

Effect of Changes in Artificial Turf on Sports Injuries in Male University Soccer Players

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Background: Studies comparing the types and severity of trauma and injuries caused by different types of field surfaces have been conducted. However, there have been no studies on sports injuries caused by temporal deterioration of long-pile artificial turf fields and related decreases in the rubber chip and silica sand infill.

Purpose: To investigate the influence of an artificial turf field on sports injuries in a university soccer team.

Study Design: Descriptive epidemiological study.

Methods: A total of 397 male soccer players who were members of a single university soccer team were surveyed over a 12-year period, from April 2003 to March 2015. During this period, the team played for 4 years on a soil field (2003-2006) and 8 years on artificial turf (2007-2014). We analyzed the effect of changes in the artificial turf on the incidence rate of sports injuries (injury rate per 1000 athlete-exposures). We calculated the incidence rate of injuries sustained by the team and compared the results for each year of the study.

Results: After conversion of the field to artificial turf, there was a significant increase in the incidence of upper extremity trauma ($P < .05$). There was a significant increase in lower extremity sprains from 2007 to 2008, 1 year after the conversion from soil to artificial turf ($P < .05$). Analysis of the incidence of lower extremity muscle strain indicated that although the injury rate increased progressively, it decreased significantly after the insertion of additional rubber chips in 2014 ($P < .05$).

Conclusion: After conversion to artificial turf, there was a significant increase in the incidence of upper extremity trauma. After the refurbishing with additional rubber chips, the incidence of lower extremity muscle strain significantly declined. When analyzing measures that could prevent sports injuries related to soccer, it is necessary to take into consideration the changes that occur to the artificial turf over time.

Keywords: soccer; sports injury; injury rate; artificial turf

Long-pile artificial turf fields were approved as the recommended turf for use in soccer games by Federation Internationale de Football Association (FIFA) in 2004,^{12,13} and

in October 2003, the Japan Football Association (JFA) established the JFA Long-Pile Artificial Turf Pitch Authorization System.¹⁷ As a result, the number of soccer fields that utilize long-pile artificial turf has been increasing. Third-generation long-pile artificial turf was released in the latter 1990s.²¹ The third generation is characterized by the fact that instead of an underpad, the artificial turf has a sand (specially treated silica sand) and rubber chip infill. The rubber chips act as a cushion, and the sand is added to maintain firmness.²⁴

In addition to player contact, the major cause of trauma and overuse injuries to players during soccer games is the ground surface of the field.¹⁰ Previous studies have reported characteristic types of trauma and overuse injuries by type of field surface. Because soil fields become slippery after rainfall, they are a cause of sprains, muscle strains, and related types of trauma.¹⁰ Artificial turf fields increase the friction between the ground and the players' spikes, which allows improved braking and acceleration.^{22,27,28} As a result, players experience more powerful impacts when they collide due to the increased speed at

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which they can run, which leads to a higher potential for trauma.^{22,27,28} Therefore, different types of field surfaces are related to different types of sports injuries. In addition, artificial turf deteriorates over time, and its original ability to absorb shock declines.²⁵ It is thought that these changes in field condition may affect the incidence of sports injuries.

Studies comparing the types and severity of trauma and injuries caused by different types of field surfaces have been conducted.¹¹⁻¹³ However, there have been no studies about sports injuries caused by the deterioration of long-pile artificial turf fields, and related decreases in the rubber chip and silica sand infill, over time.

Therefore, the present study investigated the injuries experienced by a single university soccer team during soccer play on a soil field for 4 years and an artificial turf field for 8 years, for a total of 12 years. The incidence rates of the sports injuries caused by temporal deterioration of the artificial turf field were analyzed per 1000 athlete-exposures (AEs).

METHODS

Participants

The study participants were 397 players who were part of a men's soccer team at a single university and who were observed for 12 years, from April 2003 to March 2015. We observed 41 players in 2003, 50 in 2004, 67 in 2005, 83 in 2006, 87 in 2007, 91 in 2008, 97 in 2009, 114 in 2010, 148 in 2011, 159 in 2012, 165 in 2013, and 173 in 2014. Approval for this study was obtained from the university's ethics committee. Consent was obtained from both the team staff members and players after they were provided a full explanation of the study. The mean age, height, weight, body mass index, and years playing soccer before university were 18.0 ± 0.2 years, 173.0 ± 6.1 cm, 65.3 ± 6.6 kg, 21.8 ± 1.5 kg/m², and 10.0 ± 2.0 years, respectively.

There were no replacements of the team coaches during the study period, and the players were categorized by competition level. During the study period, there were no major changes in the practice schedule, practice time, of specific types of practice, which included 1 day of rest per week and strength training. In April at the beginning of the fiscal year, new players were added to the university soccer team, and the new players increased year by year. New players were equally divided and belonged to each category divided by the soccer competition level. According to the rules of the university soccer league to which the team belonged during the study period, official games were held approximately once per week from April to June and from September to November each year. From 2003 to 2015, this team had no major change in ranking in the university soccer league.

The practice field, used exclusively by the soccer team, was a soil field between 2003 and 2006 and artificial turf thereafter. The artificial turf field (Big Turf 66-MIX; Nihon Field System Co Ltd) consisted of long-pile artificial turf (pile height, 66 mm) with a 10-mm-thick layer of rubber chips sandwiched between the turf and a 15-mm-thick lower layer of specially processed silica sand. The field was repaired as

part of a maintenance program in 2013. The repairs consisted of restoring the entire field (6300 m²) by brushing the long-pile artificial turf and inserting an additional 6.3 metric tons of rubber chips at a distribution of 1 kg/m².

Assessments

Sports Injuries. The players, coaches, and medical staff (physical therapists) on the soccer team investigated in this study worked together closely, and when an injury occurred, either the player or the coach contacted the medical staff prior to examination at the team's designated medical facility. The results of the medical examination were kept in each player's file, which allowed the confirmation of injury-related statistics. During the 12-year period between April 2003 and March 2015, we investigated a total of 1579 sports injuries that occurred in association with playing soccer. The definition of a sports injury used in this study was one that "results in the loss of at least 1 day of practice or sitting out at least 1 game," as recommended by FIFA¹⁴ and the Injury Surveillance System (ISS)⁶ and used by the National Collegiate Athletic Association (NCAA) in the United States. We excluded those cases when the player himself indicated that he could continue with practice or a game in spite of pain and cases when symptoms were mild enough to allow continuation of play after conditioning or other types of special training. Sports injuries were targeted only if they occurred on the field used by this soccer team. We excluded the following from our analysis of game-related injuries: injuries sustained on artificial turf fields during the soil field period (2003 to 2006) and injuries sustained on natural turf fields during the artificial turf field period (2007 to 2015).

Field Ground Surfaces. We measured ball rebound height using the vertical drop test in accordance with the *JFA Long-Pile Artificial Turf Pitch Official Testing Manual*.¹⁸ For the JFA test, a ball is dropped from a height measuring 2 m from the field to the bottom surface of the ball, and the height of the ball's rebound is measured at the bottom surface of the ball from video images made of the test. Each test was performed 5 times, and the mean value of the 5 measured values was calculated. This test was carried out in the penalty area (place of penalty mark), in the field (place of the midpoint between center mark and penalty mark), and in the center circle (place of center mark).

Soccer Cleats. We evaluated the number and shape of the studs on the cleats worn by players when they joined the team, at the start of each year of the study. We also noted the number and shape of the cleats, as well as other details about the shoes worn by players, at the time they sustained an injury.

Calculation of the Injury Rate

Based on the NCAA ISS, we calculated the injury rate (IR) per 1000 AEs (1 AE is defined as 1 player participating in 1 game or 1 practice session) by dividing the number of injuries by the number of AEs.¹ We calculated the 95% confidence interval (CI) in order to ensure the statistical stability of the data. We also calculated the rate ratio by showing the IR for each year of the study.

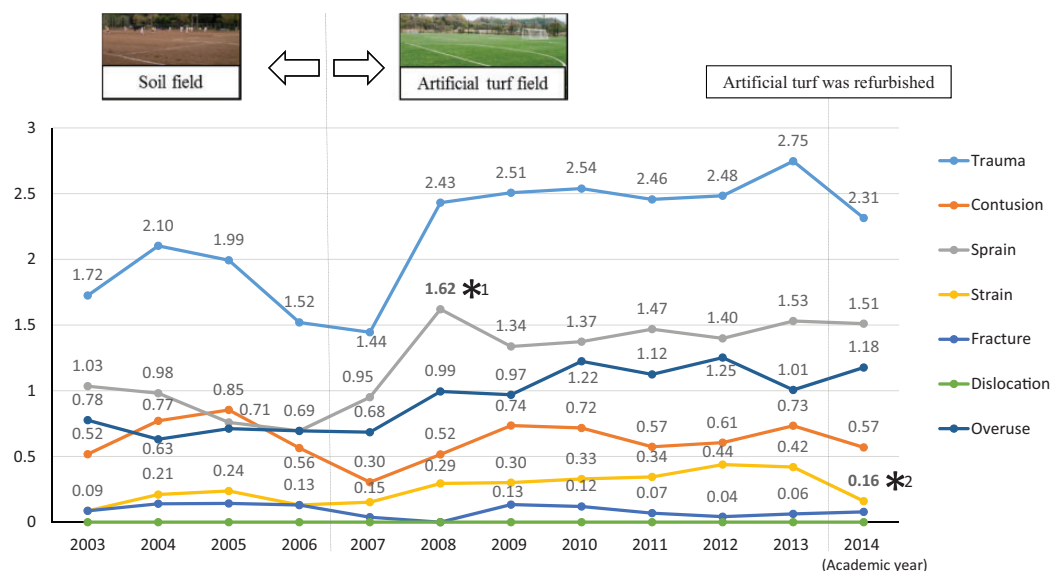


Figure 1. Injury rate (per 1000 athlete-exposures) of the lower extremity according to study year. *1: There was a statistically significantly higher rate of lower extremity sprains in 2008 compared with 2007 ($P < .05$). *2: There was a statistically significantly lower rate of lower extremity muscle strain in 2014 (after the insertion of additional rubber chips to the infill) compared with 2013 ($P < .05$).

Game AE was the total number of games in which each player participated. The definition of “game” used in this study was “official games and practice sessions involving other soccer teams.” Practice AE was the total number of days each player participated in practice.

Trauma and overuse injuries were categorized as follows: Trauma was defined as contusion, sprain, strain, fracture, and dislocation per soccer game, and overuse injuries were defined as chronic or gradually worsening symptoms.

The number of studs in soccer cleats were divided into 2 groups: ≤ 13 and ≥ 14 . We calculated the onset rate for each study year (the number of cleats worn at the time of relevant injuries/the number of relevant cleats) for each cleat group. We also divided the stud shapes into *round*, *blade*, and *other*, and calculated the injury incidence for each type in each study year.

Statistical Analysis

We performed a Z-test on the incidence for each study year and the incidence of the previous study year in order to compare the IR of each study year. We also performed a Z-test to compare the incidence of the number and stud types of the soccer cleats. We performed a Mann-Whitney U test on the vertical ball drop rebound height tests. In order to investigate factors related to trauma experienced during practice by site of injury, we performed multivariate analysis using a multivariate logistic model. The factors that we analyzed were height, weight, age, position (field player or goalkeeper), number of years playing soccer, type of field (soil or artificial turf), and cleat stud type (round or blade) as the explanatory variables and IR on the lower extremity, upper extremity, torso, and head/neck as the response variables. Statistical analysis was performed using SPSS version 11.0 (SPSS Japan Inc). The statistical significance level was set at .05.

RESULTS

Overall Trends in IR

A total of 1579 sports injuries occurred during the 12 years from 2003 to 2015. Of these, 57 were head/neck injuries (0.15/1000 AEs, 3.6% of the total number of injuries), 153 were torso injuries (0.41/1000 AEs, 9.7% of the total number of injuries), 1247 were lower extremity injuries (3.31/1000 AEs, 79.0% of the total number of injuries), and 122 were upper extremity injuries (0.32/1000 AEs, 7.7% of the total number of injuries).

IR of Lower Extremity for Each Study Year

The artificial turf field (2007 to 2015) was associated with a higher incidence of lower extremity sprains than the soil field (2003 to 2006). There was a significantly higher incidence of lower extremity sprains in 2008 (1.62/1000 AEs) than in 2007 (0.95/1000 AEs) ($P < .05$). Strained muscles in the lower extremities increased annually after the conversion to artificial turf, but the incidence of lower extremity strained muscles (0.16/1000 AEs) in 2014 (after insertion of additional rubber chips to the infill) showed a significant decline ($P < .05$) over the incidence of lower extremity strained muscles (0.42/1000 AEs) in 2013 (Figure 1).

IR During Games and Practices

When comparing injuries during games versus practices, we found the IR for games was greater. There were no significant difference in IR between the study years by type of injury sustained during games. The incidence of lower extremity trauma during practice in 2008 (2.09/1000 AEs)

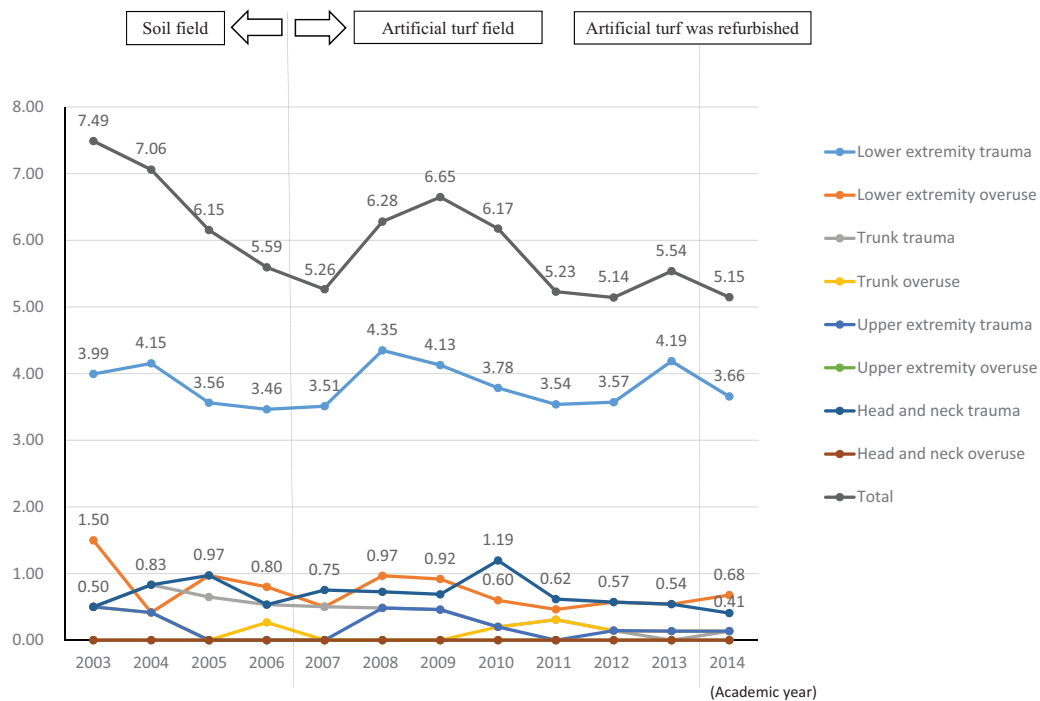


Figure 2. Injury rate (per 1000 athlete-exposures) during games according to body part. There were no statistically significant differences in injury rates during games in the period studied.

was significantly higher compared with that in 2007 (1.08/1000 AEs) ($P < .05$). The incidence of upper extremity trauma during practice (0.58/1000 AEs) in 2007 (after the conversion from soil to artificial turf) was significantly higher than the incidence rate of upper extremity trauma during practice (0.16/1000 AEs) in 2006 ($P < .05$). There was a statistically significant lower rate of lower extremity muscle strain during practice in 2014 (after the insertion of additional rubber chips) compared with that in 2013 ($P < .05$) (Figures 2 and 3).

IR for Goalkeepers and Field Players

There were no significant differences in IR in goalkeepers during the study period. The incidence of upper extremity trauma experienced by field players in 2007 (after the conversion to artificial turf; 0.52/1000 AEs) was significantly higher than the onset rate for upper extremity trauma experienced by field players in 2006 (soil field; 0.00/1000 AEs) ($P < .05$) (Figures 4 and 5).

Factors Related to the Incidence of Trauma During Practice

The results of our multivariate analysis of the factors related to the incidence rate for trauma experienced during practice are shown in Table 1. The results indicated that position played and type of field had a significant correlation to the incidence of upper extremity trauma ($P < .05$).

Assessment of Field Ground Surfaces

Our comparison of the vertical ball drop rebound height in 2007 (after the conversion to artificial turf) versus 2013 (before the refurbishing of the artificial turf with additional rubber chips) indicated that it was higher in 2013 in the penalty area (63.4 ± 1.4 cm in 2007 vs 75.6 ± 1.5 cm in 2013; $P < .01$), the center circle (63.4 ± 1.4 cm vs 75.6 ± 1.5 cm; $P < .01$), and the field (63.8 ± 1.2 cm vs 73.8 ± 1.6 cm; $P < .01$). Our comparison of data in 2013 before versus after the refurbishing indicated that the rebound height was lower after the refurbishing in the penalty area (76.5 ± 1.5 cm before vs 70.4 ± 1.7 cm after; $P < .05$), the center circle (76.4 ± 1.9 cm vs 70.0 ± 1.9 cm; $P < .05$), and the field (73.8 ± 1.6 cm vs 69.6 ± 1.6 cm; $P < .01$).

Soccer Cleat Studs

The results of our survey of soccer cleats are shown in Table 2. When we analyzed by stud shape and by number of studs, there were no statistically significant differences in onset rate for lower extremity injuries.

DISCUSSION

We believe that it is important to investigate the onset of sports injuries and analyze injury trends because this may lead to measures that will contribute to the prevention of sports injuries. The NCAA has created a system to survey injuries, and the resulting statistical data are

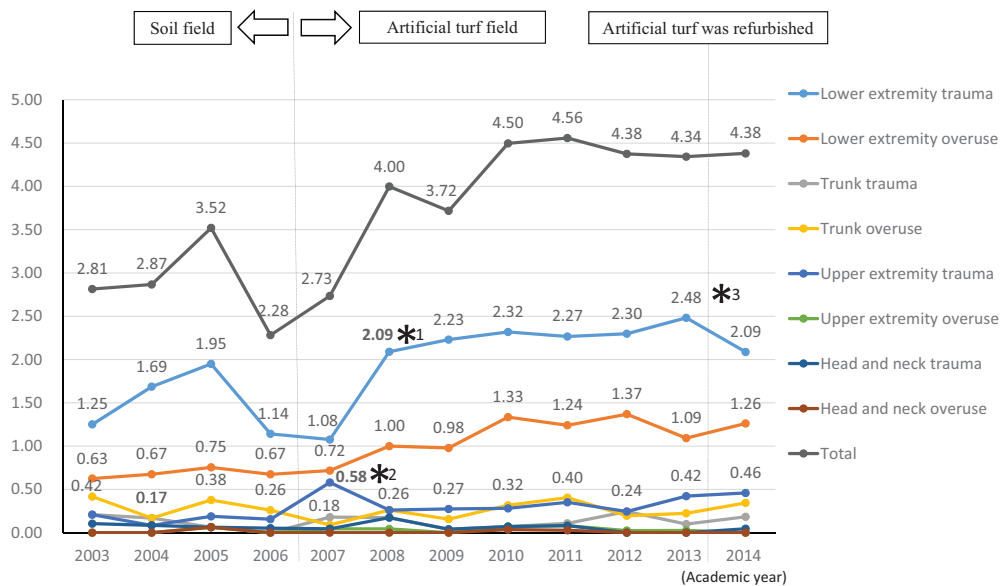


Figure 3. Injury rate (per 1000 athlete-exposures) during practices according to body part. *1: There was a statistically significantly higher rate of lower extremity trauma during practice in 2008 compared with 2007 ($P < .05$). *2: There was a statistically significantly higher rate of upper extremity trauma during practice in 2007 (after the conversion from soil to artificial turf) compared with 2006 ($P < .05$). *3: There was a statistically significantly lower rate of lower extremity muscle strain during practice in 2014 (after the insertion of additional rubber chips) compared with 2013 ($P < .05$).

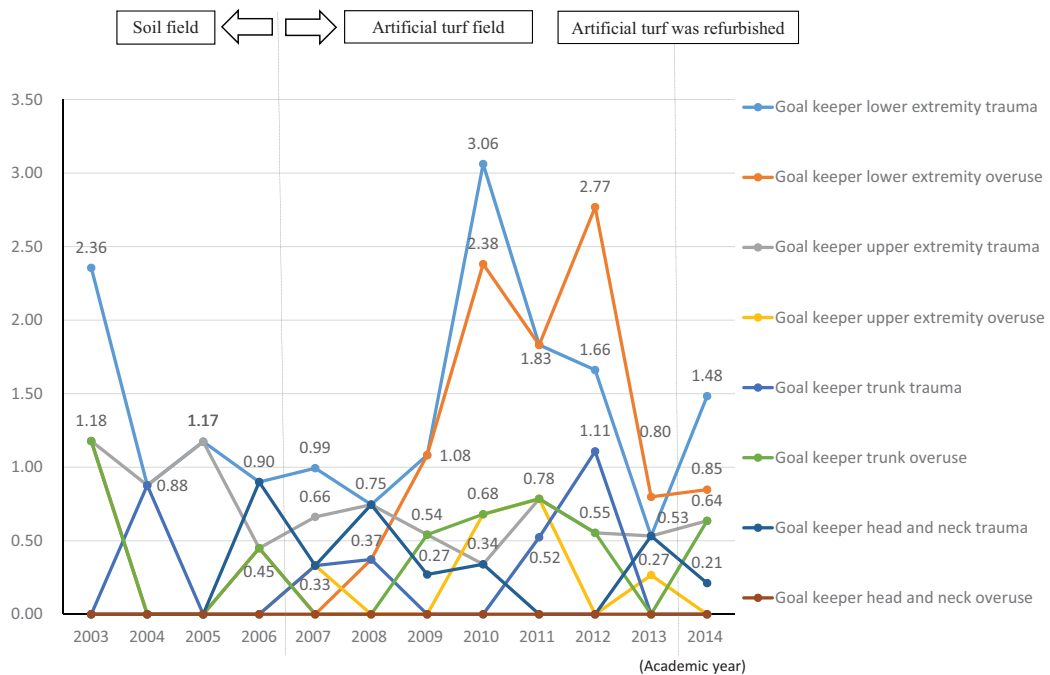


Figure 4. Injury rate (per 1000 athlete-exposures) for goalkeepers according to body part. There were no statistically significant differences in injury rates from 2003 to 2014.

useful in the prevention of injuries.⁶ Several studies have investigated the onset of sports injuries associated with soccer.^{1,4} Soccer requires mainly lower extremity movements, ranging from explosive movements such as

ball kicking, tackling, dashing, and jumping to other types of movements such as walking and running.^{26,29} Therefore, it is associated with a high incidence of injuries to the lower extremity.^{1,30}

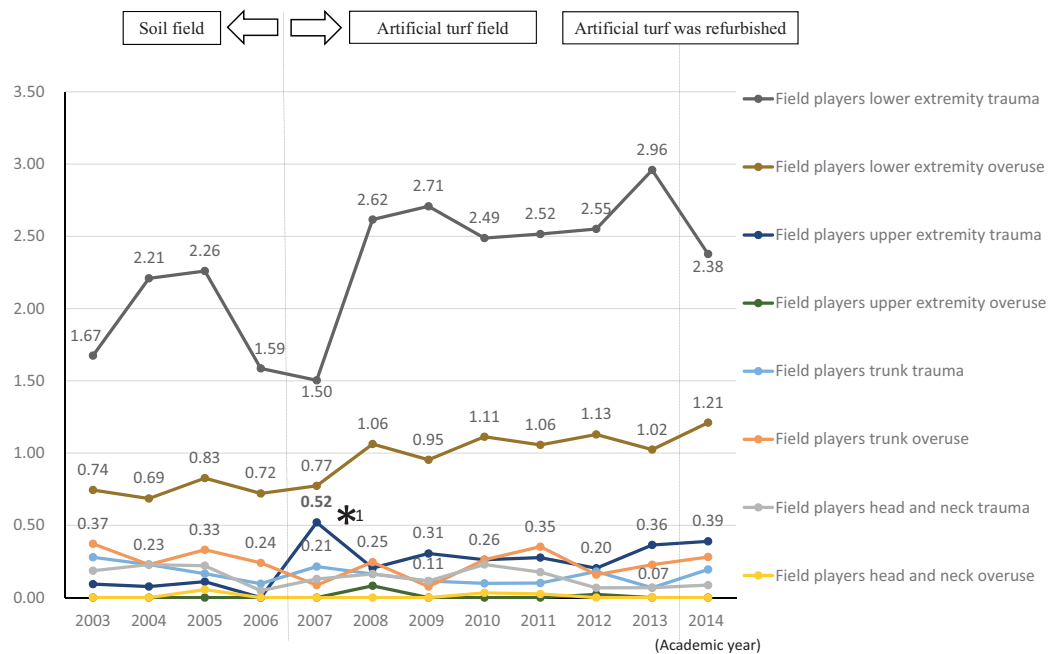


Figure 5. Injury rate (per 1000 athlete-exposures) for field players according to body part. *: There was a statistically significantly higher rate of upper extremity trauma in field players in 2007 (after the conversion from soil to artificial turf) compared with 2006 ($P < .05$).

Previous studies have evaluated the onset of injuries in both professional and adolescent soccer players,^{2,15} the incidence of injuries during World Cup games,^{7,8,19} and the long-term incidence of injuries among university soccer players who are in the late stage of adolescence and have nearly the same physiques as adults.^{1,30} These studies analyzed IRs using the 1000 AEs method, and we believe that comparisons with these studies should be made when considering ways to prevent injuries.

The results of the study show that the artificial turf field (2007 to 2015) was associated with a higher incidence of lower extremity sprains than the soil field (2003 to 2006). After the conversion to artificial turf, the incidence of upper extremity trauma experienced by field players also increased. Our investigation of lower extremity muscle strain indicated that, after the insertion of additional rubber chips into the artificial turf, the incidence of lower extremity muscle strain declined. The results of our multivariate analysis of factors related to the onset of trauma indicated a significant correlation of upper extremity trauma with position and type of field.

Sports-related injury in football is said to develop in the lower extremity.¹⁵ In the present study, the overall lower extremity IR was 79.0%, which is comparable with the study of Inklaar¹⁶ reporting the injury incidence in lower extremities ranging between 61% and 90%.

Lower extremity sprain incidence increased after the conversion from soil to artificial turf, confirming what previous studies have reported: that injury incidence may be higher because of the increased braking and acceleration that artificial turf allows.^{20,22,27,28} It is believed that the increased braking and acceleration leads to players' feet getting caught on

the field ground surface, which leads to more lower extremity sprains. The results of the vertical ball drop rebound tests in the penalty area, center circle, and field showed significantly higher rebounds on artificial turf in 2013 before the refurbishing with additional rubber infill compared with newly installed artificial turf in 2007, and significantly lower rebounds on artificial turf in 2013 after the refurbishing compared with 2013 before the refurbishing. With repeated use over the years, artificial turf loses its original ability to absorb shock.²⁵ Specifically, as artificial turf ages, the long pile itself narrows, shortens, and flattens, and the rubber chips become smaller and reduced in number. As a result, it is thought that the vertical ball drop rebound height increases due to the effect of repeated shock to the ground over the years. The manufacturer recommends replacing rubber chips after 3 to 5 years. The insertion of additional rubber chips as part of the regular maintenance of the artificial turf improved the shock absorption of the field surface. This reduced the burden on the players' muscles, which we suggest led to a decrease in the incidence of muscle strain.

Upper extremity injuries accounted for 7.7% of the total number of injuries. The upper extremity IR for goalkeepers was approximately 3 times that of field players. It has been reported that the IR for goalkeepers is 5 times that of players in field positions.⁹ Goalkeepers are the only players who are allowed to use their hands while the ball is in play. This means that they have more opportunities to grapple with other players for the ball and come into contact with other players with their upper extremities and heads. This is believed to lead to the increased incidence of upper extremity injuries experienced by goalkeepers.

TABLE 1
Factors Related to the Incidence of Trauma During Practice^a

	Odds Ratio	95% CI	P Value
Head and neck trauma			
Height	0.97	0.86-1.09	.56
Weight	1.03	0.92-1.15	.59
Age	0.52	0.08-3.53	.50
Position (field player or goalkeeper)	0.40	0.10-1.52	.18
No. of years playing soccer	0.99	0.78-1.26	.95
Type of field (soil field or artificial turf field)	0.64	0.15-2.83	.56
Cleat stud type (round or blade)	0.54	0.14-2.16	.39
Trunk trauma			
Height	1.04	0.96-1.12	.32
Weight	0.97	0.90-1.04	.35
Age	1.22	0.18-8.25	.84
Position (field player or goalkeeper)	1.24	0.35-4.33	.74
No. of years playing soccer	0.95	0.81-1.12	.55
Type of field (soil field or artificial turf field)	0.54	0.21-1.40	.20
Cleat stud type (round or blade)	0.68	0.27-1.70	.41
Upper extremity trauma			
Height	1.01	0.96-1.08	.6
Weight	1.00	0.95-1.06	.99
Age	0.93	0.22-3.89	.92
Position (field player or goalkeeper)	0.45	0.21-0.96	.04
No. of years playing soccer	1.02	0.90-1.16	.72
Type of field (soil field or artificial turf field)	2.45	1.20-4.98	.01
Cleat stud type (round or blade)	1.59	0.88-2.87	.12
Lower extremity trauma			
Height	1.00	0.92-1.09	.94
Weight	1.00	0.95-1.11	.50
Age	1.02	0.14-7.18	.99
Position (field player or goalkeeper)	1.92	0.67-5.47	.22
No. of years playing soccer	1.00	0.83-1.19	.96
Type of field (soil field or artificial turf field)	1.29	0.49-3.39	.61
Cleat stud type (round or blade)	0.05	0.37-2.40	.91

^aThe results indicated that position and type of field had a significant correlation to the incidence of upper extremity trauma ($P < .05$).

TABLE 2
Assessment of Field Ground Surfaces^a

Onset Rate, % ^b	Academic Year											
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Lower extremity trauma												
Stud shape												
Round	14.6	17.9	19.2	13.0	10.7	20.8	22.9	21.7	21.5	27.9	24.1	21.5
Blade	0.0	0.0	0.0	0.0	7.8	23.5	28.0	26.1	25.5	22.7	28.2	22.8
Other	0.0	0.0	0.0	0.0	0.0	18.2	7.1	8.6	5.7	10.5	7.6	8.1
No. of studs												
≤13	0.0	20.0	20.0	16.7	10.6	21.0	22.7	24.3	21.1	24.1	23.6	20.4
≥14	14.6	17.4	18.9	12.0	9.1	23.2	26.3	28.4	25.4	23.8	24.8	20.0
Lower extremity overuse injuries												
Stud shape												
Round	6.6	5.4	6.8	5.9	3.8	7.8	11.8	12.2	11.4	14.6	11.2	11.8
Blade	0.0	0.0	0.0	0.0	6.3	11.8	7.7	10.2	10.0	10.9	7.6	10.3
Other	0.0	0.0	0.0	0.0	0.0	0.0	3.6	5.7	2.9	5.3	3.0	5.4
No. of studs												
≤13	0.0	6.7	6.0	6.7	4.1	8.6	8.6	12.6	9.6	11.5	8.6	10.0
≥14	6.6	5.1	7.1	5.7	5.0	9.5	10.5	11.8	11.9	13.8	9.1	12.0

^aWhen we analyzed by manufacturer, stud shape, or number of studs, there were no statistically significant differences in onset rate for lower extremity injuries.

^bThe onset rate was calculated as number of cleats worn at the time of injury/number of relevant cleats.

After conversion to artificial turf, an increase in the incidence of upper extremity injuries was observed among field players. It has been reported that factors related to the playing environment influence the incidence of sports injuries,^{1,4} in particular, the ground surface is a factor related to the incidence of injuries during soccer play.¹⁰ It has also been reported that artificial turf influences the incidence of upper extremity bone fractures in young male soccer players.⁵ It is thought that increased braking and acceleration lead to increased incidence of upper extremity trauma due to contact with other players and falling after being tackled during soccer play.

Artificial turf undergoes deterioration of its long pile and reduction in the number of rubber chips through aging. It is less expensive to insert additional rubber chips than to replace long pile when performing maintenance on artificial turf. However, since performing only that type of maintenance lowers the shock of impact with the ground surface, since the long pile remains flattened, the studs of the players' cleats cannot dig into the field surface, which means that the surface will become slippery. Thus, we believe that although the insertion of additional rubber chips did lead to reduced incidence of muscle strains, it did not affect the incidence of upper extremity trauma and lower extremity sprains.

Livesay et al²³ investigated the torque combined with shoes and ground condition. Peak torque combined with shoes for natural field and artificial turf was higher than that of shoes for natural field. Thus, cleats and ground surfaces are closely related for torque. However, in our study, the shape and number of studs did not affect the number or type of sports-related injuries. The characteristics of sports shoes, such as shoe weight, rotational stiffness, and flexion stiffness, are continuously developing in order to reduce the incidence of sports-related injury. Progression or improvement in shoe design specific to these types of turf surfaces should be considered when investigating the influence of artificial turf deterioration on sports injuries.

Although the injury patterns on artificial versus natural fields have been reported to be slightly different, there have not been any difference in the incidence rates.¹¹⁻¹³ Andersson et al³ reported that male players had the impression that they experienced increased burden when on artificial turf as compared with when on natural turf. Although these issues have been studied previously, we believe it is still necessary to compare natural turf with artificial turf and to study their influence on the human body during soccer play.

One limitation of this study was the fact that although it was a long-term study, it was focused on a specific male soccer team at a single university, and for that reason, there was a paucity of AE and IR data. We believe that it is necessary to conduct further studies on chronological IRs using the same methods presented in the current study, but with increased numbers of teams. Although we surveyed artificial turf fields, because we were unable to measure the slipperiness of the ground surface and friction using measuring devices, we utilized the vertical ball drop rebound height test, which is relatively easy to perform. Thus, when investigating changes in field surface, ground slipperiness

and friction data are necessary. In addition, since we believed that both field surface and cleats are closely related to sports injuries, we surveyed the types of cleats worn by players. However, the design and positioning of the cleats change continuously. Furthermore, some players use several types with different designs of cleats, therefore it was difficult to standardize the usage of cleats. In order to consider the effect of cleats in more detail, it is necessary to investigate the type of use of cleats and duration used.

CONCLUSION

The results of this study indicated that after the conversion of the soccer field from soil to artificial turf in 2007, there was a significant increase in the incidence of upper extremity trauma. After the refurbishing of the artificial turf with additional rubber chips in 2013, the incidence of lower extremity muscle strains significantly declined. When considering measures to prevent sports injuries experienced during university soccer play, we believe it is necessary to base those measures on the fact that artificial turf undergoes changes to its condition.

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