

## SUPPLEMENT

# Risk of injury on artificial turf and natural grass in young female football players

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**Background:** Artificial turf is becoming increasingly popular, although the risk of injury on newer generations of turf is unknown.

**Aim:** To investigate the risk of injury on artificial turf compared with natural grass among young female football players.

**Study design:** Prospective cohort study.

**Methods:** 2020 players from 109 teams (mean (SD) 15.4 (0.8) years) participated in the study during the 2005 football season. Time-loss injuries and exposure data on different types of turf were recorded over an eight-month period.

**Results:** 421 (21%) players sustained 526 injuries, leading to an injury incidence of 3.7/1000 playing hours (95% CI 3.4 to 4.0). The incidence of acute injuries on artificial turf and grass did not differ significantly with respect to match injuries (rate ratio (RR) 1.0, 95% CI 0.8 to 1.3;  $p=0.72$ ) or training injuries (RR 1.0, 95% CI 0.6 to 1.5,  $p=0.93$ ). In matches, the incidence of serious injuries was significantly higher on artificial turf (RR 2.0, 95% CI 1.3 to 3.2;  $p=0.03$ ). Ankle sprain was the most common type of injury (34% of all acute injuries), and there was a trend towards more ankle sprains on artificial turf than on grass (RR 1.5, 95% CI 1.0 to 2.2;  $p=0.06$ ).

**Conclusion:** In the present study among young female football players, the overall risk of acute injuries was similar between artificial turf and natural grass.

In most countries, football is traditionally played on natural grass. However, for climatic and economic reasons, artificial turf has become a popular alternative playing surface—for example, in Scandinavia.<sup>1–3</sup> Many pitches are being built, although the risk of injury on artificial turfs is poorly documented. Concerns have been raised that playing on different surfaces and switching between turfs may lead to an increased risk of injury in elite as well as in amateur football.<sup>4–6</sup> The stiffness of the field surface, its quality and the friction between the surface and shoe are key factors involved in surface-related injuries.<sup>2–7</sup> Field stiffness affects impact forces and can result in overload of tissues such as bone, cartilage, muscle, tendon and ligament. Friction is necessary for rapid starting, stopping, cutting and pivoting in football,<sup>7–8</sup> but injuries can result if friction is too high.<sup>9</sup>

The first generation of synthetic turfs appeared in the mid 1970s.<sup>10</sup> They had short, thin fibres and were characterised by high stiffness and friction, leading to considerable differences in ball behaviour compared with natural grass. Since then, turfs have been developed with a sand filling, leading to reduced friction and lower ball bounce. In the late 1980s, the second generation of artificial turfs was introduced with longer, thicker fibres, better quality sand fillings and a rubber base under the turf itself to reduce stiffness.<sup>11</sup> These were the first turfs designed specifically for football, however, their characteristics still differed appreciably from that of natural grass. The risk of injury was higher on these turfs.<sup>4–12</sup> The third generation of synthetic turfs was introduced in Norway in 2000, consisting of even longer fibres (50–60 mm) and filled with siliceous sand and rubber granules to mimic more closely the playing characteristics of natural grass pitches.<sup>11</sup>

Some studies on American and Canadian football suggest that the incidence of major injuries and ligament sprains is lower when playing on natural grass than on later generation artificial turfs,<sup>13–14</sup> whereas others have shown conflicting

findings.<sup>15</sup> However, American and Canadian football codes differ considerably from European football in their playing characteristics and injury mechanisms so it is not known whether these results can be extrapolated to European football. A recent study from Europe, which included the first data on third generation artificial turfs, indicated that the risk of injury among professional male players is similar to that when playing on natural grass.<sup>3</sup> The purpose of this one-season prospective cohort study was to examine the risk of injury on artificial turf compared with natural grass among young female football players.

## METHODS

### Study population

This study is based on data from a large randomised trial comparing the risk of injury between an intervention group receiving a training programme to prevent injuries and a control group training as usual. The design, the intervention programme and the results of the study have been described in detail elsewhere.<sup>16</sup> All teams ( $n=157$ ) in the southeast regions of Norway registered to participate in the U-17 league system in the 2005 season were invited to take part in the study and 113 teams accepted. The competitive season lasted from the end of April until mid-October. There was a seven-week summer break with no regular league matches but some invitational tournaments. The teams were also followed for two months of the preseason period (March–April). Throughout the competitive season, the teams played 14–24 league matches and trained one to three times a week.

Before the start of the preseason, the players were given written and verbal information about the study, and it was emphasised that participation was voluntary. The regional committee for research ethics approved the study, and written consent was obtained. A player was enrolled if she was registered by the team as participating in the U-17 league

system, which meant that she had to be 16 years or younger. However, a team competing in the U-17 league can apply for exemption and employ older players if it does not have enough eligible players. All the players were screened using a questionnaire for previous injuries and current joint and muscle function at the start of the study. Players had to be uninjured to be included in the study.

### Injury and exposure registration

To monitor injuries and playing exposure, 18 physical therapists were recruited as injury recorders and assigned to the teams (typically five to seven teams each) to record injuries during the period from 1 March to 31 October 2005. All the coaches were asked to keep a log of the data requested. They were contacted by telephone and/or email at least once a month to record new injuries, as well as all training and match activities, including exposure to different types of turf: natural grass, artificial turf, gravel and indoor floor. Injured players were interviewed by the injury recorders to assess aspects of the injury with the use of a standardised injury questionnaire. A web-based system was used to record all the information.

In accordance with the consensus statement on injury definitions,<sup>17</sup> an injury was registered if the player could not fully take part in match or training sessions the day following the injury ("time loss" injury). Acute injuries were defined as injuries with a sudden onset, associated with known trauma. Overuse injuries were those with a gradual onset and no known trauma. Because overuse injuries have a gradual onset, they cannot be attributed to a particular turf type, and therefore, their incidence cannot be compared between turfs. Recurrent injuries were defined as an injury of the same type and the same site as the index injury, and which occurred after a player had returned to full participation following the index injury.

In addition to turf type, the location of the injury, the type of injury and the injury circumstances (contact vs non-contact) were recorded. Injuries were classified into three severity categories according to the time it took until the player was fully fit to take part in all types of organised football play: minor (1–7 days), moderate (8–21 days) and major (>21 days).<sup>18</sup> In almost all cases of moderate and major injuries, the player was seen in a medical centre and the injury was diagnosed based on clinical examination, imaging studies or surgery. In cases of minor injuries, a player was usually examined by a physical therapist, the coach or not at all. None of the injured players was examined or treated by any of the authors or injury recorders participating in the study.

Data on match and training exposure were collected on a team basis. The injury incidence was calculated as the number of injuries/1000 player hours, in total, during match play and during training. To calculate match exposure, match playing time (in min) was multiplied by 11 and for training exposure, training time (in min) was multiplied by the average monthly player attendance. A regular league match was played for 2×40 min, whereas a training session usually lasted 90 min.

### Statistics

Results are presented as means and 95% confidence intervals (CI), unless otherwise noted. All tests were two tailed and *p* values <0.05 were considered significant. We used a *z* test and 95% CI based on the Poisson model to compare the rate ratio between artificial turf and natural grass. Rate ratios are presented with natural grass as the reference group. Since we did not find any differences in the rates of injury in the intervention and control groups,<sup>16</sup> the analyses did not factor in group assignment.

## RESULTS

### Inclusion of players

The final study sample consisted of 109 teams with 2020 players. Before the start of the season, four teams withdrew from participation in the league system, and their players (*n* = 72) were excluded from the study. During the season, 48 players (2.3%) stopped playing football for unknown reasons.

### Overall rate of injury

During the eight-month season, including the two-month preseason, the total exposure to football on all four turf types was 142 721 h; 41 311 h during matches and 101 410 h during training (table 1). Of the 2020 players, 421 (20.8%) sustained at least one injury, with 68 (3.4%), 17 (0.8%) and 1 (0.05%) incurring two, three and four injuries, respectively, leading to a total of 526 injuries. Of these, 456 were acute injuries (343 during matches and 113 during training) (table 1) and 70 were overuse injuries. The mean (SD) age of the injured players, as well as of the total study population, was 15.4 (0.8) years.

The overall (acute and overuse) incidence of injury on all turf types was 3.7/1000 playing hours (95% CI 3.4 to 4.0). The incidence of acute injuries was 3.2 injuries/1000 h (95% CI 2.9 to 3.5)—8.3 injuries/1000 h (95% CI 7.4 to 9.2) during match play and 1.1 injuries/1000 h (95% CI 0.9 to 1.3) during training. In other words, the incidence of acute injuries was 7.5 times (95% CI 6.0 to 9.2) higher in matches than during training. For overuse injuries, the overall incidence was 0.5 injuries/1000 playing hours (95% CI 0.4 to 0.6). The most common overuse injuries were anterior lower leg pain (36% of all overuse injuries) and knee pain (21%). Of the acute injuries, 42% (191) were non-contact while 58% (265) were sustained by player-to-player contact. Ankle sprain was the commonest type of acute injury with a total of 154 injuries (34% of all acute injuries), of which 52 were recurrent ankle sprains. Of all ankle sprain injuries, 64% (*n* = 99) were contact injuries, with a higher proportion occurring during matches (82%, *n* = 81) than in training (18%, *n* = 18) (*p* < 0.001).

### Injuries on grass versus artificial turf

The relative exposure during matches was higher on grass than on artificial turf and other playing surfaces (table 1). Thus, because injuries were more common in matches and matches were more often played on grass, the proportion of match exposure to training exposure satisfies the conditions for being

**Table 1** Exposure, number of acute injuries and incidence of acute injuries on different turfs

	Exposure, playing hours (%)			Number of injuries			Injury incidence, n/1000 playing hours (95% CI)	
	Match	Training	Total	Match	Training	Total	Match	Training
Grass	27 627 (67)	45 417 (45)	73 044 (51)	230	56	286	8.3 (7.2 to 9.4)	1.2 (0.9 to 1.6)
Artificial turf	9402 (23)	30 577 (30)	39 979 (28)	82	37	119	8.7 (6.8 to 10.6)	1.2 (0.8 to 1.6)
Gravel	3905 (9)	21 251 (21)	25 156 (18)	26	16	42	6.7 (4.1 to 9.2)	0.8 (0.4 to 1.1)
Indoor	377 (1)	4165 (4)	4542 (3)	5	4	9	13.3 (1.6 to 24.9)	1.0 (0 to 1.9)
Total	41 311	101 410	142 721	343	113	456	8.3 (7.4 to 9.2)	1.1 (0.9 to 1.3)

**Table 2** Characteristics of acute injuries incurred during matches

	Grass		Artificial turf		Artificial turf vs grass
	Injuries	Incidence n/1000 h of exposure (95% CI)	Injuries	Incidence n/1000 h of exposure (95% CI)	Rate ratio (95% CI)†
Total	230	8.3 (7.2 to 9.4)	82	8.7 (6.8 to 10.6)	1.0 (0.8 to 1.3)
Injury type					
Contusion	74	2.7 (2.1 to 3.3)	22	2.3 (1.4 to 3.3)	0.9 (0.5 to 1.4)
Sprain	91	3.3 (2.6 to 4.0)	43	4.6 (3.2 to 5.9)	1.4 (1.0 to 2.0)
Strain	41	1.5 (1.0 to 1.9)	6	0.6 (0.1 to 1.1)	0.4 (0.2 to 1.1)
Other	24	0.9 (0.5 to 1.2)	11	1.2 (0.5 to 1.9)	1.3 (0.7 to 2.7)
Re-injuries	38	1.4 (0.9 to 1.8)	20	2.1 (1.2 to 3.1)	1.5 (0.9 to 2.7)
Ankle sprains	22	0.8 (0.5 to 1.1)	14	1.5 (0.7 to 2.3)	1.9 (1.0 to 3.7)
Body location					
Upper body	43	1.6 (1.1 to 2.0)	12	1.3 (0.6 to 2.0)	0.8 (0.4 to 1.6)
Lower body	187	6.8 (5.8 to 7.7)	70	7.4 (5.7 to 9.2)	1.1 (0.8 to 1.4)
Groin	8	0.3 (0.1 to 0.5)	1	0.1 (-0.1 to 0.3)	0.4 (0 to 2.9)
Thigh	32	1.2 (0.8 to 1.6)	7	0.7 (0.2 to 1.3)	0.6 (0.3 to 1.5)
Knee	31	1.1 (0.7 to 1.5)	18	1.9 (1.0 to 2.8)	1.7 (1.0 to 3.1)
Ankle	82	3.0 (2.3 to 3.6)	38	4.0 (2.8 to 5.3)	1.4 (0.9 to 2.0)
Other	34	1.2 (0.8 to 1.6)	6	0.6 (0.1 to 1.1)	0.5 (0.2 to 1.2)
Time loss (days)					
1-7	111	4.0 (3.3 to 4.8)	25	2.7 (1.6 to 3.7)	0.7 (0.4 to 1.0)
8-21	73	2.6 (2.0 to 3.2)	26	2.8 (1.7 to 3.8)	1.0 (0.7 to 1.6)
>21	46	1.7 (1.2 to 2.1)	31	3.3 (2.1 to 4.5)	2.0 (1.3 to 3.1)*

\*p&lt;0.05.

†Rate ratios between injuries on grass and artificial turf, with grass as the reference group. Subcategories for injuries on gravel and indoor floors are not shown separately because of small numbers.

a confounder. Rate ratios comparing the total injury incidence between these two turfs would have been confounded by the match to training factor. Therefore the injury incidences, rate ratios between turf types and injury characteristics are presented separately for match and training injuries. We did not find any significant differences, neither for match nor for training injuries, when the incidence of acute injuries was compared between artificial turf and grass (table 1). The rate ratio on artificial turf relative to grass was 1.0 (95% CI 0.8 to 1.3; p = 0.72) for match injuries (table 2) and 1.0 (95% CI 0.6 to 1.5; p = 0.93) for training injuries.

Injury rates were similar on artificial turf and grass for most subcategories of injury types and locations (table 2). In matches, twice as many severe injuries occurred on artificial turf as on grass (p = 0.03), whereas the rate for minor injuries tended to be significantly lower when playing on artificial turf than on grass (p = 0.06). A trend was also seen towards more ankle ligament injuries on artificial turf than on grass (rate ratio 1.5, 95% CI 1.0 to 2.2; p = 0.06), as well as for more ligament injuries in general (p = 0.07) and more knee injuries (p = 0.07).

The incidence of acute match injuries on artificial turf and grass did not differ significantly when compared for different injury mechanisms (contact: p = 0.91; and non-contact injuries: p = 0.64). However, when examining the activities leading to injury, significantly more injuries from heading duels occurred on artificial turf than on grass (p = 0.04; table 3).

There were 11 injuries of the anterior cruciate ligament, which corresponds to an incidence of 0.08/1000 playing hours; three occurred on grass, four on artificial turf, two on gravel and two on indoor floor (p = not significant). Ten of these injuries occurred in matches: four due to player-to-player contact and six in a non-contact situation. The training injuries resulted from player-to-player contact.

With regard to injuries on, there were not enough injuries and exposures to compare gravel and indoor floor between turf types.

## DISCUSSION

The principal finding of our eight-month prospective cohort study was that there was no overall difference in the risk of acute injuries between artificial turf and natural grass in a

**Table 3** Mechanisms of acute injuries incurred during matches

	Grass		Artificial turf		Artificial turf vs grass
	Injuries	Incidence n/1000 h of exposure (95% CI)	Injuries	Incidence n/1000 h of exposure (95% CI)	Rate ratio (95% CI)†
Contact	153	5.5 (4.7 to 6.4)	53	5.6 (4.1 to 7.2)	1.0 (0.7 to 1.4)
Non-contact	77	2.8 (2.2 to 3.4)	29	3.1 (2.0 to 4.2)	1.1 (0.7 to 1.7)
Activity					
Tackling	124	4.5 (3.7 to 5.3)	40	4.3 (2.9 to 5.6)	0.9 (0.7 to 1.4)
Heading duel	5	0.2 (0 to 0.3)	6	0.6 (0.1 to 1.1)	3.5 (1.1 to 11.6)*
Running	51	1.8 (1.3 to 2.4)	14	1.5 (0.7 to 2.3)	0.8 (0.4 to 1.5)
Collision	17	0.6 (0.3 to 0.9)	7	0.7 (0.2 to 1.3)	1.2 (0.5 to 2.9)
Other	33	1.2 (0.8 to 1.6)	15	1.6 (0.8 to 2.4)	1.3 (0.7 to 2.5)
Total	230	8.3 (7.2 to 9.4)	82	8.7 (6.8 to 10.6)	1.0 (0.8 to 1.3)

\*p&lt;0.05.

†Rate ratios between injuries on grass and artificial turf, with grass as the reference group. Subcategories for injuries on gravel and indoor floors are not shown separately because of small numbers.

### What is already known on this topic

- Previous research on risk of injury related to playing on artificial turf mainly relates to older turf generations and/or other football codes, and the results are conflicting.
- Only one study has compared the injury risk on third generation artificial turf with natural grass. It showed that the rate of injury is similar on both turf types among male professional football players.
- It is not known if the injury risk among young female football players differs between artificial turf and natural grass.

group of young female football players. This is the first study to assess the relationship between the types of turf and risk of injury in youth football. The main limitation is that, although this is the largest study to date on the relationship between turf types and injury risk in European football, the statistical power was still limited with respect to injury subgroups. Therefore, it is not possible to rule out differences in risk for specific injury types or for injuries on gravel and indoor floor or training injuries.

A few small, older studies examined the extrinsic risk factors for football injuries, such as weather conditions<sup>19, 20</sup> and playing surfaces,<sup>4, 12</sup> but on first generation artificial turf.<sup>4, 12</sup> The findings have been inconsistent. High friction and stiff field quality were assumed to explain the higher rates of injury observed on artificial turf in these older studies on elite male football players,<sup>4, 12</sup> but the second and third generation artificial turfs examined in the present study differ considerably from the first generation turfs and may explain the divergent results. The present results corroborate with those of a recent study on professional men's football, which showed similar incidences of injury on third generation artificial turfs and natural grass.<sup>3</sup> The overall injury incidences reported in the present study are similar to those reported in two previous epidemiological studies on female youth football.<sup>21, 22</sup>

It has been speculated that frequent changes in playing surfaces and the players' lack of adaptation to them increases the risk for overuse injuries, such as low back and lower limb pain.<sup>7</sup> This hypothesis, reinforced by several researchers,<sup>4, 6, 23</sup> is difficult to test in epidemiological studies. According to the definition, overuse injuries have a gradual onset and can neither be attributed to a specific event nor a particular turf type. Even if a player reports that they first experienced symptoms during a particular match or training session, the injury may have been incurred in one or more previous sessions on a different turf type.

When interpreting our results it is to be noted that there are several other extrinsic factors which we did not control for in the present study. Potential confounding factors include the generation of the artificial turfs used in this project and the maintenance status for both synthetic and grass turfs. Weather conditions have also been suggested to affect injury risk.<sup>13-15</sup> A US football study reported higher rates of lower extremity injury on artificial turf than on natural grass, under both wet and dry field conditions.<sup>13</sup> Since neither meteorological data nor field conditions were registered in this study, we cannot assess the contribution of these factors to injury risk. Also, we do not know how internal risk factors such as previous injuries, age, joint instability, physical fitness or skill levels may have contributed to injury rates.<sup>21, 24-28</sup>

In northern climates it may not be possible to play on natural grass for more than a few months a year, and artificial turf and

### What this study adds

- This study did not find any deleterious effect of artificial turf on the overall risk for acute injuries in young female football players when compared with natural grass.

gravel are the only surface options, particularly in youth football. In addition, artificial turf tolerates frequent, even continuous, use.<sup>11</sup> Increased pitch availability and higher utilisation of artificial turf pitches may also lead to better maintenance routines and generally more consistent pitch conditions than before. On newer generation artificial turfs, better shock absorption, supported by an underground heating system during cold periods, may attenuate impact forces to the muscle and tendon structures. However, note that we did not observe any clear trend towards fewer injuries on artificial turf than on natural grass in the present investigation. Given the practical advantages of artificial turf, it is promising that we did not find any deleterious effect of artificial turf on the overall risk for acute injuries among young female players. The number of injuries was insufficient to compare the risk of injury between turf types for each specific injury type, such as for knee sprains or injuries of the anterior cruciate ligament. Nevertheless, we did note some differences or trends with regard to the risk of injury for specific subgroups (mild and severe injuries, ankle ligament injuries, ligament injuries in general and knee injuries). Shoe-surface friction, which is assumed to be higher on synthetic than on natural material, has been associated with injuries in team handball<sup>9</sup> and in football.<sup>7, 14</sup> The observed trends for ankle and knee injuries and ligament injuries in general indicate that differences in friction may have a role. Ligament sprains to ankles and knees, the most severe injuries in this study, often occur in situations when the player is out of balance while the loaded leg is fixed to the ground.<sup>7, 29, 30</sup> However, these hypotheses need to be examined in larger studies. Moreover, it is not known whether the observed trends are specific for females. A study on team handball showed that risk of ACL injury was higher on artificial floors than on wooden floors among female players, but this difference was not seen in male players.<sup>9</sup>

### CONCLUSION

Our eight-month register of injuries among young female football players showed that the overall risk of injury is the same when playing and training on artificial turf as on natural grass.

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