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Playing football on artificial turf as a risk factor for fifth metatarsal stress fracture: a retrospective cohort study

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ABSTRACT

Objective The fifth metatarsal stress fracture is a common injury among football players. Although several risk factors have been proposed, the association between the playing surface and development of fifth metatarsal stress fractures (MT-5) has not been evaluated. We conducted an epidemiological study using a computer-based survey to investigate the association between the playing surface and development of MT-5.

Methods This study included 1854 football players, of which 41 experienced MT-5 within the past 24 months. Baseline demographic data and the percentage of time spent playing on artificial turf and clay fields were compared between the non-MT-5 and MT-5 player groups, and the risks for development of MT-5 associated with the playing surfaces were estimated by univariate and multivariate analyses.

Results There were significant differences in body mass index, years of play, playing categories and playing time on artificial turf between non-MT-5 and MT-5 groups ($p<0.05$). Generalised estimating equations analyses adjusted for multiple confounders demonstrated that relative to the risk of playing <20% of the time on each surface, the OR (OR: 95% CI) for MT-5 for playing on artificial turf >80% of the time increased (3.44: 1.65 to 7.18), and for playing on a clay field 61%–80% of the time, the OR decreased (0.25: 0.11 to 0.59).

Conclusions A higher percentage of playing time on an artificial turf was a risk factor for developing MT-5 in football players. This finding could be beneficial for creating strategies to prevent MT-5.

Strengths and limitations of this study

- This is the first study to demonstrate the relationship between development of the fifth metatarsal stress fracture (MT-5) and the use of artificial turf among football players.
- The study sample was taken from a wide range of playing categories and included a large cohort of subjects.
- We demonstrated that the overall incidence rate of MT-5 was 0.02/1000 PH, with almost two-thirds of the players affected on their non-dominant leg.
- We demonstrated that MT-5 was associated with playing on artificial turf, and the risks increased as much as three times for players who played on artificial turf >80% of the total time relative to the risk for players who played 0%–20%.
- The major limitations of this study are recall bias and the potential confounders which were not included in this model.

INTRODUCTION

Fifth metatarsal stress fracture (MT-5) commonly occurs in football (soccer) players who are required to perform fast repetitive movements, including sprinting, stopping and cutting manoeuvres.[1] Zone II and III in Torg's classification are common fracture sites, and fractures are sometimes referred to as Jones fractures.[2 3] MT-5 has been considered a potential career-ending injury causing 3–5 months of absence from playing football, and it occasionally refractures even after return to play.[4] A previous European study demonstrated that although this stress fracture was rare (0.5% of all injuries) in football players, 78% of these stress fractures were associated with MT-5.[5] Although the incidence of MT-5 among Japanese football players has been estimated to be 0.1–0.12/1000 athlete exposures (1000AEs),[6] another study indicated that 4.1% (5/127 injured players) had suffered MT-5.[7] Because of the relatively high incidence of MT-5 compared with other kinds of stress fractures, identifying risk factors of MT-5 is essential to generate a preventive strategy for football players.

A number of studies have proposed risk factors for MT-5. Previous studies have reported an association with age and sex,[4 8 9] and an anatomical study advocated that the characteristics of articulating the fifth metatarsal to the cuboid, immobilisation of a lateral band of the plantar fascia and the stiffness of the peroneus brevis were also possible mechanisms of MT-5.[3] One clinical study found an association between lack of serum 25-hydroxyvitamin D levels and MT-5.[10] Other studies have reported biomechanical factors, such as the vertical and lateral stress of the fifth metatarsal during weight bearing and physical factors associated with forefoot adduction, reduced range of hip internal rotation and toe grip strength.[6 7]

However, there is limited scientific information in relation to external factors, such as types of surface, spike cleats and frequency of training, which are also considered risks factors for developing MT-5 in football players. Studies have suggested that playing football on artificial turf produced more non-contact injuries of the lower extremities than those produced by playing on natural grass,[11 12] whereas the severity and incidence of knee and ankle injuries were reported to be significantly lower when using shoes with lower friction properties on artificial turf in American football players.[1] Presently, most players play on various field surfaces, including clay, natural grass, artificial turf and indoor sports flooring. While professional football players usually play on natural grass, college and high school players mainly play on artificial turf or clay fields. Although concerns exist for developing MT-5 by creating higher plantar pressures during football-specific movements,[13 14] a recent small study suggested no association between types of surface and spike cleats for MT-5.[6] Investigating the levels of risk associated with these factors for MT-5 in a large cohort of football players is urgently needed to inform future prevention strategies.

The primary aim of this study was to investigate the incidence of medically diagnosed MT-5 in a large cohort of football players. A secondary aim was to assess artificial turf as a risk factor for MT-5 by investigating any association between the incidence of MT-5 and the amount of time played on artificial turf.

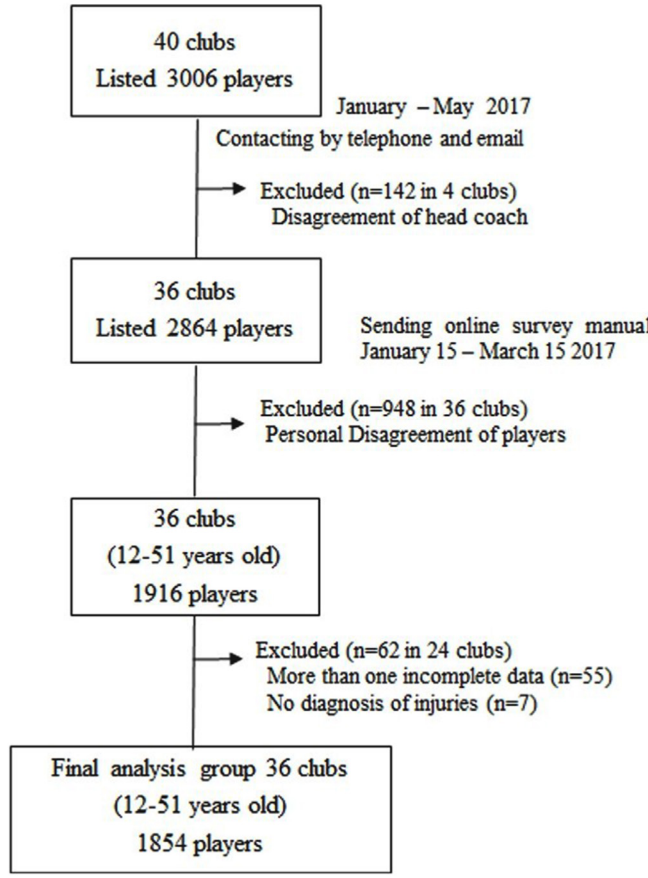

Figure 1 Flowchart of participant recruitment and screening.

MATERIALS AND METHODS

Subjects

A total of 3006 competitive-level male and female football players aged from 12 to 51 years in 40 clubs from the Kansai and the Kanto area, Japan, in different categories that belonged to the Japan Football Association were invited to participate in this study in 2017. A survey was sent to head coaches, club physicians or physiotherapists who observed players answering the questions. After providing informed consent to participate in the study, the players were supervised by team coaches, physicians and/or physiotherapists to complete the survey. All of the football facilities used third-generation or fourth-generation long-pile artificial turf. The exclusion criteria were failure to provide informed consent to complete the survey and the MT-5 without a physician's diagnosis. Additionally, if there was more than one incomplete response to the questions, that individual's data were not included in the analysis. The inclusion and exclusion criteria used are shown in figure 1.

Questionnaire

A computer-based survey was created. The participants were asked to answer questions by using their mobile phone after reading the instructions. The questions included demography, such as age, sex, height, weight, years of play, playing category and leg dominance. The medical factors were history of moderate injuries and MT-5, and who and when diagnosed. The environmental factors were the frequency of use of surfaces and type of spike cleats over the previous 24 months. For playing time on artificial or clay surface, percent of the total playing time was used. For the spike cleats, we defined the shape of studs into three types: blade (quadrangle included), circle and other types (very low or non-studs). From the answers to questions on items of training/match hours per day, frequency of training/match per week and absence of training/match per day over the previous 24 months, the total hours of training were calculated, and the number of injuries per 1000 player hours (1000 PH) was used to evaluate the incidence of MT-5.[5] To identify the reliability of the self-reported questionnaire, a sample of convenience, including 50 participants from across all categories, was randomly assigned to complete the survey a second time 1 week after the date of their first completion.[15 16]

Injury severity was defined as the number of days which have elapsed between the date of injury and the date of the return to full participation in team training.[17] We defined moderate and severe injuries as acute or overuse football-related injuries resulting in >15 days absence from the normal training. An acute injury was further defined as one that suddenly or accidentally occurred during training or competitive games, and the term 'overuse' was defined as injuries related to repetitive exercise and movements that caused worsening of pain.

Statistical analyses

Statistical analyses were performed by using IBM SPSS V.24 (IBM Corp, Chicago, Illinois, USA) and Stata V.14 (StataCorp LLC, Texas, USA). Agreement between athlete responses was measured by using intraclass correlation coefficients (ICC) and kappa statistics. The normality tests were performed by Shapiro-Wilk test. Parametric statistical tests were used where appropriate to compare the demographic baseline measures between the groups with and without MT-5 over the previous 24 months. The risk associated with the percentage of playing time on artificial turf or clay field for developing MT-5 was determined with the univariate logistic regression model, and generalised estimating equations (GEE) model for

Table 1 Comparison of demographic and baseline variables between the non-MT-5 and MT-5 group

	All participants (n=1854)		Non-MT-5 (n=1813)		MT-5 (n=41)		P value
Age (years), mean (SD)	18.66	(3.88)	18.64	(3.87)	19.68	(4.31)	0.088
Female, n (%)	113	(6.09)	112	(6.18)	1	(2.44)	0.323
Height (cm), mean (SD)	171.40	(6.44)	171.38	(6.45)	172.10	(5.88)	0.499
Weight (kg), mean (SD)	63.47	(7.39)	63.41	(7.39)	65.73	(6.99)	0.046*
BMI (kg/m^2), mean (SD)	21.55	(1.77)	21.54	(1.75)	22.14	(1.36)	0.031*
Years of play, mean (SD)	11.58	(4.29)	11.54	(4.27)	13.34	(4.82)	0.008**
Playing categories (age range), n (%)							0.013*
Junior high school (12–15)	24	(1.29)	23	(1.27)	1	(2.44)	
High school (15–18)	797	(42.99)	792	(43.68)	5	(12.20)	
College (18–22)	942	(50.81)	908	(50.08)	34	(82.93)	
Semiprofessional (18–28)	57	(3.07)	57	(3.15)	0	(0)	
Senior (40–51)	25	(1.35)	24	(1.32)	1	(2.44)	
Professional (22–28)	9	(0.49)	9	(0.50)	0	(0)	
Number of moderate injuries/1000 PH, mean (SD)	1.92	(4.01)	1.92	(4.05)	2.10	(1.35)	0.771
History of MT-5, n (%)	87	(4.69)	46	(2.54)	41	(100)	
Total playing hours/year, mean (SD)	553.60	(150.96)	552.65	(150.74)	595.32	(156.44)	0.074
Playing time on artificial turf/time on all turf, n (%)							0.005**
0%–20%	639	(34.47)	632	(34.86)	7	(17.07)	
21%–40%	291	(15.70)	286	(15.77)	5	(12.20)	
41%–60%	186	(10.03)	181	(9.98)	5	(12.20)	
61%–80%	209	(11.27)	203	(11.20)	6	(14.63)	
81–100	529	(28.53)	511	(28.19)	18	(43.90)	
Playing time on clay field/time on all turf, n (%)							0.009**
0%–20%	736	(39.70)	713	(39.33)	23	(56.10)	
21%–40%	178	(9.60)	172	(9.49)	6	(14.63)	
41%–60%	267	(14.40)	262	(14.45)	5	(12.20)	
61%–80%	486	(26.21)	482	(26.59)	4	(9.76)	
81%–100%	187	(10.09)	184	(10.15)	3	(7.32)	
Types of spike cleats, n (%)							0.876
Blade (quadrangle included)	384	(20.71)	375	(20.68)	9	(21.95)	
Circle	1428	(77.02)	1397	(77.05)	31	(75.61)	
Others (very low or non-studs)	42	(2.27)	41	(2.26)	1	(2.44)	

Significant difference: p value <0.05*,<0.01**.
BMI, body mass index; MT-5, fifth metatarsal stress fracture.

Table 2 Playing categories and playing time on the type of surface

	Playing categories						
	Junior high school	High school	Collage	Semiprofessional	Senior	Professional	Total
Playing time on artificial turf/time on all turf, n							
0%–20%	6	467	148	12	5	1	639
20%–40%	10	180	86	6	8	1	291
40%–60%	8	61	105	6	6	0	186
60%–80%	0	34	155	13	5	2	209
80%–100%	0	55	448	20	1	5	529
Playing time on clay field /time on all turf, n							
0%–20%	0	87	605	33	4	9	736
20%–40%	8	58	99	5	8	0	178
40%–60%	6	159	87	7	8	0	267
60%–80%	10	356	109	7	3	0	486
80%–100%	0	137	42	5	2	0	187

multivariate analysis was used to control for time exposure to the surface. To control for several confounders at baseline, the following criteria were included in the final GEE model: age, sex, a history of MT-5, body mass index (BMI), years of play, playing hours per year and types of spike cleats. Sex, playing categories and types of spike cleats were created as categorical variables. Playing time on artificial/clay turf has been defined in both categorical and continuous variables depending on the statistical model employed and separate multivariate analysis was performed for continuous and categorical playing time and for each playing surface. A variable of playing hours per year was used for clustering. The level of statistical significance was set at p<0.05, and 95% CI were reported for all measures.

Patient and public involvement

Football (soccer) clubs and the players gave informed consent. However, no public organisations or institutions were directly involved in the study. The results will be disseminated by this publication.

RESULTS

Predictors of MT-5

A total of 36 of 40 clubs (2864 possible participants) agreed to participate in this study. After receiving information on the research purposes of the study, 1916 players provided informed consent to participate. Of these, a further 62 participants were removed according to the exclusion criteria, which resulted in data from 1854 (64.8%) players aged from 12 to 51 years (18.66±3.88) accepted for the statistical analysis. The ICC and kappa values for test-retest reliability were excellent (ICC range=0.85–0.98) and moderate to almost perfect (k range=0.51–0.85), respectively. Cronbach's alpha (0.71) indicated acceptable internal consistency. From this cohort, 87 participants had a history of MT-5, four of them had bilateral fractures and two suffered refractures. The non-dominant side was affected in 54 participants, 37 on the dominant leg. The number of participants with MT-5 in the past 24 months was 41 (27 on the non-dominant side). The incidence of MT-5 was 0.02/1000 PH (95% CI, 0.013 to 0.027). The demographic baseline data of the non-MT-5 and MT-5 groups are compared in table 1. Significant differences between the groups in weight, BMI, years of play, playing categories and playing time on artificial turf and on clay field were found. Data with playing categories and playing time on the type of surface are displayed in table 2.

Risk assessments of developing MT-5 between artificial turf and clay field

Table 3 shows the evaluated risk for MT-5 by univariate and multivariate OR with 95% CI. Figures 2–5 also show the relative risks for MT-5 by playing on artificial turf and clay surfaces relative to 0%–20% of the time. According to the univariate logistic regression model, playing football on an artificial turf was a risk factor for MT-5, with OR 1.01 (95% CI 1.00 to 1.02)/% of the playing time (p=0.009). The OR for athletes who played on the artificial turf >80% of their total playing time relative to the athletes playing 0%–20% of the time on the artificial turf was 3.18 (95% CI 1.32 to 7.67). In contrast, the risk for MT-5 decreased for athletes who played on clay surfaces, with OR 0.99 (95% CI 0.98 to 1.00)/% of the playing time. Additionally, the OR for playing on clay 61%–80% of the total playing time was 0.26 (95% CI 0.09 to 0.75) relative to the athletes playing 0%–20% of the total playing time on clay. After adjusting for several confounders, the risks of developing MT-5 for playing on artificial turf and on clay surfaces were similar, with OR 1.01 (95% CI 1.00 to 1.02) and 0.0.99 (95%CI 0.98 to 0.99)/% of the playing time, respectively. The OR was 3.44 (95% CI 1.65 to 7.18) for playing on artificial turf >80% of the total playing time. In contrast, the

Table 3 Univariate logistic regression analysis and multivariate generalised estimating equation analysis to investigate risk factors for MT-5

	Univariate			Multivariate					
				Artificial turf			Clay field		
	OR	(95% CI)	P value	OR	(95% CI)	P value	OR	(95% CI)	P value
Age	1.05	(0.99 to 1.11)	0.100	0.98	(0.89 to 1.07)	0.609	0.97	(0.89 to 1.07)	0.555
Sex (ref. male)	0.38	(0.05 to 2.79)	0.341	0.99	(0.40 to 2.43)	0.983	1.00	(0.41 to 2.45)	0.994
BMI	1.20	(1.02 to 1.42)	0.030*	1.15	(1.00 to 1.32)	0.048*	1.15	(1.00 to 1.32)	0.046*
Years of play	1.07	(1.02 to 1.13)	0.008*	1.06	(0.97 to 1.15)	0.220	1.06	(0.97 to 1.16)	0.199
History of the MT-5				0.10	(0.05 to 2.37	0.156	0.10	(0.04 to 2.35)	0.154
% playing time on artificial turf/time on all field types	1.01	(1.00 to 1.02)	0.009*	1.01	(1.00 to 1.02)	0.001**			
21–40 (ref. 0%–20%)	1.58	(0.50 to 5.02)	0.439	1.50	(0.65 to 3.45)	0.343	–	–	–
41–60 (ref. 0%–20%)	2.49	(0.78 to 7.95)	0.122	2.42	(1.02 to 5.74)	0.045*	–	–	–
61–80 (ref. 0%–20%)	2.67	(0.89 to 8.03)	0.081	2.77	(1.20 to 6.38)	0.017*	–	–	–
81–100 (ref. 0%–20%)	3.18	(1.32 to 7.67)	0.010*	3.44	(1.65 to 7.18)	0.001**	–	–	–
% playing time on clay field/time on all field types	0.99	(0.98 to 1.00)	0.012*				0.99	(0.98 to 0.99)	0.001**
21–40 (ref. 0%–20%)	1.08	(0.43 to 2.70)	0.867	–	–	–	0.82	(0.42 to 1.58)	0.791
41–60 (ref. 0%–20%)	0.59	(0.22 to 1.57)	0.293	–	–	–	0.51	(0.25 to 1.03)	0.062
61–80 (ref. 0%–20%)	0.26	(0.09 to 0.75)	0.013*	–	–	–	0.25	(0.11 to 0.59)	0.001*
81–100 (ref. 0%–20%)	0.51	(0.15 to 1.70)	0.271	–	–	–	0.42	(0.16 to 1.12)	0.084
Types of spike cleats (ref. blade)									
Circle	0.92	(0.44 to 1.96)	0.838	0.86	(0.52 to 1.41)	0.546	0.86	(0.52 to 1.41)	0.545
Others	1.02	(0.13 to 8.22)	0.988	0.92	(0.23 to 3.68)	0.910	0.94	(0.24 to 3.77)	0.934

Generalised estimating equation (GEE) analysis adjusted for age, sex, BMI, playing hours, history of the MT-5, playing time on artificial turf or clay field and types of spike cleats.
Estimated ORs for MT-5 for the percentage of playing time on artificial turf or clay field from postestimation analysis.
*Significant difference: p value <0.05; **p<0.01.
BMI, body mass index; MT-5, fifth metatarsal stress fracture; ref, reference point.

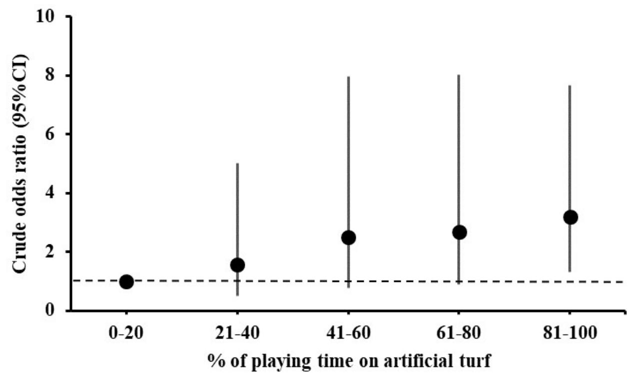

Figure 2 ORs and 95% CIs for fifth metatarsal stress fracture based on the percentage of playing time on artificial turf.

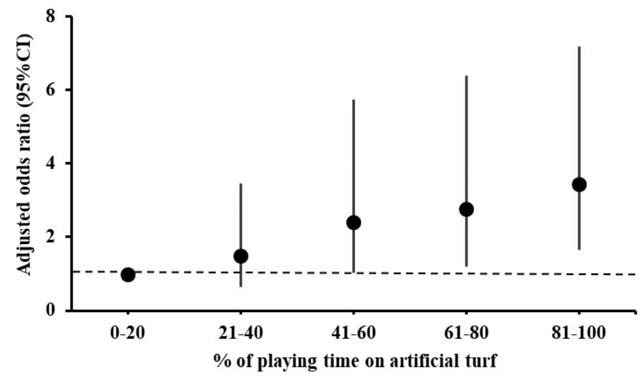

Figure 4 Adjusted ORs and 95% CIs for age, sex, body mass index, year of play, playing hours/year and spike cleats on artificial turf.

OR decreased to 0.25 (0.11–0.59) for playing on clay 61%–80% of the total playing time.

DISCUSSION

This study evaluated the incidence of MT-5 among football players from a wide range of playing categories and the association between MT-5 and the percentage of playing time on artificial turf and clay surfaces. The overall incidence rate of MT-5 was 0.02/1000 PH, with almost two-thirds of the players affected on their non-dominant leg. In addition, MT-5 was associated with playing time on artificial turf, and the risks increased as much as three times for players who played on artificial turf >80% of the total time relative to the risk for players who played 0%–20% of the total time. This is the first study to demonstrate the relationship between the risk of MT-5 and the use of artificial turf for football players.

Artificial turf has various advantages over natural grass and clay, which include lower maintenance costs and the ability to use the surface under several climate conditions as well as increasing players' running speed.[18 19] Recently, the Federation Internationale de Football Association has approved artificial turf as an official surface in international matches.[12] Newer generations of artificial turf, which have longer fibres and a sand infill, have been developed and are believed to more accurately mimic the characteristics of natural grass.[12 18] A few prospective studies among professional football athletes demonstrated that overall injury rates were not different between artificial turf and natural grass.[20–22] However, a prospective cohort study among elite football player demonstrated that the incidence of ankle sprain in artificial turf was higher than in natural grass.[18] Since injury surveillance is known to capture a small percentage of the overuse problems,[23] it is possible that no study has demonstrated the association between MT-5 and playing on artificial turf without targeting the specific injury.

Traditionally, football players from junior high school to college in Japan have mostly played on clay surfaces. Since 2001, a newer generation of artificial turf, called long-pile artificial turf, has been widely introduced and is presently played on by players of all skill levels,[24] whereas professional players usually play on natural grass. Artificial turf has become popular with high school and university football clubs for which the intensity of training is expected to be higher than that of lower academy environments. Given that many studies have speculated on

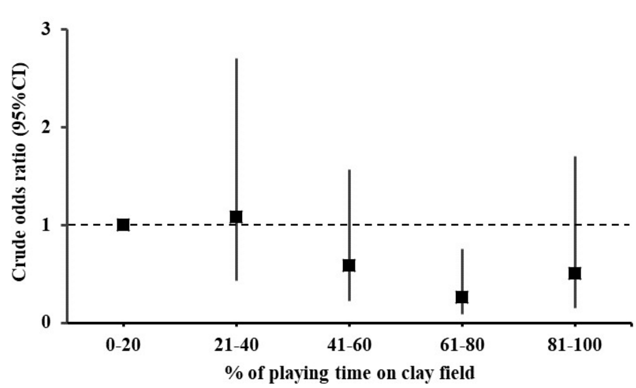

Figure 3 ORs and 95% CIs for fifth metatarsal stress fracture based on the percentage of playing time on clay field.

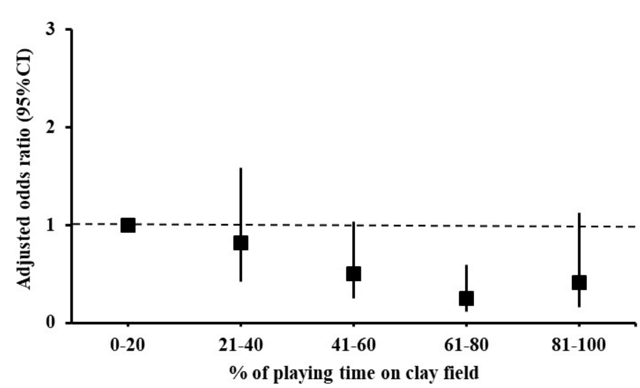

Figure 5 Adjusted ORs and 95% CIs for age, sex, body mass index, year of play, playing hours/year and spike cleats on clay field.

an association between overuse injuries and artificial turf,[1 12 18] football coaches, managers and medical staff in young academy teams have worried that playing on artificial turf could increase the risk for MT-5. However, no study has confirmed this link because the incidence rate of MT-5 is quite low and players change playing surface day by day. Therefore, a larger number of subjects with a longitudinal observation design was needed. In the present study, we recruited a large number of subjects (n=1854) and adjusted for several confounders, so we were able to demonstrate that playing on artificial turf >80% of the total playing time is a high risk factor for the development of MT-5 (OR 3.44), whereas playing on clay decreased the risk (OR 0.42) at the same percentage.

Previous studies have shown various MT-5 injury rates. Although one longitudinal study in Japan found that the incidence of MT-5 was 0.10–0.12/1000AEs for a university football team,[6] another study found that the injury rate was 0.037/1000 PH (mean age, 23±3) for European professional football players.[4] Compared with the incidence in the European study, the incidence of MT-5 in our study was lower (0.02/1000 PH), possibly because we recruited from a broad segment of the population. In fact, the MT-5 group was significantly younger than the non-MT-5 group with high school and college players aged from 15 to 22 years accounted for the majority of the MT-5 group, which was a higher proportion relative to those of other categories. Given that some studies have suggested that young football players were at higher risk of MT-5,[25 26] players in other categories, especially those aged from 15 to 22 years, may also be at high risk of MT-5.

It has been reported that the non-dominant leg has a higher risk of MT-5 than that of the dominant leg in football players.[4 6] Our study obtained similar results. Recent studies also have demonstrated associations between MT-5 and physical factors, such as forefoot adduction, varus hind foot and higher BMI.[27–29] In terms of physical factors, one study also reported that the limitation of hip internal rotation can cause MT-5 in football players with the possible mechanism being that the limitation leads to external rotation of the femur and knee joint, which causes subtalar joint supination in static alignment.[7] Football players require repetitive and specific movements during multiple changes of direction, dribbling and kicking and, in particular, the non-dominant leg acts as the pivot leg during high-impact kicking. As a previous study suggested, the kicking motion increases the lateral component of planter pressure and ultimately leads to stress fractures.[27]

In the present study, BMI was also a significant risk factor of MT-5 (p<0.03). Although previous studies have reported no association between body composition and MT-5,[4 6] a recent study found an association between higher BMI and refracture rate of MT-5.[29] Although this finding is controversial, it can be explained by some studies in which it was suggested that high BMI may decrease the ability to balance and be associated with lateral ankle sprains during repetitive movements, as well as changing the distribution of lateral planter pressures during agility tasks. These factors are thought to cause MT-5 by increasing the repetitive planter pressure of the proximal fifth metatarsal bone.[30 31]

Several limitations of this study should be acknowledged. First, outcomes could have been influenced by recall bias.[32] Survey studies are known to overestimate injury rates.[33] In this study, we included MT-5 diagnosed only by physicians; therefore, the recall bias regarding MT-5 should have been minimal. Additionally, although completing the survey was overseen by coaches and/or managers, bias may have been present in recalling the ratio of time played on each surface by each player. Second, a stress fracture is caused by accumulating stresses, and a developing MT-5 may need several months to become painful. Therefore, injuries that occurred when playing on artificial turf may not have originated by the playing surface at the time of reporting, and hence may have influenced the calculated risk. This study explored the incidence of fracture and playing surface during the same period (2 years), but the time spent on different playing surfaces before the study period may have affected the incidence of MT-5. Third, due to the low incidence of the fracture, we enrolled only 41 athletes who had a MT-5 during the period, the non-statistically significant p values in table 3 were observed when playing on the clay field 41%–60% of the total playing time (p=0.062) and more than 81% of the total playing time (p=0.084). A greater sample of MT-5 may provide a more accurate statistical significance. Finally, we included several confounders, such as age, BMI, playing time/year, a history of MT-5, year of play and type of spike cleats. However, other potential confounders such as calcium and vitamin D intake also may have affected the results. Low 25-hydroxy vitamin D levels were reported to be associated with the high incidence of the stress fractures. Therefore, insufficient vitamin D levels could increase the incidence of the MT-5.

CONCLUSIONS

We demonstrated the incidence of MT-5 with a large sample size, ranging across various ages and categories. Our study also demonstrated that MT-5 was associated with a higher BMI, playing categories and the amount of time spent playing on artificial turf. Increased playing time on artificial turf was found to be a risk factor for MT-5, whereas playing on clay surfaces decreased the risk for MT-5. These study results provide evidence that can be used to support strategies to minimise the risk of MT-5 for football players, which will benefit the players, the staff and the sport.

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