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Ankle Structures of Professional Soccer (Football) Players With Proximal Diaphyseal Stress Fractures of the Fifth Metatarsal

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ABSTRACT

Despite a high incidence of proximal diaphyseal stress fractures of the fifth metatarsal (zone 3) in soccer (football) players, studies that examine risk factors of the fractures in professional soccer players are scarce; in particular, ankle structures have not yet been investigated. This study was designed to investigate ankle structures of professional soccer players with proximal diaphyseal stress fractures of the fifth metatarsal. We reviewed the ankle radiographs of 100 professional soccer players (stress fractures n = 15; controls n = 85) and measured the medial malleolar slip angle (MMSA), the ratio of the medial malleolar length to the width of the talar dome (MML:TD ratio), the ratio of the lateral malleolar length to the width of the TD (LML:TD ratio), and the ratio of the MML to the LML (MML:LML ratio). The MMSA ($p < .01$: 28.7° ± 5.8° versus 23.0° ± 4.9°) in the stress fractures was significantly wider and the MML:TD ratio ($p = .08$: 0.49 ± 0.08 versus 0.52 ± 0.07) had a trend to be smaller compared with the values of the controls. Logistic regression analysis revealed that a wider malleolar slip angle became a factor associated with stress fractures in professional soccer players ($p < .01$: odds ratio 1.27, 95% confidence interval 1.110 to 1.463). Receiver operating characteristic curve with MMSA for the stress fractures was depicted with an area under the curve of 0.778, and the suitable cut-off point was set at MMSA > 27° with a positive likelihood ratio of 3.67 (95% confidence interval 2.173 to 6.188). Our study results show that a wide MMSA was associated with proximal diaphyseal stress fractures of the fifth metatarsal in professional soccer players.

Stress fractures at the proximal portion of the fifth metatarsal are of great concern among sports physicians, because the fractures lead to delayed healing with a high rate of nonunion (1). Fractures of the proximal portion of the fifth metatarsal are categorized into 3 types: tuberosity avulsion fractures (occurring in zone 1), fractures at the metaphyseal–diaphyseal junction, called Jones fractures (occurring in zone 2), and stress fractures at the proximal diaphysis of the fifth metatarsal (occurring in zone 3) (2). Jones fractures have been well studied, and some risk factors have been identified (3). In contrast, studies investigating predisposing factors of stress fractures of the proximal diaphysis of the fifth metatarsal are scarce. It has been suggested that proximal diaphyseal stress fractures of the fifth metatarsal are caused by submaximal repeated stress resulting in an oblique load in the proximal diaphysis of the fifth metatarsal (4). We hypothesized that ankle structures with a wide medial malleolar slip angle (MMSA) and short medial malleolus are associated with stress fractures in the proximal diaphysis of the fifth metatarsal.

This study was designed to identify potential associated factors of stress fractures of the proximal diaphysis of the fifth metatarsal in professional soccer players with the use of non-weightbearing ankle radiographs.

Patients and Methods

The study design was a retrospective case-control (15 cases of stress fractures of the proximal diaphysis of the fifth metatarsal, 85 controls) study. This was approved by the ethical committee in our institution (ethical report ID: 20160101). The subjects were 15 professional soccer players who were diagnosed as having proximal diaphyseal stress fractures of the fifth metatarsal during an annual medical checkup conducted during the off-season from January 1994 to January 2017. The controls were 85 age-, height-, and weight-matched professional soccer players without fractures who also had an annual medical checkup during the off-season from January 1994 to January 1997, including 10 goalkeeper (GK), 25 defender (DF), 30 midfielder (MF), and 20 forward (FW) players. None of the subjects enrolled in this study wore custom functional orthotics during play. Proximal diaphyseal stress fractures of the fifth metatarsal were diagnosed by 2 senior orthopaedic surgeons based on radiolucent fracture lines with surrounding reactive sclerosis in addition to the reduced medullary canal width (5). For the control group, foot radiographs were examined, and individuals with fractures in the fifth metatarsal were firmly excluded. In total, 100 soccer players were categorized into the following groups based on the history of the proximal diaphyseal stress fractures of the fifth metatarsal: injured with the stress fractures (stress fractures, n = 15) and noninjured (controls, n = 85).

Ankle radiographs with the anteroposterior (AP) view were taken without weightbearing during medical checkups. First, a line was drawn from the second toe to the heel

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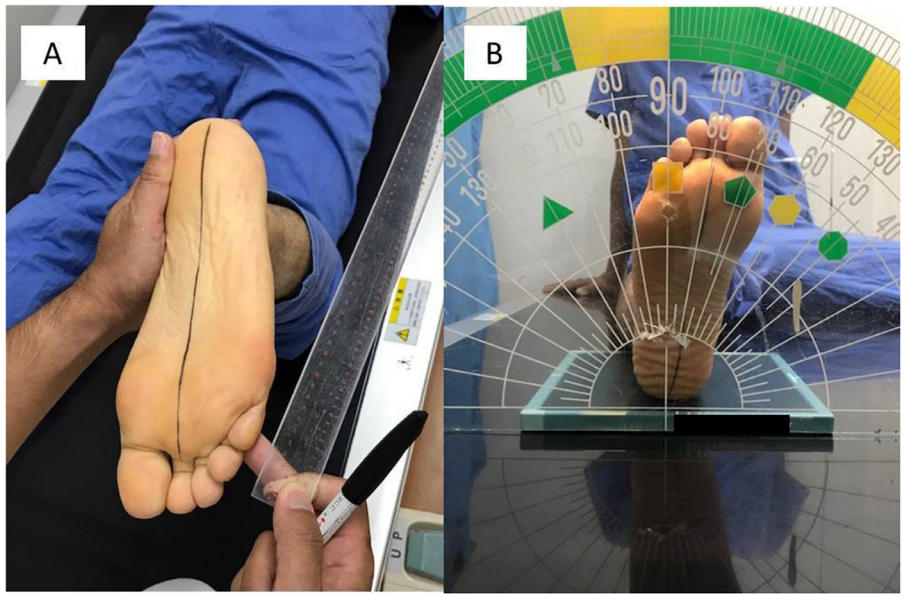

Fig. 1. (*A*) Taking a non-weightbearing anterioposterior (AP) ankle radiograph. First, a line was drawn from the second toe to the heel on the foot plantar. In reference to a 90° line, the foot was positioned 10° internally rotated on the film cassette (*B*) and a non-weightbearing ankle radiograph with AP view was taken.

on the foot plantar (Fig. 1*A*). In reference to a 90° line, the foot was positioned 10° internally rotated on the film cassette (Fig. 1*B*) and a non-weightbearing AP ankle radiograph was taken as shown in Fig. 2. This technique was continued throughout the entire study period (1994 to 2017). With the ankle radiographs, the MMSA, the ratio of the medial malleolar length to the lateral malleolar length (MML:LML ratio), the ratio of the MML to the width of the talar dome (MML:TD ratio), and the ratio of the LML to the width of the TD (LML:TD ratio) were examined, as shown in Fig. 2.

Values are expressed as the mean ± SD otherwise stated. We used the statistical software StatView 5.0 (SAS Institute, Inc., Cary, NC, USA) and XLSTAT-Biomed (Addinsoft, Paris, France). Radiographic parameters were calculated by 3 orthopedic surgeons twice after a 1-week interval. A value of $p < .05$ (5%) was considered statistically significant. An unpaired Student's *t* test was used to compare parameters between 2 groups. To calculate intraobserver and interobserver reliability correlations of repeated interval scale measures, reliability analyses were conducted using intraclass correlation coefficients with XLSTAT-Biomed (Addinsoft), and the reliabilities were expressed with 95% confidence intervals (CIs). To identify associated factors of proximal diaphyseal stress fractures of the fifth metatarsal, logistic regression analysis was conducted as described with odds ratios (ORs). In addition, receiver operating characteristic (ROC) curves were depicted for identifying the suitable MMSA cut-off point for the presence of proximal diaphyseal stress fractures of the fifth metatarsal. With the calculated cut-off point in MMSA, the positive likelihood ratio (LR+) and negative likelihood ratio (LR–) were calculated.

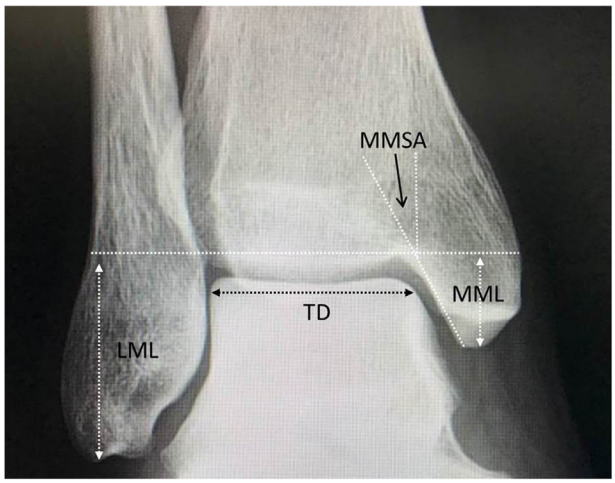

Fig. 2. Measuring ankle radiographic parameters in professional soccer players. Measurements were taken on a non-weightbearing anteroposterior (AP) ankle radiograph. The medial malleolar slip angle (MMSA) was the angle between a line of the medial malleolar articular surface and a line perpendicular to the continuous line of the tibial plafond. The medial malleolar length (MML) was the perpendicular distance from the medial malleolar tip to the continuous line of the tibial plafond. The lateral malleolar length (LML) was the perpendicular distance from the lateral malleolar tip to the continuous line of the tibial plafond. The talar distance (TD) was the length of the talar dome.

Results

On ankle radiographs, intraobserver and interobserver reliabilities in this study were satisfactory, as seen in Table 1. MMSA in the stress fractures was significantly wider and MML:TD ratio also had a trend to be smaller compared with control values. Other parameters were not significantly different between groups, as seen in Table 2. Logistic regression analysis revealed that MMSA became a statistically significant associated factor ($p < .01$) among professional soccer players (OR 1.27, 95% CI 1.110 to 1.463). The ROC curve with MMSA for the presence of the stress fractures showed that the area under the curve was 0.778 (Fig. 3), and when the cut-off point was set at MMSA > 27°, the LR+ and LR– for proximal diaphyseal stress fractures of the fifth metatarsal were 3.67 (95% CI 2.173 to 6.188) and 0.33 (95% CI 0.143 to 0.777), respectively.

Discussion

Fractures on the fifth metatarsal often occur among professional athletes because of the intensive rapid or repeated loads applied on the

Table 1
Intraobserver and interobserver reliability of radiographic parameters

Parameter	Reliability (95% CI)	
	Intraobserver	Interobserver
MMSA	0.955 (0.937 to 0.967)	0.854 (0.783 to 0.904)
MML:TD ratio	0.953 (0.925 to 0.971)	0.927 (0.891 to 0.952)
LML:TD ratio	0.974 (0.959 to 0.984)	0.918 (0.879 to 0.946)
MML:LML ratio	0.941 (0.906 to 0.963)	0.795 (0.697 to 0.865)

Abbreviations: CI, confidence interval; MMSA, medial malleolar slip angle; MML, medial malleolar length; TD, talar dome; LML, lateral malleolar length.Radiographic parameters were measured by 3 orthopedic surgeons twice after a 1-week interval.
Reliability analyses were conducted using intraclass correlation coefficients.

Table 2
Ankle structures in proximal diaphyseal stress fractures of the fifth metatarsal and controls

	Players With Stress Fractures	Control Subjects	*p* Value
n	15	85	
Age (y)	25 ± 6	25 ± 5	.87
Height (cm)	176.3 ± 6.5	176.4 ± 6.2	.93
Weight (kg)	72.1 ± 10.3	71.3 ± 6.5	.68
MMSA (°)	28.7 ± 5.8	23.0 ± 4.9	<.01
MML:LML ratio	0.56 ± 0.11	0.59 ± 0.07	.58
MML:TD ratio	0.49 ± 0.08	0.52 ± 0.07	.08
LML:TD ratio	0.86 ± 0.09	0.90 ± 0.09	.13

Abbreviations: LML, lateral malleolar length; MML, medial malleolar length; MMSA, medial malleolar slip angle; TD, talar dome.
Values are expressed as the mean ± SD. Unpaired *t* test was used to compare parameters between the 2 groups.

fifth metatarsal (6). The distinction between Jones fractures and stress fractures of the proximal diaphysis of the fifth metatarsal is often misunderstood (7,8). Jones fractures were first described by Sir Robert Jones in 1902 (9), and the fractures are typically caused by rapid loading of the lateral foot. Jones fractures occur in zone 2 on the metaphyseal–diaphyseal junction with strong abduction force to the forefoot, causing a bending moment at the metaphyseal–diaphyseal junction (6). Stress fractures of the proximal diaphysis of the fifth metatarsal result from repetitive loading with axial, rotational, and adduction forces in zone 3 (6). It has been suggested that Jones fractures are associated with forefoot adduction (3), varus hindfoot (10), and metatarsus adductus (11). In contrast, proximal diaphyseal stress fractures of the fifth metatarsal occur with repetitive stress on the plantar-lateral side of fifth metatarsal, suggesting the influence of ankle supination.

To our best knowledge, this is the first report presenting that ankle structures potentially become associated factors for proximal diaphyseal stress fractures of the fifth metatarsal in professional soccer players. Our findings would be helpful in screening for asymptomatic proximal diaphyseal stress fractures of the fifth metatarsal, because the findings in ankle structures do not depend on whether ankle radiographs are taken with or without weightbearing. If these signs are detected, preventive options such as game play restriction, use of a functional metatarsal brace, or use of a stiff-soled shoe should be considered (12).

The study has several limitations. First, this study was conducted retrospectively. To confirm that ankle structures would truly become predisposing factors of proximal diaphyseal stress fractures of the fifth metatarsal, a prospective study should be done on professional soccer players. Second, as a risk factor of proximal diaphyseal stress fractures of the fifth metatarsal in professional soccer players, the OR with MMSA 1.27 (95% CI 1.110 to 1.463) was moderate, although it was statistically significant. In the present study, the small sample size possibly brought about the moderate OR, which might be a possible type 1 error. To verify our result, a prospective study in a large cohort with multiple club teams would be ideal. Third, our study prepared only selected covariates and might suffer from the effects of residual confounding.

In conclusion, based on the present study, we clarified that a wide MMSA has become an associated factor of proximal diaphyseal stress fractures of the fifth metatarsal. We speculated that the ankle structure with a wide MMSA may lead to increasing repetitive stress on the plantar-lateral side of the fifth metatarsal, resulting in the proximal diaphyseal stress fracture of the fifth metatarsal. Future work will be needed to verify this apparent association.

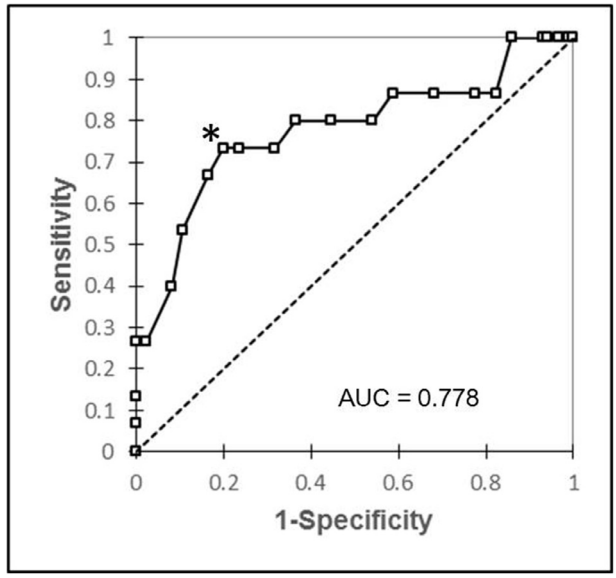

Fig. 3. Receiver operating characteristic curve for the presence of the proximal diaphyseal stress fractures of the fifth metatarsal. The asterisk represents the suitable cut-off point set at a medial malleolar slip angle >27° with sensitivity of 0.733 and specificity of 0.800.

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