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## SUPPLEMENT

# Comparison of the incidence, nature and cause of injuries sustained on grass and new generation artificial turf by male and female football players. Part 1: match injuries

Colin W Fuller, Randall W Dick, Jill Corlette, Rosemary Schmalz

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**Objective:** To compare the incidence, nature, severity and cause of match injuries sustained on grass and new generation artificial turf by male and female footballers.

**Methods:** The National Collegiate Athletic Association Injury Surveillance System was used for a two-season (August to December) prospective study of American college and university football teams (2005 season: men 52 teams, women 64 teams; 2006 season: men 54 teams, women 72 teams). Injury definitions and recording procedures were compliant with the international consensus statement for epidemiological studies of injuries in football. Athletic trainers recorded details of the playing surface and the location, diagnosis, severity and cause of all match injuries. The number of days lost from training and match play was used to define the severity of an injury. Match exposures (player hours) were recorded on a team basis.

**Results:** The overall incidence of match injuries for men was 25.43 injuries/1000 player hours on artificial turf and 23.92 on grass (incidence ratio 1.06;  $p=0.46$ ) and for women was 19.15 injuries/1000 player hours on artificial turf and 21.79 on grass (incidence ratio=0.88;  $p=0.16$ ). For men, the mean severity of non-season ending injuries was 7.1 days (median 5) on artificial turf and 8.4 days (median 5) on grass and, for women, 11.2 days (median 5) on artificial turf and 8.9 days (median 5) on grass. Joint (non-bone)/ligament/cartilage and contusion injuries to the lower limbs were the most common general categories of match injury on artificial turf and grass for both male and female players. Most injuries were acute (men: artificial turf 24.60, grass 22.91;  $p=0.40$ ; women: artificial turf 18.29, grass 20.64;  $p=0.21$ ) and resulted from player-to-player contact (men: artificial turf 14.73, grass 13.34;  $p=0.37$ ; women: artificial turf 10.72; grass 11.68;  $p=0.50$ ).

**Conclusions:** There were no major differences in the incidence, severity, nature or cause of match injuries sustained on new generation artificial turf and grass by either male or female players.

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There is growing interest, at all levels of football, in new generation artificial turf surfaces that use synthetic infill materials.<sup>1</sup> This interest has developed for several reasons. First, the surfaces closely reflect the performance characteristics of grass, which led the Fédération Internationale de Football Association (FIFA) to approve their use for all matches.<sup>2</sup> Second, artificial turf surfaces have benefits compared with grass in situations where the climatic conditions are unsuitable for the installation and maintenance of good quality year-round grass pitches and where pitches have a high use requirement.<sup>1</sup> Third, modern football stadiums, which are designed to deliver improved spectator facilities, do not always provide the ideal growing conditions for grass.<sup>1</sup> Despite the advantages and although many football teams use them to provide year-round, all-weather training facilities, acceptance of artificial turf surfaces for match play by elite professional teams has been limited because of negative opinions related to older types of artificial turf<sup>3</sup> and the continuing perception that more injuries occur on artificial turf than on grass. Therefore, before new generation artificial turf surfaces will achieve wider acceptance within football, it is essential to compare the incidence, severity, nature and cause of injuries sustained on artificial turf with injuries sustained on grass.

Comparative data about the incidence and nature of match injuries sustained on artificial turf and grass in football are limited<sup>4-6</sup> and the available information is restricted mainly to elite male players. Ekstrand and Nigg<sup>4</sup> reviewed the effect of artificial turf on football injuries and suggested that abrasion injuries were more common on artificial turf than on grass.

Árnason *et al*<sup>5</sup> reported that the incidence of match injuries among elite male Icelandic footballers playing on older types of artificial turf was twice the level recorded on grass surfaces ( $p<0.01$ ); however, match and training exposures were combined for this comparison so it was not possible to determine the contribution to this increased risk from match exposures alone. Ekstrand *et al*<sup>6</sup> on the other hand, reported that there was no significant difference between the overall incidence of match injuries sustained by elite male European footballers using the new artificial turf and grass pitches, although the incidence of ankle sprains on artificial turf was almost twice and lower limb strains almost half that found on grass ( $p<0.05$ ). Studies within other football codes, such as American Football, have identified a higher risk of lower limb,<sup>7,8</sup> head/neck,<sup>8</sup> muscle strain/spasm<sup>9</sup> and non-contact<sup>9</sup> injuries on artificial turf surfaces than on grass. However, Meyers *et al*<sup>9</sup> reported lower incidences of concussion and ligament tears on artificial turf compared with grass. Higher incidences of lower limb injuries on playing surfaces are usually linked to increased surface hardness or shoe-surface traction,<sup>10</sup> which were factors associated with the older style artificial turf surfaces.

Preliminary epidemiological data from trials of the new generation artificial turf surfaces during the FIFA U-17 men's world cup football tournaments in 2003 and 2005 indicated

**Abbreviations:** FIFA, Fédération Internationale de Football Association; ISS, Injury Surveillance System; NCAA, National Collegiate Athletic Association

that there were no significant differences between the incidence, severity, nature or cause of match injuries sustained on artificial turf and grass; however, the study was too small for the results to reach statistical significance.<sup>11</sup> The present study aimed to undertake a larger, more detailed investigation of the epidemiology of match injuries sustained on synthetic infill artificial turf and grass by male and female players in order to obtain statistically significant conclusions that could inform the debate on whether the risk of injury in football is greater on artificial turf than on grass. A similar comparative study of injuries sustained during training activities on artificial turf and grass by male and female footballers is reported separately in this supplement.<sup>12</sup>

## METHOD

To achieve the aims of this study, our prime requirement was for the study sample size to be sufficiently large to provide statistically significant results.<sup>13</sup>

### Sample size calculation

For the above mentioned purpose we estimated the incidence of match injuries on grass for male and female players to be 25 injuries/1000 player hours based on data presented in the review of football injuries by Junge and Dvorak.<sup>14</sup> It was also necessary, in the context of the study objective, to specify what should be considered to be a significant effect, if there was an increased level of injury on artificial turf. In the UK, the standard set by the Industrial Injuries Advisory Council<sup>15</sup> for a sporting activity to be designated as an occupational hazard is that the activity must at least double the incidence of the adverse event when compared with the non-exposed situation. This standard is based on a balance of probabilities because, with double the incidence of injury, there is a 50% probability that any adverse event in an exposed population would be associated with the activity. For this study, however, an increase in the incidence of injury on artificial turf of one-third (33%) the level experienced on grass was adopted as the significant size effect: this is a higher standard than that used by the Industrial Injuries Advisory Council as it equates to a 25% probability that an injury in an exposed population could be associated with the artificial turf surface. Because in this study, data on a much larger number of teams playing on grass were available compared with data on teams playing on artificial turf, it was possible to increase the statistical power of the study by using a 4:1 ratio of grass to artificial turf player exposures. The minimum sample sizes required for a study to identify an effect of this size with a 95% significance level and 90% power<sup>13</sup> were calculated to be 5552 player hours for the artificial turf cohorts and 22 210 player hours for the control cohorts playing on grass.

### Implementation

Our prospective two-cohort study evaluated men's and women's football match injuries collected by the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS)<sup>16</sup> over a two-season period (2005 and 2006). The NCAA, which was established in 1906, is an organisation of over 1000 colleges and universities in the USA. A fundamental purpose of the organisation is to manage the health and safety of athletes at these institutions, and thus the NCAA established the ISS in 1982 to collect athlete injury and exposure data from a representative sample of NCAA institutions involved in each sport undertaken at the institutions. The present study included all organised matches from preseason, in-season and post-season football competitions (August through December). The sample of American college and university teams (2005 season: men 52 teams, women 64 teams; 2006 season: men 54 teams,

women 72 teams) represented approximately 7% of all NCAA schools sponsoring football over the period. Eighteen men's and 18 women's teams used artificial turf as their home pitch and 44 men's and 56 women's teams used grass as their home pitch. All squad players in each of the teams were included in the study. We defined a match injury as:

*"any physical complaint sustained by a player during a football match that prevented the player from taking a full part in training or match play activities for one or more days beyond the day of injury."*

We did not include absences from competition and/or training caused by medical conditions not related to football. The severity of individual injuries was defined by the number of days the player missed from training and/or competition or, where the injury persisted beyond the end of the season, as a "season ending" injury. Injury severities were grouped as minimal (1–3 days), mild (4–7 days), moderate (8–28 days) and severe (>28 days plus season ending injuries). Player match exposures were recorded on a team basis on the assumption that each team game involved 11 players and lasted for 90 min. Athletic trainers who worked with the teams and were qualified health professionals recorded every match injury according to the specified requirements of the NCAA-ISS<sup>16</sup>; these included details of the playing surface (grass/synthetic infill artificial turf) and the location, type, diagnosis, severity and cause (acute/gradual onset; contact/non-contact) of injury. The definitions and procedures used in this study were consistent with the international consensus statement on injury definitions and procedures for epidemiological studies of football injuries.<sup>17</sup> An NCAA research review board approved the data collection procedures with regard to the protection of human subjects.

### Data analysis

Incidences of match injuries were reported as the number of injuries/1000 player match hours with 95% CI.<sup>13</sup> We considered differences between the incidence of match injuries on artificial turf and grass to be significant if the 95% CI of the incidence ratio (equivalent to relative risk) did not include the value of 1.0 and the p value of the two-sided z test for the comparison of rates<sup>13</sup> was <0.05. Differences in the mean and median severity (days) of match injuries for different groups of players were assumed to be significant if the 95% CI did not overlap. Differences in the distributions of match injuries as a function of the location and type of injury were considered significant if the p value of the two-sided z test for the comparison of proportions<sup>13</sup> was <0.05.

**Table 1** Number of team matches and player exposures on artificial turf and grass for male and female players

	Male players		Female players	
	Artificial turf	Grass	Artificial turf	Grass
<b>2005</b>				
Team matches	209	842	189	1089
Match exposure (player hours)	3449	13 893	3119	17 969
<b>2006</b>				
Team matches	227	843	235	1169
Match exposure (player hours)	3746	13 910	3878	19 289
<b>Total</b>				
Team matches	436	1685	424	2258
Match exposure (player hours)	7195	27 803	6997	37 258

**Table 2** Incidence (injuries/1000 player match hours) of match injuries on artificial turf and grass for male and female players as a function of injury severity

Injury severity	Male players				Female players			
	Incidence (95% CI)		Incidence ratio* (95% CI)	p Value (z test)	Incidence (95% CI)		Incidence ratio* (95% CI)	p Value (z test)
	Artificial turf	Grass			Artificial turf	Grass		
All injuries	25.43 (22.00 to 29.40)	23.92 (22.17 to 25.81)	1.06 (0.90 to 1.25)	0.46	19.15 (16.17 to 22.68)	21.79 (20.35 to 23.35)	0.88 (0.73 to 1.05)	0.16
Minimal (1–3 days)	8.34 (6.47 to 10.74)	7.80 (6.83 to 8.92)	1.07 (0.80 to 1.42)	0.65	6.29 (4.68 to 8.45)	6.36 (5.60 to 7.22)	0.99 (0.72 to 1.36)	0.94
Mild (4–7 days)	7.37 (5.63 to 9.64)	6.91 (5.99 to 7.96)	1.07 (0.79 to 1.45)	0.67	3.86 (2.65 to 5.63)	6.25 (5.50 to 7.11)	0.62 (0.41 to 0.92)	0.02
Moderate (8–28 days)	5.00 (3.61 to 6.94)	6.19 (5.33 to 7.18)	0.81 (0.56 to 1.16)	0.25	4.14 (2.88 to 5.96)	3.92 (3.33 to 4.61)	1.06 (0.71 to 1.58)	0.78
Severe (>28 days)†	4.17 (2.92 to 5.96)	2.81 (2.25 to 3.50)	1.49 (0.98 to 2.26)	0.07	4.00 (2.76 to 5.80)	4.75 (4.10 to 5.50)	0.84 (0.57 to 1.25)	0.40

\*Incidence ratio values are based on grass as the reference.

†Includes season ending injuries.

## RESULTS

Table 1 presents the numbers of team matches and player exposures on artificial turf and grass for men and women in each of the two seasons. The total number of match injuries recorded for men was 848 (artificial turf: 183; grass: 665) and for women was 946 (artificial turf: 134; grass: 812).

### Incidence and severity of injury

We did not find any significant differences between the overall incidence of match injuries on artificial turf and grass in male or female players (table 2). Nor was the incidence of injury significantly greater on artificial turf than on grass for any injury severity subcategory for either male or female players (table 2).

For injuries that were not season ending, the mean or median severity of injuries sustained on artificial turf and grass for either male or female players did not differ significantly (table 3). The most common season ending injury for men on artificial turf was a hamstring tear (artificial turf: 26% (7), 95%

CI 9% to 43%; grass: 8% (4), 95% CI 0 to 16%;  $p = 0.03$ ) whereas on grass it was an anterior cruciate ligament tear (grass: 16% (8), 95% CI 6% to 26%; artificial turf: 11% (3), 95% CI 0 to 23%,  $p = 0.56$ ). For women, the most common season ending injury was an anterior cruciate ligament tear on both playing surfaces (artificial turf: 53% (9), 95% CI 29% to 77%; grass: 45% (58), 95% CI 36% to 53%;  $p = 0.52$ ).

### Nature of injury

The most common general injury location on artificial turf and grass for both male and female players was the lower limb; however, whereas the ankle and thigh were the structures most commonly injured by male players, the knee and ankle were the most commonly injured structures among female players (table 4). The incidence of head/neck injuries was significantly ( $p < 0.01$ ) higher on artificial turf than grass for men; these injuries were largely concussions and lacerations caused by player-to-player contact. The most common type of injury on artificial turf and grass for both male and female players was a joint (non-bone)/ligament/cartilage injury (table 5). Laceration/skin lesion in men was the only type of injury that was significantly higher on artificial turf than grass ( $p < 0.01$ ).

On cross-tabulation of the location and type of injury we did not find any significant differences between the distributions of injuries on artificial turf and grass for male or female players (table 6); joint (non-bone)/ligament/cartilage and contusion injuries to the lower limb were the most common categories on both surfaces for all players.

Table 7 presents the incidences of the most common specific injury diagnoses for men and women on artificial turf and grass. The three most common injuries on artificial turf for men (ankle lateral ligament complex tear, hamstring tear,

**Table 3** Mean and median severity of match injuries (excluding season ending injuries) sustained on artificial turf and grass for male and female players

Players	Mean severity, days (95% CI)		Median severity, days (95% CI)	
	Artificial turf	Grass	Artificial turf	Grass
Male	7.1 (6.0 to 8.1)	8.4 (7.6 to 9.2)	5 (4 to 5)	5 (4 to 5)
Female	11.2 (8.2 to 14.2)	8.9 (8.1 to 9.7)	5 (4 to 7)	5 (5 to 5)

**Table 4** Incidence (injuries/1000 player match hours) of match injuries on artificial turf and grass for male and female players as a function of injury location

Injury location	Male players				Female players			
	Incidence (95% CI)		Incidence ratio (95% CI)	p Value (z test)	Incidence (95% CI)		Incidence ratio (95% CI)	p Value (z test)
	Artificial turf	Grass			Artificial turf	Grass		
Head/neck	4.31 (3.03 to 6.13)	2.37 (1.86 to 3.02)	1.82 (1.18 to 2.78)	<0.01	2.57 (1.62 to 4.08)	3.41 (2.86 to 4.06)	0.75 (0.46 to 1.24)	0.26
Upper limbs	1.67 (0.95 to 2.94)	1.51 (1.12 to 2.04)	1.10 (0.58 to 2.10)	0.79	1.57 (0.87 to 2.84)	1.50 (1.16 to 1.95)	1.05 (0.55 to 2.00)	0.89
Trunk	2.36 (1.47 to 3.80)	3.88 (3.22 to 4.69)	0.61 (0.36 to 1.01)	0.06	1.57 (0.87 to 2.84)	2.12 (1.70 to 2.64)	0.74 (0.39 to 1.39)	0.35
Lower limbs	17.10 (14.33 to 20.40)	16.11 (14.69 to 17.68)	1.06 (0.87 to 1.30)	0.56	13.43 (10.98 to 16.44)	14.76 (13.58 to 16.05)	0.91 (0.73 to 1.13)	0.40
Hip/groin	1.11 (0.56 to 2.22)	2.34 (1.83 to 2.98)	0.48 (0.23 to 0.99)	0.05	1.00 (0.48 to 2.10)	0.91 (0.65 to 1.28)	1.10 (0.49 to 2.47)	0.83
Thigh	4.73 (3.38 to 6.61)	3.92 (3.25 to 4.73)	1.21 (0.82 to 1.77)	0.34	2.43 (1.51 to 3.91)	2.28 (1.84 to 2.82)	1.06 (0.63 to 1.79)	0.81
Knee	3.75 (2.57 to 5.47)	3.09 (2.50 to 3.82)	1.21 (0.79 to 1.87)	0.38	4.86 (3.47 to 6.80)	4.94 (4.27 to 5.71)	0.98 (0.68 to 1.42)	0.93
Lower leg	1.67 (0.95 to 2.94)	2.16 (1.68 to 2.78)	0.77 (0.42 to 1.44)	0.42	1.43 (0.72 to 2.66)	1.83 (1.44 to 2.31)	0.78 (0.40 to 1.52)	0.47
Ankle	4.59 (3.26 to 6.45)	4.57 (3.84 to 5.44)	1.00 (0.68 to 1.47)	0.98	3.00 (1.96 to 4.60)	4.21 (3.60 to 4.93)	0.71 (0.45 to 1.12)	0.14
Foot	2.36 (1.47 to 3.80)	2.37 (1.86 to 3.02)	1.00 (0.58 to 1.70)	0.98	1.72 (0.97 to 3.02)	1.50 (1.16 to 1.95)	1.14 (0.61 to 2.13)	0.68

**Table 5** Incidence (injuries/1000 player match hours) of match injuries on artificial turf and grass for male and female players as a function of the type of injury

Injury type	Male players				Female players			
	Incidence (95% CI)		Incidence ratio (95% CI)	p Value (z test)	Incidence (95% CI)		Incidence ratio (95% CI)	p Value (z test)
	Artificial turf	Grass			Artificial turf	Grass		
Fracture/bone stress	1.39 (0.75 to 2.58)	1.22 (0.87 to 1.71)	1.14 (0.56 to 2.30)	0.72	0.71 (0.30 to 1.72)	1.64 (1.27 to 2.10)	0.44 (0.18 to 1.09)	0.08
Joint (non bone)/ligament/cartilage	8.76 (6.84 to 11.21)	7.52 (6.56 to 8.61)	1.16 (0.88 to 1.54)	0.29	7.72 (5.91 to 10.08)	9.07 (8.15 to 10.09)	0.85 (0.64 to 1.13)	0.27
Muscle/tendon	5.70 (4.20 to 7.74)	6.47 (5.59 to 7.49)	0.88 (0.63 to 1.24)	0.46	3.57 (2.41 to 5.29)	3.17 (2.64 to 3.79)	1.13 (0.73 to 1.74)	0.58
Contusion	5.28 (3.84 to 7.26)	6.33 (5.46 to 7.34)	0.83 (0.59 to 1.18)	0.31	4.57 (3.23 to 6.47)	5.05 (4.37 to 5.82)	0.91 (0.62 to 1.32)	0.61
Laceration/skin lesion	1.81 (1.05 to 3.11)	0.61 (0.38 to 0.98)	2.95 (1.44 to 6.08)	<0.01	0.29 (0.07 to 1.14)	0.24 (0.13 to 0.46)	1.18 (0.26 to 5.5)	0.83
Central/peripheral nervous system	2.36 (1.47 to 3.80)	1.40 (1.02 to 1.92)	1.68 (0.95 to 2.98)	0.07	2.14 (1.29 to 3.56)	2.31 (1.87 to 2.85)	0.93 (0.54 to 1.61)	0.79
Other	0.14 (0.02 to 0.99)	0.36 (0.19 to 0.67)	0.39 (0.05 to 3.02)	0.36	0.14 (0.02 to 1.01)	0.32 (0.18 to 0.57)	0.44 (0.06 to 3.41)	0.43

concussion) and women (ankle lateral ligament complex tear, concussion and anterior cruciate ligament tear) were the same as those on grass. There were, however, some differences between male and female players. For example, the incidence of hamstring tears was significantly lower in women than in men on both artificial turf (0.57 vs 2.6, respectively; incidence ratio 0.22;  $p < 0.01$ ) and grass (0.78 vs 1.8, respectively; incidence ratio 0.42;  $p < 0.01$ ) and the incidence of adductor tears was significantly lower in women than in men on grass (0.27 vs 1.3, respectively; incidence ratio 0.21;  $p < 0.01$ ). Conversely, the incidence of anterior cruciate ligament tears was more than three times higher in women than in men on both artificial turf (1.3 vs 0.42, respectively; incidence ratio 3.08;  $p = 0.09$ ) and grass (1.6 vs 0.47, respectively; incidence ratio 3.50;  $p < 0.01$ ).

We specifically investigated the overall incidences of ankle sprains and lower limb strains on artificial turf and grass in men and women in order to review the conclusions reached on these injuries by Ekstrand *et al.*<sup>6</sup> The incidence of ankle sprains for men on artificial turf and grass did not differ significantly (4.31, 95% CI 3.03 to 6.13 and 3.81, 95% CI 3.15 to 4.61, respectively; incidence ratio 1.13, 95% CI 0.76 to 1.69;  $p = 0.55$ ), but the incidence in women on artificial turf was significantly lower than on grass (2.00, 95% CI 1.18 to 3.38 and 3.62, 95% CI 3.06 to 4.29, respectively; incidence ratio 0.55, 95% CI 0.32 to 0.96;  $p = 0.03$ ). There was also no significant difference between the incidence of lower limb strains on artificial turf and on grass among men (3.47, 95% CI 2.34 to 5.14 and 3.09, 95% CI 2.50 to 3.82, respectively; incidence ratio 1.12, 95% CI 0.72 to 1.75;  $p = 0.61$ ) or women (1.86, 95% CI 1.08 to 3.20 and 1.58, 95% CI 1.22 to 2.04, respectively; incidence ratio 1.18, 95% CI 0.65 to 2.15;  $p = 0.60$ ).

### Injury causation

The incidences of acute, gradual onset, contact or non-contact injuries on artificial turf and grass did not differ significantly for either male or female players (table 8).

Although the proportion of injuries caused by player-to-surface contact in women (artificial turf: 11.2%; grass: 15.5%) was almost twice that in men (artificial turf: 6.6%; grass: 7.8%) we did not find any significant differences between artificial turf and grass in either men or women. In women, 33% (3/9) of anterior cruciate ligament injuries sustained on artificial turf and 38% (22/58) on grass were the result of non-contact events. No concussion injuries sustained on artificial turf (men: 17; women: 14) were caused by player-to-surface contact; on the other hand, 13% of concussion injuries sustained on grass by men (5/38) and 7% by women (6/81) were caused by player-to-surface contact.

### DISCUSSION

Although a range of manufacturers supplied the artificial turf surfaces included in this study, all the surfaces incorporated synthetic infill materials, such as rubber crumb. The number of player hours of exposure on artificial turf was limited by the number of teams that used these surfaces; however, by increasing the total player hours of match exposure in the control groups playing on grass, the power of the study was increased compared with what would have been achieved by using sample populations of equal size.<sup>13</sup> The player hours of match exposure recorded in this study, for both male and female players, exceeded the numbers calculated to identify, with statistical significance, a relative risk of 1.33 for the overall incidence of injury on artificial turf compared with grass. These exposure levels were also sufficient to identify, with statistical significance, a relative risk of 2.00 (the standard adopted by the Industrial Injuries Advisory Council<sup>15</sup>) for subcategories of injury where the incidence of injury was at least 3.0 injuries/1000 player hours on grass (ie, ~12% of the estimated overall incidence of injury).

The incidences of injury recorded in this study on grass for male (23.92) and female (21.79) players were consistent with values reported previously<sup>14</sup> (men: 10–30; women: 14–24). The incidences of injury in male players were higher than those reported in the comparative study of elite professional footballers<sup>6</sup> for both artificial turf (25.4 vs 19.6, respectively) and grass (23.9 vs 21.5, respectively) but the previous study excluded gradual onset/overuse injuries from the calculations of incidence of match injuries. The present results are similar to those reported for the FIFA men's U-17 world cup tournaments<sup>11</sup> (grass: 28; artificial turf: 26). There are no equivalent published data to compare the incidence of injury in women's football on artificial turf surfaces. The overall incidences or the mean and median severities of injuries on artificial turf and grass did not differ significantly for either male or female players, which is consistent with Ekstrand and colleagues<sup>6</sup> conclusions for male players. In the present study, the incidence of injury decreased with increasing injury severity on artificial turf and grass, for both male and female players. This is in contrast with Ekstrand and colleagues<sup>6</sup> study in male players in which the incidence of injury increased with increasing severity on both artificial turf and grass, with the incidence peaking for injuries of moderate severity (8–28 days).

Joint (non-bone)/ligament/cartilage injuries to the lower limb were the most common combination of injury type and location on artificial turf and grass surfaces for both male and female players: this is similar to the results reported in previous studies of football injuries on grass.<sup>18–22</sup> The incidence of injury to specific structures of the lower leg on artificial turf and grass

**Table 6** Distribution of match injuries as a function of location and type of injury for male and female players on artificial turf and grass

	Artificial turf, % (95% CI)				Grass, % (95% CI)					
	Head/neck	Upper limb	Trunk	Lower limb	All	Head/neck	Upper limb	Trunk	Lower limb	All
<b>Male players</b>										
Fracture/bone stress	1.1 (0 to 2.6)	2.2 (0.1 to 4.3)	0.0 (-)	2.2 (0.1 to 4.3)	5.5 (2.2 to 8.8)	1.4 (0.5 to 2.2)	0.9 (0.2 to 1.6)	0.5 (0 to 1.0)	2.4 (1.2 to 3.6)	5.1 (3.4 to 6.8)
Joint (non-bone)/ligament/cartilage	0.0 (-)	3.3 (0.7 to 5.9)	1.6 (0 to 3.5)	29.5 (22.9 to 36.1)	34.4 (27.5 to 41.3)	0.0 (-)	3.8 (2.3 to 5.2)	0.5 (0 to 1.0)	27.2 (23.8 to 30.6)	31.4 (27.9 to 35.0)
Muscle/tendon	0.0 (-)	0.5 (0 to 1.6)	4.9 (1.8 to 8.1)	16.9 (11.5 to 22.4)	22.4 (16.4 to 28.4)	0.3 (0 to 0.7)	0.5 (0 to 1.0)	10.8 (8.5 to 13.2)	15.5 (12.7 to 18.2)	27.1 (23.7 to 30.4)
Contusion	0.0 (-)	0.5 (0 to 1.6)	2.7 (0.4 to 5.1)	17.5 (12.0 to 23.0)	20.8 (14.9 to 26.6)	0.5 (0 to 1.0)	0.9 (0.2 to 1.6)	4.1 (2.6 to 5.6)	21.1 (18.0 to 24.2)	26.5 (23.1 to 29.8)
Laceration/skin lesion	6.0 (2.6 to 9.5)	0.0 (-)	0.0 (-)	1.1 (0 to 2.6)	7.1 (3.4 to 10.8)	1.8 (0.8 to 2.8)	0.0 (-)	0.0 (-)	0.8 (0.1 to 1.4)	2.6 (1.4 to 3.8)
Central/peripheral nervous system	9.3 (5.1 to 13.5)	0.0 (-)	0.0 (-)	0.0 (-)	9.3 (5.1 to 13.5)	5.7 (4.0 to 7.5)	0.0 (-)	0.0 (-)	0.0 (-)	5.9 (4.1 to 7.7)
All	16.9 (11.5 to 22.4)	6.6 (3.0 to 10.1)	9.3 (5.1 to 13.5)	67.2 (60.4 to 74.0)	100	9.9 (7.7 to 12.2)	6.3 (4.5 to 8.2)	16.2 (13.4 to 19.0)	67.4 (63.8 to 70.9)	100
<b>Female players</b>										
Fracture/bone stress	0.0 (-)	0.0 (-)	0.0 (-)	3.7 (0.5 to 6.9)	3.7 (0.5 to 6.9)	1.5 (0.6 to 2.3)	1.7 (0.8 to 2.6)	0.4 (0 to 0.8)	3.9 (2.6 to 5.3)	7.5 (5.7 to 9.3)
Joint (non bone)/ligament/cartilage	0.0 (-)	5.2 (1.5 to 9.0)	0.7 (0 to 2.2)	34.3 (26.3 to 42.4)	40.3 (32.0 to 48.6)	0.2 (0 to 0.6)	3.2 (2.0 to 4.4)	1.4 (0.6 to 2.1)	36.8 (33.5 to 40.1)	41.6 (38.2 to 45.0)
Muscle/tendon	0.7 (0 to 2.2)	0.7 (0 to 2.2)	3.7 (0.5 to 6.9)	13.4 (7.7 to 19.2)	18.7 (12.1 to 25.3)	0.9 (0.2 to 1.5)	0.9 (0.2 to 1.5)	3.1 (1.9 to 4.3)	9.7 (7.7 to 11.8)	14.5 (12.1 to 17.0)
Contusion	0.7 (0 to 2.2)	2.2 (0 to 4.7)	3.0 (0.1 to 5.9)	17.9 (11.4 to 24.4)	23.9 (16.7 to 31.1)	1.4 (0.6 to 2.1)	1.1 (0.4 to 1.8)	4.2 (2.8 to 5.6)	16.5 (13.9 to 19.1)	23.2 (20.3 to 26.1)
Laceration/skin lesion	1.5 (0 to 3.5)	0.0 (-)	0.0 (-)	0.0 (-)	1.5 (0 to 3.5)	0.9 (0.2 to 1.5)	0.0 (-)	0.0 (-)	0.2 (0 to 0.6)	1.1 (0.4 to 1.8)
Central/peripheral nervous system	10.4 (5.3 to 15.6)	0.0 (-)	0.0 (-)	0.7 (0 to 2.2)	11.2 (5.9 to 16.5)	10.1 (8.0 to 12.2)	0.0 (-)	0.1 (0 to 0.4)	0.4 (0 to 0.8)	10.6 (8.5 to 12.7)
All	13.4 (7.7 to 19.2)	8.2 (3.6 to 12.9)	8.2 (3.6 to 12.9)	70.1 (62.4 to 77.9)	100	15.6 (13.1 to 18.1)	6.9 (5.2 to 8.6)	9.7 (7.7 to 11.8)	67.7 (64.5 to 70.9)	100

did not differ significantly in either male or female players. Ekstrand *et al*<sup>6</sup> stated that there may be a higher incidence of ankle sprains and lower incidence of lower limb strains for men on artificial turf than on grass, and these effects were specifically investigated in this study for both male and female players. For lower limb ankle sprains, there was a small non-significant increase in the incidence of injury for men (incidence ratio 1.13) and a significant reduction in the incidence for women (incidence ratio 0.55) on artificial turf. For lower limb strains, there were small increases in the incidence of injury on artificial turf for men (incidence ratio 1.12) and women (incidence ratio 1.18) but the differences were not significant.

The three most common injuries sustained on artificial turf for men (ankle lateral ligament complex, hamstring tear, concussion) and women (ankle lateral ligament complex, concussion, anterior cruciate ligament) were also the most common injuries sustained on grass. The appearance of anterior cruciate ligament tears as one of the most common injuries for women but not for men reflects the well-documented higher incidence of these injuries among women than men. The incidence of these injuries on grass (1.64) was similar to the value (2.2) reported by Faude *et al*<sup>22</sup> for elite German female players. Although there were significantly more head injuries on artificial turf than on grass among men, these injuries were mainly concussions and lacerations caused by player-to-player contact and were therefore not related to the playing surface. There was no indication of more non-contact or gradual onset match injuries on artificial turf compared with grass in either male or female players.

This study consisted of a large uniform sample population of male and female American college and university students, who played regular football at a high standard: this population therefore provided an ideal setting to compare the risks of injury on new generation artificial turf and grass. The protocols employed were consistent with the international consensus statement on injury definitions and procedures for studies of injuries in football<sup>17</sup> and with the procedures used by Ekstrand *et al*<sup>6</sup> and Fuller<sup>11</sup> in previous comparative studies of injuries sustained on artificial turf and grass by elite professional footballers. In addition, the protocols had been implemented

### What is already known on this topic

- In football, new generation artificial turf is becoming more popular as an alternative playing surface to natural grass for matches.
- This situation is particular common where climatic conditions are unsuitable for the installation and maintenance of good-quality year-round grass pitches and where pitches have a high usage.
- However, there is limited information about the incidence, nature and causes of match injuries sustained on artificial turf surfaces for both male and female players.

### What this study adds

- There are no major differences in either the overall level of risk or the cause of match injuries sustained on new generation artificial turf and grass in both male and female players.

**Table 7** Incidence (injuries/1000 player hours) of the most common match injuries (three most common injuries on artificial turf and grass for male and female players are identified as superscripts)

Injury (main body region and diagnosis)	Incidence of injury (injuries/1000 player hours)			
	Male players		Female players	
	Artificial turf	Grass	Artificial turf	Grass
Head/neck				
Concussion	2.36 <sup>(3)</sup>	1.37 <sup>(3)</sup>	2.00 <sup>(1)</sup>	2.17 <sup>(2)</sup>
Scalp laceration	0.69	0.22	0.00	0.03
Facial laceration	0.56	0.22	0.29	0.13
Nasal fracture	0.28	0.22	0.00	0.30
Upper limbs				
Acromioclavicular sprain	0.42	0.18	0.14	0.08
Ulnar fracture	0.28	0.04	0.00	0.00
Wrist sprain	0.00	0.07	0.43	0.08
Lower limbs				
Ankle lateral ligament complex tear	3.20 <sup>(1)</sup>	2.52 <sup>(1)</sup>	1.57 <sup>(2)</sup>	2.42 <sup>(1)</sup>
Hamstring tear	2.64 <sup>(2)</sup>	1.84 <sup>(2)</sup>	0.57	0.78
Foot/toe contusion	1.53	1.11	0.57	0.54
Quadriceps contusion	1.11	1.22	1.00	0.81
Knee contusion	0.83	0.79	0.57	0.56
Lower leg contusion	0.69	1.01	0.29	1.15
Medial (deltoid) ligament tear	0.69	0.61	0.14	0.35
Quadriceps tear	0.56	0.54	0.86	0.48
Iliopsoas/sartorius tear	0.56	0.43	0.14	0.16
Lateral meniscal tear	0.56	0.14	0.57	0.27
Anterior cruciate ligament tear	0.42	0.47	1.29 <sup>(3)</sup>	1.64 <sup>(3)</sup>
Medial collateral ligament tear	0.42	0.90	0.57	0.81
Ankle contusion	0.28	0.68	0.86	0.46
Adductor (groin) tear	0.28	1.26	0.43	0.27

**Table 8** The incidence (injuries/1000 player match hours) of acute and gradual onset match injuries on artificial turf and grass for male and female players

Injury causation factor	Male players				Female players			
	Incidence (95% CI)		Incidence ratio (95% CI)	p Value (z test)	Incidence (95% CI)		Incidence ratio (95% CI)	p Value (z test)
	Artificial turf	Grass			Artificial turf	Grass		
Nature of onset								
Acute	24.60 (21.23 to 28.51)	22.91 (21.20 to 24.76)	1.07 (0.91 to 1.27)	0.40	18.29 (15.38 to 21.75)	20.64 (19.23 to 22.15)	0.89 (0.74 to 1.07)	0.21
Gradual	0.69 (0.29 to 1.67)	0.90 (0.61 to 1.33)	0.77 (0.30 to 2.02)	0.60	0.71 (0.30 to 1.72)	1.07 (0.79 to 1.46)	0.67 (0.26 to 1.69)	0.39
Cause of onset								
Contact with player	14.73 (12.18 to 17.82)	13.34 (12.05 to 14.77)	1.10 (0.89 to 1.37)	0.37	10.72 (8.55 to 13.44)	11.68 (10.63 to 12.83)	0.92 (0.72 to 1.17)	0.50
Contact with surface	1.67 (0.95 to 2.94)	1.87 (1.43 to 2.45)	0.89 (0.48 to 1.67)	0.72	2.14 (1.29 to 3.56)	3.38 (2.84 to 4.03)	0.63 (0.37 to 1.08)	0.10
Contact with object/ball	1.95 (1.15 to 3.29)	1.15 (0.81 to 1.63)	1.69 (0.90 to 3.17)	0.10	1.29 (0.67 to 2.47)	1.53 (1.18 to 1.98)	0.84 (0.42 to 1.70)	0.33
Non-contact	6.95 (5.27 to 9.17)	7.45 (6.50 to 8.53)	0.93 (0.69 to 1.27)	0.66	4.86 (3.47 to 6.80)	5.13 (4.45 to 5.91)	0.95 (0.66 to 1.37)	0.77

routinely as part of the NCAA-ISS for over 25 years. The statistical power of the present study allowed a greater depth of analysis of injury subcategories than has been achieved previously. The results confirm that there are no major differences between the overall incidence, severity, nature or cause of injuries sustained on artificial turf and grass in either male or female players. These results, when taken in conjunction with the results reported separately for training injuries<sup>12</sup> and the results reported for injuries sustained on artificial turf and grass by elite male players,<sup>6, 11</sup> suggest that the risks of injury to male and female footballers on new generation artificial turf surfaces are not significantly different from the risks experienced on grass.

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