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The Nordic Football Injury Audit: higher injury rates for professional football clubs with third-generation artificial turf at their home venue

Karolina Kristenson,[1,2] John Bjørneboe,[3] Markus Waldén,[1,2] Thor Einar Andersen,[3] Jan Ekstrand,[1,2,4] Martin Hägglund[2,5]

[1] Division of Community Medicine, Department of Medical and Health Sciences, Linköping University, Linköping, Sweden.

[2] Football Research Group, Linköping University, Sweden.

[3] Department of Sports Medicine, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway.

[4] UEFA Medical Committee, Nyon, Switzerland

[5] Division of Physiotherapy, Department of Medical and Health Sciences, Linköping University, Linköping, Sweden.

Correspondence should be addressed to:

Karolina Kristenson, Department of Medical and Health Sciences, Linköping University, SE-581 83 LINKÖPING, SWEDEN

E-mail: karolina.kristensson@liu.se

Tel: +46 739 414156

Fax: +46 13 351112

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ABSTRACT

Background: Previously, no difference in acute injury rate has been found when playing football on artificial turf (AT) compared to natural grass (NG).

Aim: To compare acute injury rates in professional football played on AT and NG at the individual player level; and to compare, at club level, acute and overuse injury rates between clubs that have artificial turf at their home venue (AT clubs) and clubs that have natural grass (NG clubs).

Methods: 32 clubs (AT, n=11; NG, n=21) in the male Swedish and Norwegian premier leagues were followed prospectively during the 2010 and 2011 seasons. Injury rate was expressed as the number of time loss injuries/1000 hours and compared with rate ratio (RR) and 99% confidence interval (CI).

Results: No statistically significant differences were found in acute injury rates on AT compared to NG during match play (RR 0.98, 99% CI 0.79 to 1.22) or training (RR 1.14, 99% CI 0.86 to 1.50) when analysing at the individual player level. When analysing at club level, however, AT clubs had significantly higher acute training injury rate (RR 1.31, 99% CI 1.04 to 1.63), and overuse injury rate (RR 1.38, 99% CI 1.14 to 1.65) compared to NG clubs.

Conclusions: At the individual player level, no significant differences were found in acute injury rates when playing on AT compared to NG. However, clubs with AT at their home venue had higher rates of acute training injuries and overuse injuries compared to clubs that play home matches on NG.

INTRODUCTION

First and second generation artificial turfs (ATs) were associated with a higher injury rate and a different injury pattern compared to natural grass (NG).[1] Third-generation AT is different from its precursors, characterised by longer (50-60 mm) and more outspread grass-like fibres, interspersed with sand and rubber granules.[2,3] Studies comparing injury rates on third-generation AT and NG at youth[4-6] and collegiate levels[7,8] have not revealed statistically significant differences in general. Three previous studies have reported injury rates in elite male football when playing on third-generation AT compared to NG.[9-11] The first two studies, carried out between 2003 and 2008, included European clubs with AT installed at their home venue,[9,11] and the third study followed Norwegian elite clubs between 2004 and 2007.[10] All three studies found similar acute injury rates on AT and NG, but contradictory results were reported regarding injury patterns. In one cohort, AT exposure was associated with lower rates of quadriceps and calf muscle injuries, and a higher rate of ankle sprains,[9,11] while in the other cohort no significant difference in injury patterns were found between the two surfaces.[10]

The majority of previous studies have only compared acute injury rates between the different playing surfaces,[4,5,10] and knowledge about the influence of AT exposure on overuse injuries in elite football is limited.[12] Only one previous study has included a control group consisting of clubs playing their home matches on NG.[9] However, the limited sample in that study did not allow for detailed analysis of potential variations in injury rates between clubs having AT at their home venue and those having NG.

The aims of this study were to compare acute injury rates in professional football played on AT and NG at the individual player level; and to compare, at club level, acute and overuse injury rates between clubs that have AT at their home venue (AT clubs) and clubs that have NG (NG clubs).

MATERIALS AND METHODS

All clubs in the male premier leagues in Norway (Tippeligaen) and Sweden (Allsvenskan) were invited to participate in the study. Clubs were followed prospectively for two consecutive seasons, 2010 and 2011, including pre-season (January to late March) and competitive season (late March to late October or early November). In 2010, 12/16 Norwegian and 14/16 Swedish clubs participated in the study. In 2011, the participation was 14/16 and 15/16 clubs, respectively (figure 1). After season 2010, 4 clubs left the study (3 due to relegation, 1 declined participation). In 2011, 6 new clubs were included (3 promoted from the 2nd league; 3 clubs that declined to participate in 2010 entered the study). AT and NG club cohorts had similar characteristics (table 1). All AT surfaces in this study held the Fédération Internationale de Football Association (FIFA) recommended, two star licence.[3] Further details about the AT surfaces included in this study are presented in a web appendix (table 4).

All players with a first-team contract were eligible for inclusion. Participation was voluntary and could be ended at any time. From the clubs that entered the study, eight players from two clubs declined participation. New players who were injured at the start of each new season were included in the study, but their present injuries were not taken into account. Players who left the club before the end of a season were included for as long as they participated. One player generating any football exposure during one season was regarded as a player season.

Data collection

The development of the study design has been published previously.[13] A representative from each club's medical team was responsible for informing players about the study, and for reporting injury and exposure data to the research group. Individual participation of players in all training sessions and matches was registered in minutes. Three standardised forms were used. A baseline form was used to collect the player's age, height, weight, leg dominance (preferred kicking leg), playing position and previous severe injuries and surgery. The exposure form included club and national

team training and match exposures in minutes (according to AT, NG or any other surface). The injury form contained questions regarding injury date, return to play date, activity (type of match or training), injury type, injury location, injury mechanism and, for acute injuries, whether the injury occurred on AT, NG or other surface. The Swedish and the Norwegian research groups each appointed one controller who was responsible for data collection within their country. Identical manuals were distributed to all participating clubs, and controllers had continuous contact during the study period to ensure consistency of injury classification in Swedish and Norwegian data. Exposure and injury forms were sent to controllers on a monthly basis and were checked for completeness. Prompt feedback was sent regularly to all clubs in order to correct any missing or unclear data.

Definitions

Injury and exposure definitions harmonize with the consensus statement established for studying football injuries.[14] Briefly, a time loss injury definition was used, i.e. a physical complaint sustained during football training or match play leading to a player being unable to fully participate in future training or match play. A player was regarded as injured until he was declared fit by the medical team to be able to fully participate in all types of training and be available for match selection. Injuries were divided into acute injuries (sudden onset and known cause), and overuse injuries (insidious onset and no known trauma).[14] Injury severity was based on the number of days that elapsed from injury to return to play and were categorised into: slight injuries (0 days), minimal (1-3 days), mild (4–7 days), moderate (8-28 days), and severe injuries (>28 days). Clubs were defined as AT club or NG club according to the surface installed at their home venue.

Data analyses

Due to the fact that pre-season football activities was largely carried out on AT (Figure 2), and due to the difficulty in attributing overuse injuries to a specific match or training session, and thus a specific surface, only acute injuries during the competitive season were included when comparing injury rates on AT and NG at the individual player level.

Injury rate is expressed as the number of injuries/1000 exposure hours with 95% confidence interval (95% CI). For overuse injuries, the seasonal cumulative incidence rate (CIR) was calculated as the number of players sustaining at least one new overuse injury each season/total number of players participating each season x 100. One club changed surface in the middle of season 2010 and was therefore excluded in the CIR analyses. Mean value of CIR for seasons 2010 and 2011 was compared between groups. Groups were compared using a rate ratio (RR) for injury incidences and CIR, and significance was tested using z-statistics.[15]

For continuous normally distributed variables, groups were compared using the t-test. Mean values are presented with the corresponding standard deviation (SD). All analyses were two-sided and, due to the number of comparisons made, the significance level was set at $p<0.01$.

RESULTS

In total, 1063 match injuries and 1178 training injuries were registered during 48 922 match hours and 318 568 training hours. This resulted in a total cohort injury rate of 21.7/1000 match hours and 3.7/1000 training hours, regardless of playing surface. Data registered on surfaces other than AT and NG included 54 injuries during 12 match hours and 49 442 training hours (predominately conditioning and resistance training), and were not included in the following analyses.

Exposure and injury data for Swedish and Norwegian clubs

The Swedish clubs reported 559 match injuries during 25 774 match hours, and 627 training injuries during 142 590 training hours. The Norwegian clubs reported 503 match injuries during 23 136 match hours, and 498 training injuries during 126 535 training hours. There were no statistically significant differences in match injury rates (21.7 vs. 21.7/1000 hours, RR 1.00, 99% CI 0.85 to 1.17) or training injury rates (4.4 vs. 3.9/1000 hours, RR 1.12, 99% CI 0.96 to 1.30) between Swedish and Norwegian clubs.

Injury rates on artificial turf and natural grass

Overall, there were 156 381 hours of football exposure on AT (49%) and 161 655 hours on NG (51%) among all clubs included (figure 1). At the individual player level, there were no statistically significant differences in acute match or training injury rates when playing on AT compared to NG (table 2). When analysing specific injury types, a lower rate of lower leg muscle injuries ($p=0.03$) during match play was found on AT, and similarly in training, lower rates of lower extremity muscle injuries ($p=0.05$) and, specifically, hamstring muscle injuries ($p=0.01$) were seen on AT (table 2), whereas the rate of contusion was higher ($p<0.001$).

Injury rates in AT clubs compared to NG clubs

Clubs with AT had a total of 85 767 hours exposure on AT (83%) and 17 966 hours on NG (17%), whereas clubs with NG had 70 614 hours exposure on AT (33%) and 143 689 hours on NG (67%) (figure 1). AT clubs had a statistically significantly higher acute training injury rate compared to NG clubs, and the same tendency was seen for the match injury rate (table 3, figure 3). The AT clubs increased injury rates were observed for minimal and mild injury. When analysing specific injury types, AT clubs had significantly higher rates of contusion and muscle/tendon injury (table 3). In detail, AT clubs had a higher rate of overuse muscle/tendon injury (RR 1.51, 99% CI 1.21 to 1.89) while no differences were found in acute muscle/tendon injury rates in training (RR 0.98, 99% CI 0.67 to 1.45) or match play (RR 1.22, 99% CI 0.89 to 1.68). AT clubs had a 38% higher total overuse injury rate compared to NG clubs ($p<0.001$) (table 3). The mean seasonal CIR for overuse injury was 40% in AT clubs vs. 32% in NG clubs (RR 1.24, 95% CI 1.08 to 1.43).

When analysing injury rates according to surface, AT clubs had higher injury rates than NG clubs on both playing surfaces; match play on AT (17.4 vs. 13.2/1000 hours, RR 1.31, 99% CI 0.91 to 1.91), match play on NG (20.9 vs. 15.2/1000 hours, RR 1.38, 99% CI 1.01 to 1.89), and training on AT (2.2 vs. 1.5/1000 hours, RR 1.46, 99% CI 0.88 to 2.41). There was no difference in acute training injury rate on NG between AT clubs and NG clubs (1.7 vs. 1.8/1000 hours, RR 0.95, 99% CI 0.41 to 2.20).

When the two countries were analysed separately, a more prominent difference in acute injury rates between AT clubs and NG clubs was evident for Sweden (match play 19.6 vs. 15.0/1000 hours, RR 1.31, 99% CI 0.99 to 1.72; training 3.0 vs. 2.0/1000 hours, RR 1.50, 99% CI 1.10 to 2.04) compared to Norway (match play 16.8 vs. 15.4/1000 hours, RR 1.09, 99% CI 0.83 to 1.43; training 2.2 vs. 1.8/1000 hours, RR 1.19, 99% CI 0.86 to 1.66).

DISCUSSION

The main findings in this study were that, at the individual level, no differences in acute injury rates were found when playing on AT compared to NG in the total cohort analysis. However, at club level, professional football clubs with AT installed at their home venue had a higher acute training injury rate and overuse injury rate compared to clubs with NG at their home venue.

No difference in acute injury rates on artificial turf vs. natural grass

No significant difference in acute injury rate on third-generation AT compared to NG was found in this study. This is in accordance with previous studies in elite male football, [9-11] but differ from newly published results in the American football code, were higher rates of ankle and knee sprains (including anterior cruciate ligament injuries) have been found on artificial turf.[16,17] The pattern with a lower rate of muscle injuries when playing on AT is in accordance with a previously studied cohort of European elite clubs.[9,11] In that cohort, an increased rate of ankle sprain was reported on AT compared to NG,[11] while in the present study similar rates of ankle sprain were found between surfaces, thus replicating the findings from a previous study on Norwegian elite clubs.[10] The European cohort, followed during a period when AT was progressively being introduced for competitive elite matches, consisted of a mixture of ATs with and without FIFA license, whereas the Norwegian cohort and the present study included only FIFA-licensed ATs. Therefore, the fact that no increased rate of ankle sprain was evident in the latter two cohorts could be interpreted as a continuous improvement in the quality of AT playing surfaces used in football. In the present study, a higher rate of contusion was found on AT. Interestingly, it has been reported that short passes are more common on AT than on NG, and that players report difficulties in carrying out technical manoeuvres at high speed on AT.[18] These observations suggest a difference in playing style between AT and NG, which could possibly explain the slight differences in injury patterns between surfaces.

Increased injury rates for clubs with artificial turf at their home venue.

An increased injury rate was observed for clubs with AT installed at their home venue. However, this increased injury rate for AT clubs was evident on both playing surfaces, and it is thus unlikely that this can be attributed to high AT exposure per se. A plausible explanation for the higher injury rate is a rapid switching between playing surfaces and inadequate adaptation to a new surface, which has been proposed as a risk factor for injury, especially overuse injury.[12,19] Since there were fewer AT clubs than NG clubs in this cohort, players from AT clubs had to alternate between surfaces more often when playing away matches. It is possible that such frequent shifts between surfaces could lead to a greater load on musculoskeletal tissues and an increased overuse injury rate. In support of this, a higher match injury rate for AT clubs was only evident during the competitive season when switching between surfaces at away matches occurred frequently, while match injury rates were similar during the pre-season, when most friendly matches were played on AT (figure 3, table 3). The increased injury rates for AT clubs were also most pronounced among the Swedish clubs. This could have been due to the relatively fewer AT clubs in Sweden (4/16 clubs) compared to Norway (7/16), causing the Swedish AT club players to switch more frequently between surfaces.

Sweden and Norway are located in the northern part of Europe and cross several climate zones.[20] Previous studies have shown higher injury rates in clubs from the most northern (coldest) regions: among female players in Sweden[21] and among male players in various European countries.[22] It is possible that clubs with AT installed at their home venue could have chosen this surface because of a generally colder climate, which itself could influence injury rates. When considering clubs according to their climate zone, 67% of AT clubs (8/12) were located in the cold climate zone, while the equivalent figure for NG clubs was 24% (5/21). Therefore, the role of climate as a potential risk factor for football injury when evaluating injury rates on

different surface types should be addressed in future studies. It is also possible that clubs chose AT turf at their home venue because of the saving in costs. Consequently, differences in club economy could be another contributing factor to the differences in injury rates observed.

Methodological considerations

The obvious strength of this study is the homogenous sample of professional football players in a setting where about one-third of the clubs had AT installed at their home venue, thus enabling detailed analysis of injury patterns in AT clubs compared to NG clubs. The registration of individual player exposure allowed for a detailed data check. Any missing or inaccurate data were immediately corrected after contact between the research group and the club medical team, thereby increasing the internal validity of the study. Moreover, the participation rate among clubs was high, thus increasing the external validity. Pre-season training in Scandinavian football, characterised by a heavy training load, is mainly performed on AT. Therefore, an important methodological consideration was to only include data from the competitive season when comparing injury rates on AT with those on NG.

This study has some limitations. First, when using a time loss injury definition, the frequency and severity of overuse injuries is likely to be underestimated.[23] However, there is no obvious reason why the magnitude of any such underestimation should differ between AT and NG clubs. The differences in overuse injury rates observed in this study are therefore considered to be valid.

Second, despite the relatively large study sample, Type II errors cannot be ruled out for sub-analyses of specific injury patterns, as shown by the sometimes wide confidence intervals.

Third, in this study, as in previous studies comparing injury rates on AT and NG, distinctions were made between these two general surface types only. All AT surfaces were analysed together, even though various brands were included. Similarly, no regard was taken to the

quality of the NG pitches, even though pitch quality is likely to differ between venues due to variations in weather, maintenance etc.

Finally, high frictional forces between the foot and the playing surface is a proposed risk factor for injury, and experimental studies have shown that peak torques vary between different shoe types.[24] However, due to the practical problems of registering shoe type, not only at injury but during all activities, the specific influence of shoe type on injury occurrence was not evaluated in this study.

Conclusion

This study supported the findings of previous research showing that there is no overall difference in acute injury rate when playing professional football on AT or NG. However, clubs with AT installed at their home venue had a higher rate of acute training injury and overuse injury than NG clubs. The reason for the latter finding could not be established in this study, but the potential influence of frequent switching between surfaces and different climates should be the subject of further research.

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Contributor statement

MW, TEA, JE, and MH were responsible for the conception and design of the study. KK and JB have been involved in the data collection. KK conducted the analyses which were planned and checked with the co-authors. All authors contributed to the interpretation of findings and had full access to all data. KK wrote the first draft of the paper which was critically revised by JB, MW, TEA, JE, and MH. The final manuscript has been approved by all authors. MH is the study guarantor.

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Competing interests

None.

Ethical approval

The study protocol was approved by the Local Ethics Committees in Linköping, Sweden and Region Øst-Norge and the Norwegian Social Science Data, Norway, respectively.

Provenance and peer review

Not commissioned; externally reviewed.

SUMMARY BOX

What are the new findings

- No statistically significant difference was found in total acute injury rate when playing on artificial turf compared to natural grass.
- Professional football clubs with artificial turf installed at their home venue had a higher rate of acute training injuries and overuse injuries compared to clubs with natural grass.

How might it impact clinical practice in near future

- Overuse injuries are difficult to ascribe to a certain inciting event due to their insidious onset by nature. Based on the results of this study, professional football clubs playing on different surfaces are recommended to monitor the effects of frequent alterations between playing surfaces and to ensure adequate adaptation to the new playing surface in order to avoid overuse injury.

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TABLE AND FIGURE LEGENDS

Table 1 Cohort characteristics for clubs with artificial turf and natural grass at their home venue.

Table 2 Acute match and training injury rates when playing on artificial turf compared to natural grass for all clubs included.

Table 3 Comparison of injury rates between clubs with artificial turf and clubs with natural grass at their home venue.

Table 4 Details of the 12 clubs with artificial turf at their home venue**.**

Figure 1 Flowchart of study design and analysis. AT, artificial turf; NG, natural grass.

*One club (27 players) shifted from NG to AT during the first season 2010 and was after that regarded as an AT club.

† Total match and training exposure data also include 12 match hours and 49 442 training hours carried out on other surfaces than artificial turf and natural grass.

Figure 2 Aggregated match and training exposure on artificial turf and grass throughout the season for all clubs included.

Figure 3 Match and training injury rates over the season, according to the clubs' home surface; artificial turf (AT) and natural grass (NG).

Table 1 Cohort characteristics for clubs with artificial turf and natural grass at their home venue.

	Surface at home venue	
	Artificial turf	**Natural grass**
Club seasons	18	37
Player seasons	496	1011
Cohort characteristics[†]		
Age (years)	25.2 (5.0)	25.0 (4.9)
Height (cm)	182.5 (6.2)	182.7 (6.4)
Weight (kg)	78.2 (6.8)	78.3 (7.1)
Training hours[‡]	202 (83)	216 (88)*
Match hours[‡]	33 (20)	32 (20)

*$p<0.05$.

[†]Values are mean (standard deviation).

[‡]Mean exposure/player/season.

Table 2 Acute match and training injury rates when playing on artificial turf compared to natural grass for all clubs included.

	Acute match injuries					Acute training injuries				
	Artificial turf		Natural grass			Artificial turf		Natural grass		
	N	Injury rate (95% CI)	N	Injury rate (95% CI)	Rate Ratio (99% CI)	N	Injury rate (95% CI)	N	Injury rate (95% CI)	Rate Ratio (99% CI)
Total acute injury rate	222	15.8 (13.9 to 18.0)	392	16.1 (14.6 to 17.8)	0.98 (0.79 to 1.22)	153	2.0 (1.7 to 2.4)	199	1.8 (1.6 to 2.1)	1.14 (0.86 to 1.50)
Injury severity										
Slight	2	0.1 (0.0 to 0.6)	4	0.2 (0.1 to 0.4)	0.86 (0.09 to 8.04)	9	0.1 (0.1 to 0.2)	0	-	-
Minimal	49	3.5 (2.6 to 4.6)	53	2.2 (1.7 to 2.9)	1.60 (0.96 to 2.66)	38	0.5 (0.4 to 0.7)	41	0.4 (0.3 to 0.5)	1.37 (0.77 to 2.45)
Mild	52	3.7 (2.8 to 4.9)	85	3.5 (2.8 to 4.3)	1.06 (0.67 to 1.66)	32	0.4 (0.3 to 0.6)	37	0.3 (0.2 to 0.5)	1.28 (0.69 to 2.38)
Moderate	84	6.0 (4.8 to 7.4)	167	6.9 (5.9 to 8.0)	0.87 (0.62 to 1.23)	47	0.6 (0.5 to 0.8)	74	0.7 (0.5 to 0.8)	0.94 (0.58 to 1.52)
Severe	35	2.5 (1.8 to 3.5)	83	3.4 (2.8 to 4.2)	0.73 (0.43 to 1.22)	27	0.4 (0.3 to 0.5)	47	0.4 (0.3 to 0.6)	0.85 (0.46 to 1.58)
Injury type										
Fractures/bone stress	11	0.8 (0.4 to 1.4)	19	0.8 (0.5 to 1.2)	1.00 (0.38 to 2.66)	5	0.1 (0.03 to 0.2)	10	0.1 (0.05 to 0.2)	0.74 (0.18 to 3.03)
Joint/ligament	62	4.4 (3.4 to 5.7)	112	4.6 (3.8 to 5.6)	0.96 (0.64 to 1.44)	57	0.8 (0.6 to 1.0)	74	0.7 (0.5 to 0.8)	1.14 (0.72 to 1.80)
Knee	24	1.7 (1.1 to 2.5)	55	2.3 (1.7 to 2.9)	0.75 (0.40 to 1.42)	18	0.2 (0.2 to 0.4)	32	0.3 (0.2 to 0.4)	0.83 (0.39 to 1.78)
Ankle	32	2.3 (1.6 to 3.2)	44	1.8 (1.3 to 2.4)	1.26 (0.69 to 2.29)	32	0.4 (0.3 to 0.6)	37	0.3 (0.2 to 0.5)	1.28 (0.69 to 2.38)
Muscle/tendon	78	5.6 (4.4 to 6.9)	158	6.5 (5.6 to 7.6)	0.85 (0.60 to 1.22)	46	0.6 (0.5 to 0.8)	93	0.8 (0.7 to 1.0)	0.73 (0.46 to 1.17)
Hip/groin	18	1.3 (0.8 to 2.0)	42	1.7 (1.3 to 2.3)	0.74 (0.36 to 1.53)	15	0.2 (0.1 to 0.3)	22	0.2 (0.1 to 0.3)	1.01 (0.43 to 2.39)
Quadriceps	8	0.6 (0.3 to 1.1)	15	0.6 (0.4 to 1.0)	0.92 (0.30 to 2.85)	8	0.1 (0.1 to 0.2)	11	0.1 (0.1 to 0.2)	1.08 (0.33 to 3.56)
Hamstring	44	3.1 (2.3 to 4.2)	70	2.9 (2.3 to 3.6)	1.09 (0.66 to 1.78)	10	0.1 (0.1 to 0.2)	37	0.3 (0.2 to 0.5)	0.40 (0.16 to 1.00)
Lower leg	4	0.3 (0.1 to 0.8)	22	0.9 (0.6 to 1.4)	0.31 (0.08 to 1.27)	4	0.1 (0.02 to 0.1)	17	0.2 (0.1 to 0.2)	0.35 (0.08 to 1.46)
Contusions	56	4.0 (3.1 to 5.2)	78	3.2 (2.6 to 4.0)	1.24 (0.79 to 1.95)	41	0.5 (0.4 to 0.7)	15	0.1 (0.1 to 0.2)	4.05 (1.86 to 8.80)
Lacerations/skin lesion	1	-	3	-	-	1	-	3	-	-
CNS/PNS	14	1.0 (0.6 to 1.7)	16	0.7 (0.4 to 1.1)	1.51 (0.59 to 3.88)	1	-	4	-	-
Concussion	13	0.9 (0.5 to 1.6)	16	0.70 (0.4 to 1.1)	1.40 (0.54 to 3.67)	1	-	3	-	-

Injury rate is expressed as the number of injuries/1000 hours. Natural grass is used as the reference group. Data from competitive season (April to November)are included.

CNS, central nervous system; PNS, peripheral nervous system; CI, confidence interval.

Table 3 Comparison of injury rates between clubs with artificial turf and clubs with natural grass at their home venue.

	Surface at home venue				
	Artificial turf		Natural grass		
	N	Injury rate (95% CI)	N	Injury rate (95% CI)	Rate ratio (99% CI)
Total season					
Acute training injury	213	2.5 (2.2 to 2.9)	355	1.0 (1.7 to 2.1)	1.31 (1.04 to 1.63)
Acute match injury	292	17.9 (15.9 to 20.0)	493	15.1 (13.9 to 16.5)	1.18 (0.98 to 1.43)
Overuse injury	326	3.2 (2.9 to 3.6)	508	2.3 (2.1 to 2.6)	1.38 (1.14 to 1.65)
Pre-season*					
Acute training injury	84	3.3 (2.6 to 4.0)	132	2.3 (2.0 to 2.8)	1.40 (0.98 to 2.01)
Acute match injury	54	15.5 (11.8 to 20.2)	117	16.5 (13.8 to 19.8)	0.94 (0.61 to 1.43)
Competitive season†					
Acute training injury	129	2.2 (1.8 to 2.6)	223	1.7 (1.5 to 2.0)	1.25 (0.94 to 1.67)
Acute match injury	238	18.5 (16.3 to 21.0)	376	14.8 (13.3 to 16.3)	1.25 (1.01 to 1.55)
Injury severity					
Slight	20	0.2 (0.1 to 0.3)	23	0.1 (0.07 to 0.2)	1.87 (0.85 to 4.10)
Minimal	193	1.9 (1.7 to 2.2)	277	1.3 (1.1 to 1.4)	1.50 (1.17 to 1.90)
Mild	211	2.1 (1.8 to 2.4)	306	1.4 (1.3 to 1.6)	1.48 (1.18 to 1.96)
Moderate	270	2.7 (2.4 to 3.0)	492	2.3 (2.1 to 2.5)	1.18 (0.97 to 1.43)
Severe	137	1.4 (1.1 to 1.6)	254	1.2 (1.0 to 1.3)	1.16 (0.88 to 1.52)
Injury type					
Fractures/bone stress	31	0.3 (0.2 to 0.4)	59	0.3 (0.2 to 0.4)	1.13 (0.64 to 2.00)
Joint/ligament	185	1.8 (1.6 to 2.1)	369	1.7 (1.5 to 1.9)	1.08 (0.85 to 1.36)
Muscle/tendon	393	3.9 (3.5 to 4.3)	631	2.9 (2.7 to 3.1)	1.34 (1.13 to 1.58)
Contusions	141	1.4 (1.2 to 1.6)	148	0.7 (0.6 to 0.8)	2.04 (1.51 to 2.77)
Lacerations/skin lesion	7	0.07 (0.03 to 0.15)	11	0.05 (0.03 to 0.09)	1.37 (0.39 to 4.74)
CNS & PNS	19	0.2 (0.1 to 0.3)	37	0.2 (0.1 to 0.2)	1.10 (0.53 to 2.28)
Other	54	0.5 (0.4 to 0.7)	101	0.5 (0.4 to 0.6)	1.15 (0.74 to 1.77)
Overuse injury location‡					
Hip/adductors	75	0.7 (0.6 to 0.9)	102	0.5 (0.4 to 0.6)	1.58 (1.07 to 2.34)
Hamstrings	28	0.3 (0.2 to 0.4)	48	0.2 (0.2 to 0.3)	1.25 (0.68 to 2.31)
Calf	18	0.2 (0.1 to 0.3)	9	0.04 (0.02 to 0.08)	4.29 (1.50 to 12.28)
Patellar tendon	13	0.1 (0.07 to 0.2)	18	0.08 (0.05 to 0.1)	1.55 (0.61 to 3.96)
Lower back	13	0.1 (0.07 to 0.2)	20	0.09 (0.06 to 0.1)	1.40 (0.56 to 3.49)
Achilles tendon	8	0.08 (0.04 to 0.2)	24	0.1 (0.07 to 0.2)	0.72 (0.25 to 2.05)
Knee (excluding tendons)	8	0.08 (0.04 to 0.2)	23	0.1 (0.07 to 0.2)	0.75 (0.26 to 2.15)
Quadriceps	8	0.08 (0.04 to 0.2)	12	0.06 (0.03 to 0.1)	1.43 (0.44 to 4.46)
Iliotibial band of the knee	6	0.06 (0.03 to 0.1)	6	0.03 (0.01 to 0.06)	2.15 (0.49 to 9.49)

Injury rate is expressed as the number of injuries/1000 hours. Natural grass clubs are used as the reference group.

*January to Mars. †April to November. ‡Most common overuse injury locations.

CNS, central nervous system; PNS, peripheral nervous system; CI, confidence interval.

Table 4 Details of the 12 clubs with artificial turf at their home venue**.**

Country	Club	Arena	Type of arena	Producer	FIFA licence
Sweden	Gefle IF	Strömvallen	Outdoor	Saltex	**
	IF Elfsborg	Borås Arena	’’	Fieldturf	**
	IFK Norrköping	Idrottsparken	’’	Polytan	**
	Åtvidabergs FF	Kopparvallen	’’	Greenfields	**
	Örebro SK	Behrn Arena	’’	Mondo	**
Norway	Aalesunds FK	Color Line Stadium	’’	Greenfields	**
	Hønefoss BK	AKA Arena	’’	Fieldturf	**
	Odd Grenland BK	Skagerak Arena	’’	Fieldturf	**
	Sarpsborg 08 FF	Sarpsborg Stadion	’’	Fieldturf	**
	Strømsgodset Drammen	Marienlyst Stadion	’’	Saltex	**
	Tromsø IL	Alfheim Stadion	’’	Fieldturf	**
	Stabæk Fotball	Telenor Arena	Indoor	Fieldturf	**

** Qualified for the Fédération Internationale de Football Association (FIFA) recommended 2 star mark

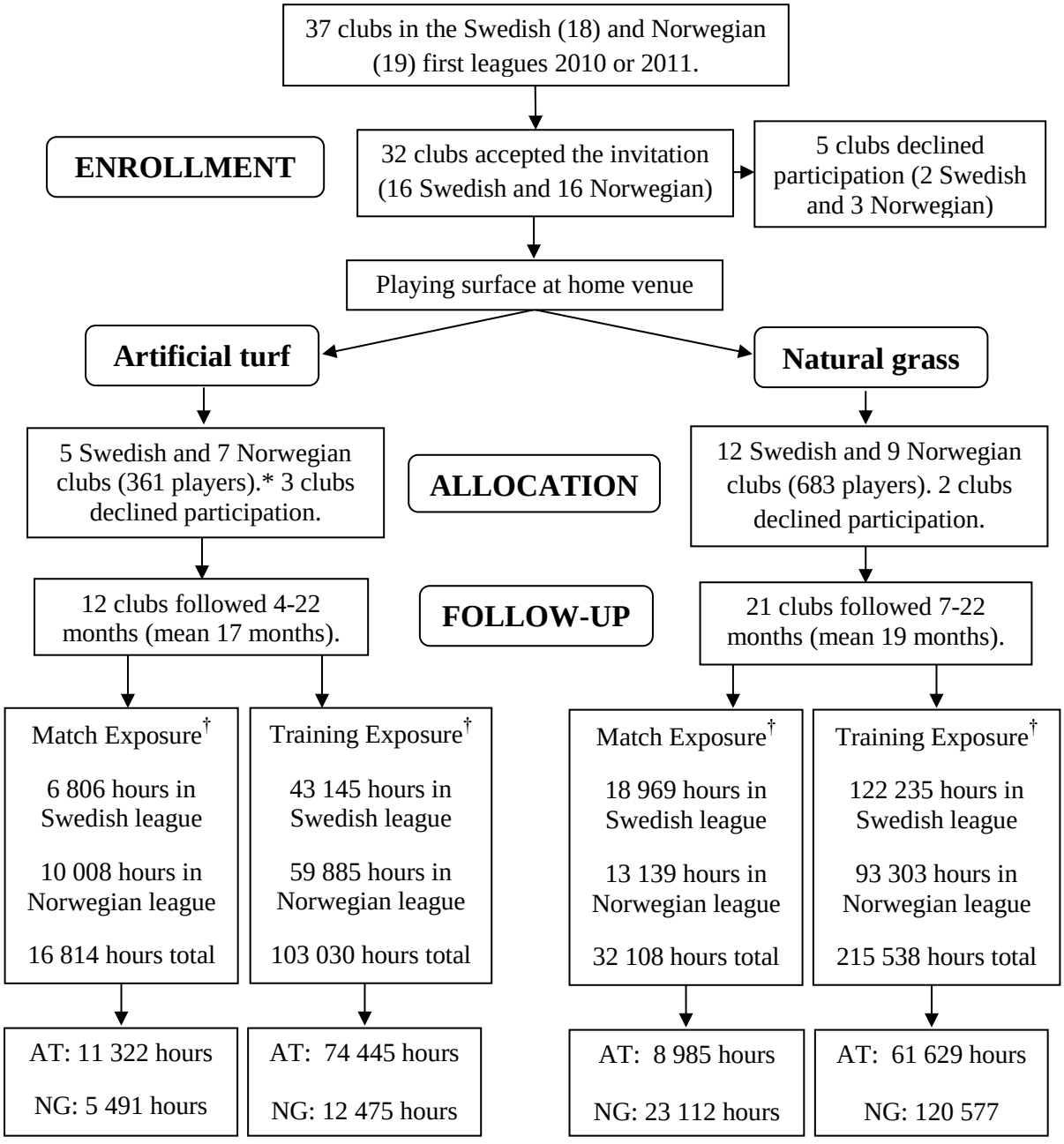

Figure 1 Flowchart of study design and analysis. AT, artificial turf; NG, natural grass.

*One club (27 players) shifted from NG to AT during the first season 2010 and was after that regarded as an AT club.

†Total match and training exposure data also include 12 match hours and 49 442 training hours carried out on other surfaces than artificial turf and natural grass.

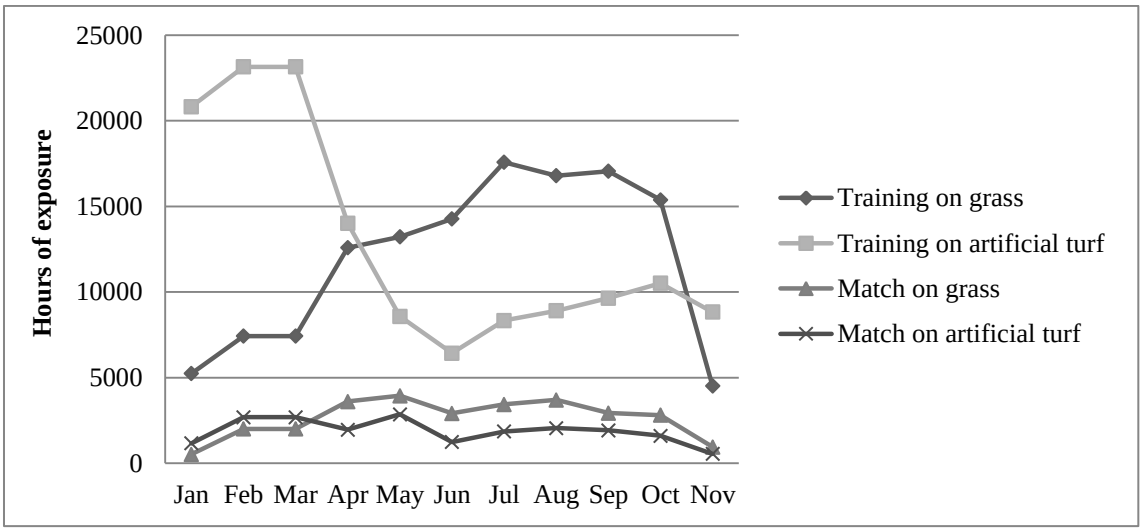

Figure 2 Aggregated match and training exposure on artificial turf and grass throughout the season for all clubs included.

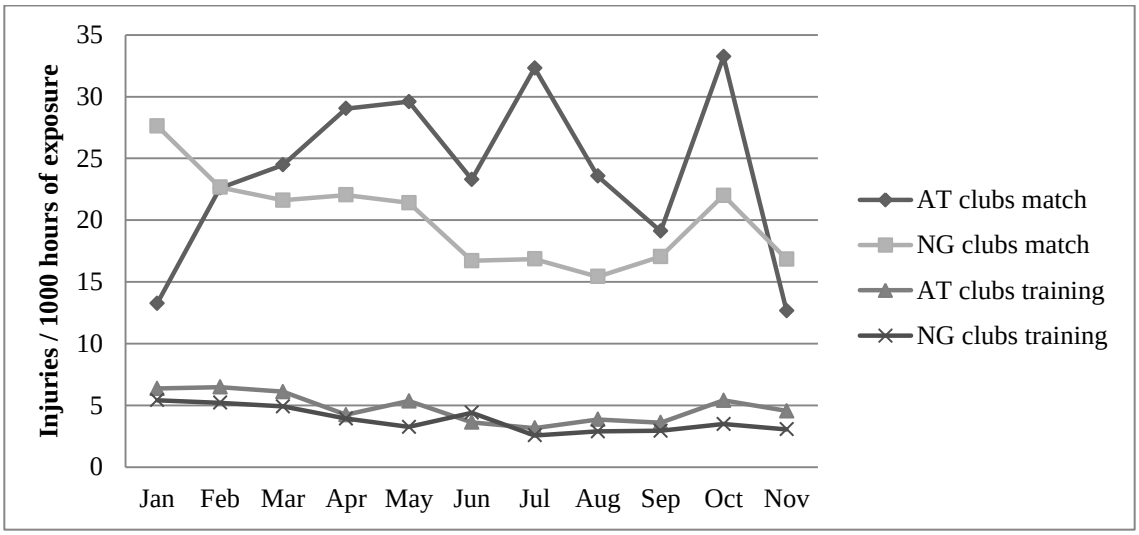

Figure 3 Match and training injury rates over the season, according to the clubs' home surface; artificial turf (AT) and natural grass (NG).