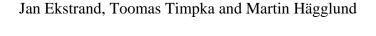
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Risk of injury in elite football played on artificial turf versus natural grass – a prospective two-cohort study

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Key words: Athletic injuries, football, surface properties, soccer, artificial turf

Word count: 2573 Abstract: 234

ABSTRACT

Objective: To compare the injury risk when playing elite football on artificial turf

versus natural grass.

Design: Prospective two-cohort study

Setting: Male European elite football leagues

Participants: 290 players from 10 elite European clubs that had installed third-

generation artificial turf surfaces 2003-04, and 202 players from the Swedish Premier

League acting as a control group.

Main outcome measures: Injury incidence.

Results: The incidence of injury during training and match play did not differ

between surfaces for the teams in the artificial turf cohort, being 2.42 vs. 2.94

injuries/1000 training hours and 19.60 vs. 21.48 injuries/1000 match hours when

playing on artificial turf and grass respectively. The risk for ankle sprain was

increased when playing matches on artificial turf compared to grass (4.83 vs. 2.66

injuries/1000 match hours; rate ratio 1.81, 95% CI 1.00 to 3.28). No difference in

injury severity was seen between surfaces.

Compared to the control cohort who played home games on natural grass, teams in the

artificial turf cohort had a lower injury incidence during match play (15.26 vs. 23.08

injuries/1000 match hours; rate ratio 0.66, 95% CI 0.48 to 0.91).

Conclusions: No evidence of a greater risk for injury when playing football on

artificial turf compared to playing on natural grass was found. The higher incidence of

ankle sprain on artificial turf warrants further attention, though this result should be

interpreted with caution as the number of ankle sprains was low.

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INTRODUCTION

Grass is the traditional surface for football matches and practice, but many regions in the world have a climate that makes the culture of adequate natural grass pitches difficult. Furthermore, modern specially designed football stadiums have a roof under which grass pitches do not thrive.

The use of artificial football pitch surfaces has been put forward as a solution to these problems. A comparison between first-generation artificial turf and natural grass pitches revealed that the utilisation of artificial turf pitches was 12 times greater than natural grass pitches and the maintenance costs only 15%. However, playing football on first- and second-generation artificial turf had the disadvantage of a distorted bounce and roll of the ball, and a there was concern that the risk for injury was greater. Renström et al. reported results from a 2-year study in Sweden in 1975 when the first artificial soccer surface was introduced.² They observed that playing on artificial turf in cleated shoes increased the rate of injury. Engebretsen and Kase ³studied 16 teams over a 2-year period in Norway in the 80:s. They found 30 injuries/1000 match hours on artificial turf compared to 20 injuries/1000 hours on grass (ns, probably due to small numbers). Similar results were reported by Hort ⁴ in the 70:s who found more overuse injuries when playing on artificial turf compared to natural grass. However, these two studies were too small to reach statistical significance. In 1991, Árnason et al ⁵ investigated the risk for injury in Icelandic elite football. They found a significantly higher injury risk when playing on artificial turf compared to natural grass (25 vs. 10 injuries/1000 hours of exposure, p<0.01). The relationship between artificial surfaces and a greater risk for injury, however, is poorly documented since the few studies reported have been small and have methodological limitations.

The negative experience with first-generation artificial surfaces led to the development of improved artificial turf specially designed for football with playing characteristics similar to natural grass. 'Third-generation' artificial turfs were introduced in the late 90:s, made of long (>40 mm) and much wider spread fibres of polypropylene or polyethylene filled with rubber granules. The use of the term "football turf" instead of "artificial or synthetic turf of the 3rd generation" is the official terminology chosen by FIFA and UEFA for artificial turf most suitable for the game of football based on test criteria identical to those of the best natural turf. Positive preliminary experience from youth tournaments encouraged FIFA to allow international matches to be played on these new surfaces.⁶ However, no studies have evaluated the injury risk when playing elite football on football turf (third-generation artificial turf pitches). The aim of this study was to examine the injury risk associated with playing elite football on artificial turf compared to natural grass. Based on experience from studies on previous generation artificial turf, our hypothesis was that the injury risk is higher when playing on artificial turf than when playing on natural grass.

METHODS

A prospective two-cohort design was used for the study (Figure 1). **Male** players from ten European elite football clubs who had reported the installation of football turf (third-generation artificial turf) to UEFA (European Union of Football Associations) during the 2003-04 seasons constituted the study cohort. UEFA defines *elite level* as the two highest national football league divisions. Intra-cohort differences in injury incidence on football turf and grass were used to assess the impact of the playing surface. To adjust for any home ground effect, and to further evaluate the impact of

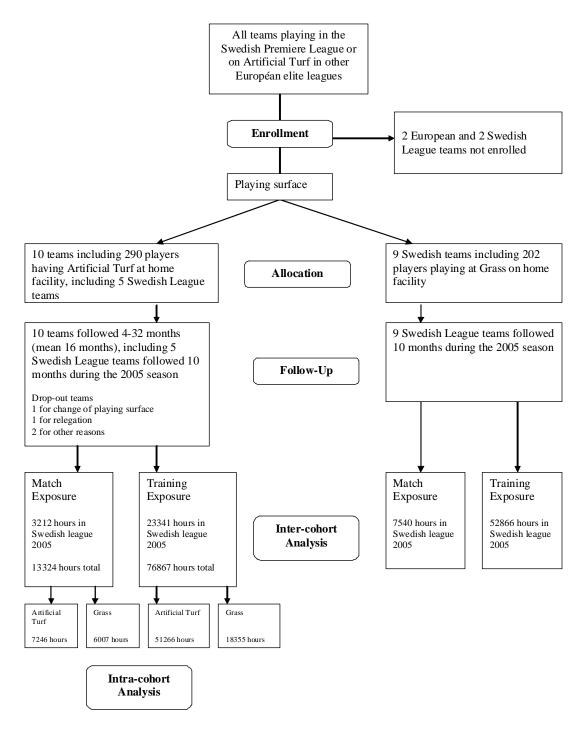


Figure 1. Flowchart of the prospective two-cohort study design and analysis.

the playing surface, the Swedish teams in the artificial turf cohort were also compared with a control cohort consisting of the players from Swedish Premier League clubs playing their home matches on grass.

Study period and subjects

Artificial turf cohort: ten teams (290 players age 25±5, range 16-39 years) accepted to participate and entered the study between February 2003 and January 2005. Two European clubs with artificial turf at their home ground were not included in the study; one due to language difficulties and one due to lack of resources.

Control cohort: nine (202 players; mean age 24±5, range 16-37 years) of the eleven Swedish Premier League teams playing on home ground with grass accepted to participate and delivered complete data during the 2005 season. One team declined participation due to lack of resources and one team was unable to deliver complete data and was excluded.

All first team players who accepted to participate signed an informed consent form. Data from both cohorts were collected until November 2005. The clubs in the artificial turf cohort collected data over 4 – 32 months (mean 16±9 months) (see Table 1), while all clubs in the control cohort participated over 10 months. Data collection included individual exposure and injury registration (by team medical staff) on standard forms. Data from players that left the study (due to transfer or other reasons) or clubs that left the study (one artificial turf cohort team dropped out due to change of home ground surface, one team was relegated to a lower division, and two discontinued data collection for other reasons) prior to the end of the study in November 2005 were included in the analysis for the entire time of their participation.

Table 1. Details of the 10 teams playing on facilities with third-generation artificial surfaces.

Team	Study period	Months of data collection	Country	Level of play ^a	Season	Type of artificial turf
1	2003-02 - 2005-10	32	Sweden	2 nd division	Spring – Autumn	Mondoturf
2	2004-01 - 2005-10	19	Sweden	2 nd division	Spring – Autumn	Saltex
3	2004-07 - 2005-04	8	Sweden	1st division	Spring – Autumn	Fieldturf
4	2005-01 - 2005-10	10	Sweden	1st division	Spring – Autumn	Limonja
5	2005-01 - 2005-10	10	Sweden	1st division	Spring – Autumn	Fieldturf
6	2004-01 - 2005-10	20	Finland	1st division	Spring – Autumn	Mondoturf
7	2004-04 - 2004-10	7	Norway	2 nd division	Spring – Autumn	Astroplay
8	2004-01 - 2004-04	4	Austria	1st division	Autumn – Spring	Polytan
9	2003-07 - 2005-10	26	Netherlands	1 st /2 nd division	Autumn – Spring	Arcadis
10	2003-10 - 2005-05	19	Scotland	1st division	Autumn – Spring	XL turf

^a 1st and 2nd divisions being the two highest domestic leagues.

Study procedure and validity

The development and validation of the protocols and methodology used in the present study have been described previously. The definitions and data collection procedures used follow the recommendations of the consensus statement for football injury studies. 8

Player exposure and surface type were registered for all training sessions and matches (including matches with reserve teams) on a standard form by a member of the team squad that was present at all training session and matches (same person throughout the study for each team). The team medical staff recorded all injuries on a standard form immediately after the event. All forms were sent to the study group on a monthly basis and regular feedback was given to ensure complete records. All teams and contact persons were provided with a study manual describing all procedures related to injury and exposure registration to increase reliability of the records.

The study protocol was approved by the ethics committee of Linköping University, Sweden and the total study design was approved by FIFA and UEFA.

Definitions

A recordable injury was defined as an injury resulting from football training or match play leading to a player being unable to take full part in training or match play at any time following the injury. A player was considered injured until cleared by the team medical officer for full participation in team training and match play. Injuries were divided into four categories of severity according to the length of absence from training sessions and matches: slight (1-3 days); minor (4-7 days); moderate (8-28 days); and severe (> 28 days).

Training exposure was defined as any physical activity carried out under the supervision of the team coach. Match exposure for players paticipating included all matches (first, reserve and national teams).

Analyses

The primary outcome measure was injury incidence (injuries/1000 hours of exposure) in training and match play. Secondary outcomes included injury severity and incidences of various injury types. In the intra-cohort analysis, injury incidences in the artificial turf group were aggregated and compared between exposure on grass and on artificial turf. In the inter-cohort analysis, comparisons were made with the control group who played on natural grass. For this analysis, total exposure time and injuries during the same period (January to October 2005) for the five Swedish teams in the artificial turf cohort (Table 1, Teams 1-5) were used for comparison with the control cohort. In addition, to adjust for a home ground effect, exposure and traumatic injuries sustained during home league matches during the 2005 season were analysed specifically. Injury incidences were compared between groups using rate ratios with 95% confidence intervals (rate ratio / exp[1.96 × standard error of log(rate ratio)] to rate ratio × exp[1.96 × standard error of log(rate ratio)]). The significance level was set at p<0.05.

RESULTS

Intra-cohort analysis

Exposure

There was a total of 90,191 hours of football exposure recorded during the study period in the artificial turf cohort. 65% of training and match exposure was played on artificial turf, 27% on grass and 8% on other surfaces (Table 2). The relative exposure to artificial turf varied between teams, ranging from 47 to 81% (median 70%). As seen in Figure 2, the relative exposure to artificial turf was highest at the beginning and at the end of the year for both training and matches.

Table 2. Exposure and injuries on different surfaces and intra-cohort analysis of injury incidence on artificial turf and grass for the 10 teams playing on facilities with third-generation artificial surfaces.

	Artificial turf		Gras	Grass		Other surface	
Exposure (hours)	58512	2	2436	2	7317		
- Training	51266	5	1835	5	7246		
- Match play	7246	7246		6007		71	
Injuries (number)	483		274		18		
- Training	301		100		12		
- Match play	182		174		6		
	Artifi	cial turf	Gras	s			
Training injuries (trauma)	N	Inc	N	Inc	RR	(95% CI)	
Total	124	2.42	54	2.94	0.82	(0.60 to 1.13)	
- Slight	38	0.74	20	1.09	0.68	(0.40 to 1.17)	
- Minor	33	0.64	10	0.54	1.18	(0.58 to 2.40)	
- Moderate	35	0.68	20	1.09	0.63	(0.36 to 1.09)	
- Severe	18	0.35	4	0.22	1.61	(0.55 to 4.76)	
Lower extremity	115	2.24	48	2.62	0.86	(0.61 to 1.20)	
- Sprain	48	0.94	12	0.65	1.43	(0.76 to 2.70)	
- Ankle sprain	27	0.53	6	0.33	1.61	(0.67 to 3.90)	
- Knee sprain	16	0.31	6	0.33	0.95	(0.37 to 2.44)	
- Strain	32	0.62	24	1.31	0.48	(0.28 to 0.81)**	
- Hamstring strain	14	0.27	8	0.44	0.63	(0.26 to 1.49)	
- Groin strain	7	0.14	6	0.33	0.42	(0.14 to 1.24)	
Match injuries (trauma)	N	Inc	N	Inc	RR	(95% CI)	
Total	142	19.60	129	21.48	0.91	(0.72 to 1.16)	
- Slight	36	4.97	35	5.83	0.85	(0.54 to 1.36)	
- Minor	44	6.07	40	6.66	0.91	(0.59 to 1.40)	
- Moderate	46	6.35	41	6.83	0.93	(0.61 to 1.42)	
- Severe	16	2.21	13	2.16	1.02	(0.49 to 2.12)	
Lower extremity	128	17.66	107	17.82	0.99	(0.77 to 1.28)	
- Sprain	51	7.04	34	5.66	1.24	(0.81 to 1.92)	
- Ankle sprain	35	4.83	16	2.66	1.81	(1.00 to 3.28)*	
- Knee sprain	15	2.07	16	2.66	0.78	(0.38 to 1.57)	
- Strain	27	3.73	37	6.16	0.60	(0.37 to 0.99)*	
- Hamstring strain	13	1.79	14	2.33	0.77	(0.36 to 1.64)	
- Groin strain	6	0.82	9	1.50	0.55	(0.20 to 1.55)	

Significant at * p<0.05; ** p<0.01

RR: Rate ratio

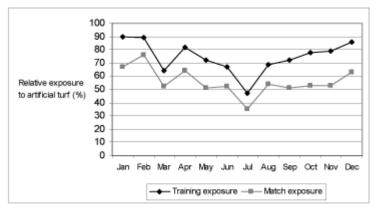


Figure 2. Relative exposure to artifical turf vs. grass during the year.

Injury incidence and injury pattern

A total of 775 injuries was recorded, of which 455 (59%) were traumatic (5.04/1000 hours) and 320 (41%) overuse injuries (3.54/1000 hours). For the intra-cohort analysis of injury incidences on artificial turf verses natural grass, only traumatic injuries were included. This analysis showed no difference between surfaces in overall injury incidence during training or match play (Table 2).

Ligament sprain (N=151), contusion (N=134) and muscle strain (N=127) were the most common traumatic injury types. No abrasions or lacerations were recorded. The intra-cohort analysis showed an increased risk for ankle sprain on artificial turf, reaching significant levels in match play (Table 2). On the contrary, the rate of lower extremity strains was lower on artificial turf (p<0.05)(Table 2).

There was no difference in incidence of severe injuries between surfaces, although the tendency was that fewer severe injuries occurred on grass in training (Table 2).

The rates of traumatic injury during match and training over the year are shown in Figure 3. Match injury incidence was high at the beginning and at the end of the year, with another peak in September.

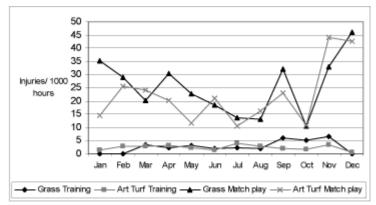


Figure 3. Distribution of traumatic injury during the year.

Inter-cohort analysis

The five Swedish teams in the artificial turf cohort registered a total of 26,553 hours of exposure (23,341 training, 3212 match play) and 177 injuries. In the control cohort, there were 60,406 hours of football exposure (52,866 training, 7540 match play) and 443 injuries recorded. The inter-cohort comparison showed that teams in the artificial turf cohort had a lower match injury incidence compared to the control cohort (p<0.05), while the incidence during training was similar (Table 3). When data was reduced to include exposure and traumatic injuries only during home league games, the incidence of injury was still lower for the artificial turf teams (p<0.01)(Table 3). Compared to the control cohort, players in the artificial turf cohort had a lower incidence of lower extremity strains (p<0.01).

Table 3. Inter-cohort analysis of injury incidence for teams playing on facilities with third-generation artificial surfaces compared to control teams playing on natural grass at home.

		Art turf cohort		ol cohort		
Total injuries	N	Inc	N	Inc	RR	(95% CI)
All injuries	177	6.67	443	7.33	0.91	(0.76 to 1.08)
- Primary injury	149	5.61	377	6.24	0.90	(0.74 to 1.09)
- Re-injury ¹	28	1.05	66	1.09	0.97	(0.62 to 1.50)
- Overuse	74	2.79	148	2.45	1.14	(0.86 to 1.50)
- Primary injury	60	2.26	115	1.90	1.19	(0.87 to 1.62)
- Re-injury ¹	14	0.53	33	0.55	0.97	(0.52 to 1.80)
- Trauma	103	3.88	295	4.88	0.79	(0.63 to 0.99)
- Primary injury	89	3.35	262	4.34	0.77	(0.61 to 0.98)*
- Re-injury ¹	14	0.53	33	0.55	0.97	(0.52 to 1.80)
Training injuries (trauma)						
Total	54	2.31	121	2.29	1.01	(0.73 to 1.39)
- Slight	21	0.90	33	0.62	1.44	(0.83 to 2.49)
- Minor	11	0.47	34	0.64	0.73	(0.37 to 1.45)
- Moderate	14	0.60	40	0.76	0.79	(0.43 to 1.46)
- Severe	8	0.34	14	0.26	1.29	(0.54 to 3.09)
Lower extremity	43	1.84	109	2.06	0.89	(0.63 to 1.27)
- Sprain	21	0.90	27	0.51	1.76	(0.99 to 3.12)
- Ankle sprain	10	0.43	18	0.34	1.26	(0.58 to 2.73)
- Knee sprain	8	0.34	9	0.17	2.01	(0.78 to 5.22)
- Strain	10	0.43	40	0.76	0.57	(0.28 to 1.13)
 Hamstring strain 	5	0.21	13	0.25	0.87	(0.31 to 2.44)
- Groin strain	5	0.21	9	0.17	1.26	(0.42 to 3.75)
Match injuries (trauma)						
Total	49	15.26	174	23.08	0.66	(0.48 to 0.91)*
- Slight	19	5.92	43	5.70	1.04	(0.60 to 1.78)
- Minor	8	2.49	51	6.76	0.37	(0.17 to 0.78)**
- Moderate	17	5.29	57	7.56	0.70	(0.41 to 1.20)
- Severe	5	1.56	23	3.05	0.51	(0.19 to 1.34)
Lower extremity	39	12.14	150	19.89	0.61	(0.43 to 0.87)**
- Sprain	20	6.23	40	5.31	1.17	(0.67 to 2.01)
- Ankle sprain	11	3.42	26	3.45	0.99	(0.49 to 2.01)
- Knee sprain	9	2.80	14	1.86	1.51	(0.65 to 3.49)
- Strain	8	2.49	51	6.76	0.37	(0.17 to 0.78)**
- Hamstring strain	4	1.25	20	2.65	0.47	(0.16 to 1.37)
- Groin strain	2	0.62	18	2.39	0.26	(0.06 to 1.12)
Home league matches						
Exposure (hours)	868		1740			
Traumatic injuries	8	9.21	48	27.59	0.33	(0.16 to 0.71)**

Re-injury of the same type and at the same site within two months of the final rehabilitation day of the index injury.

* Significant at p<0.05; ** p<0.01

RR: Rate ratio

DISCUSSION

The strength of this study is that it is based on an injury recording system and a player sample specifically developed to address this issue. The recording of data followed the international consensus agreements on procedures for epidemiological studies of football injuries recommended by FIFA and UEFA. The only available data source on the injury risk associated with artificial turf among elite players is the few elite clubs already playing on artificial turf. We therefore contacted 12 elite European clubs that had installed third-generation artificial turf surfaces 2003-04 and invited them to participate in the study. Ten of these accepted and provided data. Nine of the 11 clubs in the Swedish Premier League that play on natural grass at home acted as control cohort.

The principal finding of this study was that both intra-cohort and inter-cohort analyses revealed that the injury incidence was similar when playing elite-level football on either artificial turf or natural grass. The incidences of injury during training and match play found in the present study are comparable with other studies on elite football in Europe. ¹⁰⁻¹⁵

The relative exposure to training and match play on artificial turf compared to natural grass was high in November to February, probably due to poor climate and grass pitch condition at that time of the year. The rate of traumatic match injuries was also high during these months, both on artificial turf and grass. This could imply that the rate ratio between artificial turf and natural grass injuries observed during matches in the present study (0.91) may be somewhat overestimated. Had exposure on artificial turf and grass been more evenly distributed during these two months of the year when the

risk for injury is high it is probable that the rate ratio would have been even lower.

This could further support the conclusion that the overall risk for injury when playing on artificial turf is not higher than grass.

The only significant difference in injury pattern in this study was a higher risk for ankle sprain during matches on artificial turf and a lower risk for lower extremity muscle injuries on artificial turf. However, these differences in injury pattern should be interpreted with caution. Comparison of injury incidences between surfaces for specific injury sub-groups is restricted by small numbers and we must consider the possibility of Type II error due to limited data. The tendency towards a lower rate of severe injuries on grass during training, however, should be investigated further.

Previous studies evaluating injury patterns on the first two generations of artificial turf reported a higher incidence of overuse injuries.⁴ As a result one particular feature of third-generation artificial surfaces is improved shock absorption. Even though a causal relationship between this intervention and a reduction in overuse injury is difficult to establish using our study design, the artificial turf cohort did not show a higher injury incidence compared to the control cohort. Similarly, the incidence of overuse injury in the artificial turf cohort is well in line with the overall incidence of overuse injury (2.6-5.6/1000 hours of exposure) found in previous studies on elite football in Europe using the same study design.¹³⁻¹⁵ Although not conclusive this is an encouraging observation.

Wounds, burns and friction injuries have been reported to be more frequent when playing on artificial turf.^{1,2,16} Injuries that did not cause absence from full training or

matches were not included in this study and we may therefore have underestimated this problem.

It is well-known that the cause of football injury is multifactorial and there are many confounding risk factors to consider. ¹⁷⁻²⁰ One advantage of our intra-cohort design was that the same teams were followed when playing their home matches on artificial turf with the majority of their away matches being played on natural grass. This eliminated many of the confounding factors related to inter-team differences, e.g. variation in reporting and differences in climate. On the other hand, comparison with the control cohort allowed us to adjust for a home ground effect and evaluate the impact of playing surface on the rate of overuse injury. The study was limited by the fact that it was performed at a time when third-generation artificial turf was allowed and progressively introduced for competitive matches at elite level. A number of different brands of artificial surfaces were included in the study and not all of these met the quality criteria subsequently drawn up by FIFA. Future studies would be better controlled if FIFA standardised testing is introduced universally. Furthermore, even though the study used the only data source available, the small database is still a limitation of the study, especially in sub-group analysis.

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Competing interest

All authors declare that the answers to the questions on your competing interest form bmj.com/cgi/content/full/317/7154/291/DC1 are all "No" and therefore have nothing to declare

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Information box

What is already known on this topic

- Artificial turf pitches for football have advantages in terms of lower maintenance costs and a higher utilisation time compared to natural grass pitches.
- The first- and second-generation artificial surfaces have been associated with a higher risk for injury and changed injury pattern.
- The injury risk when playing on third-generation artificial turf is not known.

What this study adds

- This is the first study that has evaluated the risk for injury when playing on thirdgeneration artificial turf pitches (football turf) compared to playing on natural grass.
- Our data showed no increase in injury incidence when playing elite football on artificial turf compared to playing on natural grass.
- From the medical point of view there is no contraindication to expansion of artificial turf technology.