaminants, which can get evaporated or solved in rainwater, hence threaten the human health as well as environment[47]. This issue was also assessed by Castellano *et al* (2008), who investigated the potential health risks of hazardous materials in artificial grass made of rubber granules. Their results showed that the concentration of aromatic hydrocarbons, PAH and heavy metals in artificial grass is well below the legally allowed values, so exposure to these substances (through inhalation) is not dangerous[47,48].

Iacovell *et al* (2016) reported that the rate of lower extremity injuries on abnormal surfaces is 2.61 times greater than on normal surfaces[49]. A study by Zanetti *et al* (2009) on amateur players reported that infill material affects the ball's rebound, pitch hardness, wear, and fatigue; and that all players preferred the SBR rubber granules44. It was also reported that Ball's rolling is one of the first criteria by which artificial grass fails to meet the standard[50]. Jan-Kieft (2009) showed that the ball rolls faster after seven years passes of the artificial turf's age, but the contributing factors are not fully understood[45].

Stud

For an average player, surface-shoe traction has a correlation with the incidence of injury[24]. Webb *et al* (2014) made a continuous measurement of torque resistance and rotational angle of soccer shoes using tensile and rotational sensors, and then plotted the torque-angle plot. This plot showed a high stiffness region followed by a low stiffness region. In general, the greater was the length of stud, the greater was the stiffness of both regions. The actual foot rotation was found to be much lower than the amount needed to produce peak torque resistance shown in this plot. Stiffness of the first region of the plot was a better indicator for underlying mechanisms of generated traction[25]. In the study of Webb *et al* (2015) on traction mechanism in the third generation artificial turfs, it was found that force increases with the number of studs; and also layout of studs affects the force generation and traction mechanism[26]; and that neither the number of studs nor the height of soccer shoes are associated with the likelihood of injury[25,51]. Müller *et al* (2010) also showed that using unsuitable studs leads to poorer energy distribution and causes the stud pressure to be felt more by the player[52].

Environmental factors

The use of artificial turf can be associated with environmental and health risks, but the complexity of involved chemical compounds make this issue difficult to assess[53]. When exposed to sunlight, surface temperature of artificial grass becomes much higher than that of natural grass, and this may put the athletes' health a risk[54]. Jim (2006) studied the temperature at heights of 150 cm, 50 cm, 15 cm, and at surface and substrate of the turf. The results of that study showed that in sunny days, temperature of artificial turfs get unusually high (the artificial turfs made of polyethylene and black rubber granules had milder results in this respect). It was also found that artificial turf quickly absorbs short-wave and long-wave radiations, which increase its temperature to 70.2°C at surface and to 69.3°C at substrate, while the temperature of natural grass remains below 40 °C. It was concluded that this issue exposes athletes to an intense radiation-energy and heat sensitive environment[55]. Petrass *et al* (2014) also reported that the materials used in infills and shockpads have significant impact on temperature rise of artificial turfs. It was concluded that the sunlight, ambient temperature, and humidity as the only environmental factors affecting the temperature. Therefore, a combination of materials and environmental conditions were recognized as factors affecting the temperature[56].

Although the pitch performance is influenced by the weather, amateur soccer players prefer artificial turf to natural grass, because natural grass is dry and hard during summer, and muddy or frozen in winter. The critical weather conditions for artificial grass are "hot weather" and "rain"[44]. Charalambous *et al* (2015) investigated the effects of temperature of artificial turf on mechanical and kinematic properties of players during landing and acceleration maneuvers. The results showed that difference in temperature has a significant impact on the turf's mechanical properties such as force absorption, energy restitution, rotational resistance, and the height at which head injury occurs. Also, step length and contact time of the initial step after the landing was found to be significantly longer on the warm artificial turf. This study also reported significant differences in the range of motion and joint angular velocity[57]. The study of Alentorn-Geli *et al* (2014) on prevention of ACL injuries in sports found that dry weather conditions could increase the risk of non-traumatic ACL injury among male athletes. They stated that ACL injury among the male athletes have a number of factors, and added that there are limited evidence in support of neuromuscular and biomechanical risk factors, and that the majority of evidences are associated with environmental and anatomical risk factors[58].

Rate and nature of injuries on artificial turfs in comparison to natural grass

From the perspective of players, the ultimate objective of for improvement of playing surfaces should be to maximize performance and comfort and minimize occurrence of injuries. The most common method of assessment of injury on artificial turfs is epidemiologic study, these studies however are time-consuming, have a costly data collection phase, and have to deal with a great number of factors affecting the rate of injury[8]. A summary of studies in relation to prevalence of injuries is presented in Table 2.

Bianco *et al* (2016) studied the prevalence of injuries among young male soccer players playing on artificial turf. This assessment was made for both trainings and competitions and over the course of a soccer season. They reported that of 107 total injuries, 85 occurred during training and 22 occurred during competition[59]. In contrast, the study of Sousa *et al* (2013) on the injuries of amateur soccer players on artificial turf during a soccer season reported that injuries occur more frequently during competition rather than training. But in agreement with the results of Bianco *et al* (2016), hip, knee and ankle were found to be the most injury-prone areas and most frequent treatments were those performed for thigh strain/muscle tear. They found that the majority of injuries (79%)

Table 2. Summary of studies on Rate and nature of injuries

Study	***Subject***	***Level of Performance***	***Training or match***	***Type of injury***	***Incidence (No per 1000 hours)***	
Fuller et al *(2007)*	Sex, Age	college and university football teams	Training	Hip/groin Knee	5.29 2.3 3.2	5.15 2.23 3.48
Fuller et al *(2007)*	Male	college and university football teams	Training	Hip/groin Knee	2.5 3.28 2.88	3 3 2.43
Bjørneboe et al *(2010)*	106 team	professional	Match	Hip/groin Knee	3.6 3 3.1	1.9 2 2.2
Ekstrand et al *(2011)*	Female	Elite	Match	Hip/groin Knee	2.21 3.83 3.24	1.85 3.99 4.45
Ekstrand et al *(2011)*	136 team	Elite	Match	Hip/groin Knee	0.44 0.29 0.15	0.18 0.56 0.76
Soligard et al *(2012)*	Male	Amateur	Match	Hip/groin Knee Ankle	5.2±0.4 5.6±0.3 8.4±0.4	3.2±1 4.6±0.9 4.3±0.8
Almutawa et al *(2014)*	14 team	Elite	Match	Hip/groin Knee	14.2 12.8 8.8	7.4 3.7 14.2
Bianco et al *(2016)*		professional	Training	Hip/groin Knee Ankle/Achilles tendon		0.29 0.22 0.14
Bianco et al *(2016)*	613 male	professional	Match	Hip/groin Knee Ankle/Achilles tendon		0.37 0 0.18
Lanzetti et al *(2016)*	Age 25±5	Elite	Match	Contact Non-contact	3.8 11.4	7.87 10.23

were traumatic, 21% were overuse injuries, and 10% were re-injuries[60].

There have been many studies dedicated to comparing injuries occurred on natural grass and artificial turf (Table 2). Ekstrand *et al* (2011) compared the prevalence and patterns of injury between elite male and female soccer players on artificial turf and natural grass. Their results showed that 71% of injuries were traumatic and 29% were overuse injuries, and showed no significant difference between overuse injuries of males and females and the use of artificial and natural grass. Also, the incidence of acute injury showed no significant difference between artificial and natural grass[61]. Soligard *et al* (2012) found similar results for the risk of acute injury among young male and female soccer players playing on third generation artificial turfs[62]. A study by Lanzetti et al (2016) on the safety of third-generation artificial turf for male elite professional soccer players playing in Italian major league also found equal risks of injury during competition on artificial turf and natural grass[63]. Fuller et al (2007) also compared the prevalence, nature and cause of injuries on natural grass and third-generation artificial turf amongst young male and female soccer players and found similar prevalence among males and females and on natural and artificial grass[64].

Hägglund *et al* (2016) assessed the risk factors for acute knee injuries, particularly in ACL, among young female soccer players. The results of this study showed no difference in injury rates between artificial and natural grass[65]. Bjørneboe *et al* (2010) compared the acute injuries of male soccer players on natural grass and third generation artificial turf and found no significant difference between the area, type, and severity of injury between these types of grass[66]. Kristenson *et al* (2014) also studied the rate of acute injuries in professional soccer players on artificial turf and natural grass and – like previous studies- found no significant difference between artificial and natural grass in this respect. However, this study reported that the clubs using artificial grass pitches had a higher rate of training and overtraining acute injury[67]. Almutawa *et al* (2014) compared the prevalence, severity, and nature of injuries of members of Saudi Arabia national football team during competition and training on artificial turf and natural grass. This study reported that most injuries occurred on both surfaces were very mild and did not require medical attention, and hence did not lead to player missing a match or training session. However, more severe injuries occurred on natural grass; lower extremity injuries, which were the most common injuries on both surfaces, were more frequent on natural grass (almost twice as frequent); and natural grass also had a higher rate of traumatic injuries (almost 4 times higher)[68]. In a study by O'Kane *et al* (2016), 11 to 15 years old female soccer players were surveyed in regard to their injuries, type of shoe, and position on the field and the pitch on which they play so as to assess the rate of acute lower extremity injuries and external risk factors for this group of athletes. This study found that the number of players injured on natural grass was 3 times greater than the number of those injured on artificial turf. Also, the players who wore rounded studs on natural grass surface were injured 2.4 times more than players falling in other shoe-surface combination categories[69].

In support of these results, the study of Meyers (2010) on location, duration, and severity of injury showed that traumatic injuries are significantly more frequent on natural grass than on artificial turf (almost twice as much)[70]. Meyers (2013) also compared the prevalence, severity and mechanism of match injuries of female soccer players on artificial turf and natural grass and reported lower rates of injury and lower frequency of traumatic injuries on artificial grass. They stated that although there are similarities between natural and artificial grass, artificial turf is a viable alternative to reduce the rate of injury in female college soccer players[71]. Taylor *et al* (2012) reviewed the literature dedicated to artificial playing surfaces, surface-shoe interaction, and lower extremity injuries in athletes and concluded that elite athletes training on artificial turf are more susceptible to injury than those training on natural grass, while players of lower levels are safer on artificial grass. This could be because elite players are heavier and generate more power than amateur and college players and therefore produce more torque and traction[27]. This may explain the conflicting results obtained for rate of injuries on natural grass and artificial turf.

To assess the damage caused by sliding on artificial turf, Peppelman *et al* (2013) studied the interaction between skin and dry natural grass, wet natural grass, and artificial grass. They took clinical photographs and 3-mm biopsy of damaged tissue immediately and 24 hours after the sliding. Their results showed that from clinical perspective, sliding on artificial turf causes less erythema (inflammation) and more abrasion than sliding on natural grass. It was also reported that at histological level, artificial turf and dry natural grass induce more damage on the stratum corneum. While immediately after the sliding this histological effect were normal, 24 hours later they exhibited an increase[72]. Tay *et al* (2016) stated that the most important concern in regard to artificial turf is the increased incidence of skin abrasion and suggested the use and development of skin-friendly products[73].

The studies on relation of artificial turf and upper extremity injuries are quite few in numbers. De Putter *et al* (2009) investigated the rate of upper body fractures among young male soccer players in the Netherlands and found that this rate is highest among 11 to 14 years old boys and that there is a significant relationship between the number of artificial grass pitches and the number of upper body fractures[74]. But the study of Meyers (2010) on the incidence, severity and mechanism of match injuries on artificial turfs found no significant difference in terms of head, knee or shoulder injuries[70].

Conclusion

The use of artificial turfs in soccer pitches is on the rise and today many players, especially the youth, train and compete on these surfaces. Although artificial turfs have passed the FIFA tests, degradation of their qualities with time can affect the performance or even injure the players. Over time, infill layers of these turfs gets compressed and quality of their shockpads degrades, and these developments lead to increasing hardness of surface. These changes result in elongated artificial grass fibers and therefore increased friction between shoe and surface. They also increase the rotational traction and thus escalate the likelihood of injury on artificial turf. Most results provided in the literature suggest that the use of artificial turf does not increase the rates of injury, especially acute injuries, during competition. However, there have been reports of higher rates of injury during training on artificial turf as compared to natural grass. In addition, comparing the results of the literature in relation to performance of players showed that, for elite players, the rate of injury have been higher on artificial turf than on natural grass, but this has not been true for women, amateur players, and young players (from toddlers until youth), so for these groups are safer to use artificial turf. This difference may be due to low rates of injury, especially traumatic injuries, in youth soccer. And since the rate of non-traumatic injuries has been lower on artificial turf than on natural grass, the lower rate of injury in this group of players is expected. Furthermore, elite players are heavier and generate more power than amateur and college players, so they produce more torque and traction.

In studies conducted with the aim of assessing the opinions of players in regard to training and competition on the artificial turf, elite players stated that, in comparison to natural grass, artificial turf is "too hard / harder", "flatter" and "more abrasive" and "thinner". But the average scores given by amateur soccer players showed that in their opinion, artificial turfs are better than natural grass, except in the category of risk of abrasion. Thus, the results show that players' perception of pitch properties depends on their experience from different levels of play during youth and adulthood.

Most studies in the literature have reported high rates of ankle injuries on artificial turf, so injury prevention strategies should take this issue into consideration. Also, pitch temperature triggers different requirements for players, and both coaches and players should be aware of these differences. Health consequences of heat-stress in artificial grass during summers require precautionary-preventive measures for players and reassessment of true utility of transition from natural grass to artificial turf.

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