Original Article
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Age, Body Mass Index, and Spur Size Associated with Patients' Symptoms in Plantar Fasciitis

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Background: Plantar fasciitis is a common cause of heel pain affecting 10% of the general population. This study aimed to investigate the specific symptoms in patients with plantar fasciitis using the Foot and Ankle Outcome Score (FAOS) questionnaire and their relationship with demographic and radiographic factors.

Methods: We retrospectively analyzed 73 consecutive patients (mean age, 53.8 ± 10.0 years; 20 men and 53 women) with plantar fasciitis who had visited our foot and ankle clinic and undergone weight-bearing foot X-ray examinations. Their demographic data, anteroposterior and lateral talo-first metatarsal angles, intermetatarsal and hallux valgus angles, and responses to the FAOS questionnaire were recorded.

Results: The quality-of-life subscale showed the lowest score of all FAOS subscales. Age was significantly correlated with quality of life ($r = 0.297$, $p = 0.011$), and body mass index was correlated with the function in sports and recreational activities ($r = -0.251$, $p = 0.032$). Age and body mass index were statistically significantly correlated with calcaneal spur size ($r = 0.274$, $p = 0.027$ and $r = 0.324$, $p = 0.008$, respectively). The calcaneal spur size was significantly correlated with pain ($r = -0.348$, $p = 0.004$), function in daily living ($r = -0.410$, $p = 0.001$), and function in sports and recreational activities ($r = -0.439$, $p < 0.001$).

Conclusions: Demographic factors were associated with specific symptoms in patients with plantar fasciitis. Calcaneal spur size was the only radiographic parameter correlated with symptoms. These findings help communicate with patients, set appropriate treatment goals, and evaluate treatment effectiveness.

Keywords: *Plantar fasciitis, Demographic, Radiographic, Symptom, Foot and Ankle Outcome Score*

Plantar fasciitis is the most common cause of heel pain and a very common foot and ankle condition, affecting up to 10% of the general population during their lifetime.[1,2] It accounts for a considerable amount of healthcare costs.[3] The plantar fascia is a fibrous aponeurosis arising from the calcaneal tuberosity and inserting into the plantar aspect of the toes. It plays a critical role in maintaining the longitudinal foot arch and absorbing forces across the midtarsal joint.[4] Therefore, it is continuously at risk of overuse injury and degeneration that may cause plantar heel pain.[5-8]

Although foot radiography is frequently performed in the evaluation of plantar heel pain, the relationship between radiographic parameters and symptoms of plantar fasciitis has not been sufficiently investigated except for calcaneal spurs.[9,10] However, the exact role of a calcaneal spur in the symptomatology of plantar fasciitis is still debatable because it can be seen in asymptomatic patients and concur with foot arthritis.[11] Furthermore, evidence of the effect of common foot deformities, including hallux valgus and flatfoot, on plantar fasciitis is scarce.

Therefore, this study aimed to investigate the specific symptoms and their relationship with demographic and radiographic factors in plantar fasciitis using the validated Foot and Ankle Outcome Score (FAOS) questionnaire.

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METHODS

This study has been approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB No. B-2101-661-103) and informed consent was waived due to retrospective nature of the study.

Patient Selection

Consecutive patients who had visited our foot and ankle clinic (a tertiary referral center) for plantar fasciitis were eligible between January 2019 and June 2019. We searched the clinical database of our hospital (Electronic Medical Record Adoption Model, Stage 7; Healthcare Information and Management Systems Society, Chicago, IL, USA) for patients using keywords and the International Classification of Diseases code for plantar fasciitis (M72.2). All patients underwent weight-bearing foot radiographs (anteroposterior [AP] and lateral views) and were required to fill out the FAOS questionnaire that had been validated.[12,13)]

The diagnosis of plantar fasciitis was made clinically by a single orthopedic surgeon (KML) with a practical experience of 19 years, of which he spent 12 years as a specialist in foot and ankle surgery. The assessment focused on the history of maximum heel pain when getting up in the morning and the tender point at the medial and distal aspect of the calcaneal tuberosity to distinguish plantar fasciitis from other causes of heel pain, such as fat pad atrophy.[14)] Patients with (1) previous foot or ankle surgery, (2) neuromuscular diseases, (3) congenital anomalies, (4) musculoskeletal tumors or infections, (5) radiographic evidence of osteoarthritis of the foot and ankle, (6) inflammatory arthritis, such as rheumatoid arthritis, (7) any conditions that could change the normal anatomy of the foot and ankle, and (8) any other condition that could affect the FAOS, except plantar fasciitis, hallux valgus, and pes planovalgus deformity, were excluded. Fig. 1 shows the selection flow of patients through our study.

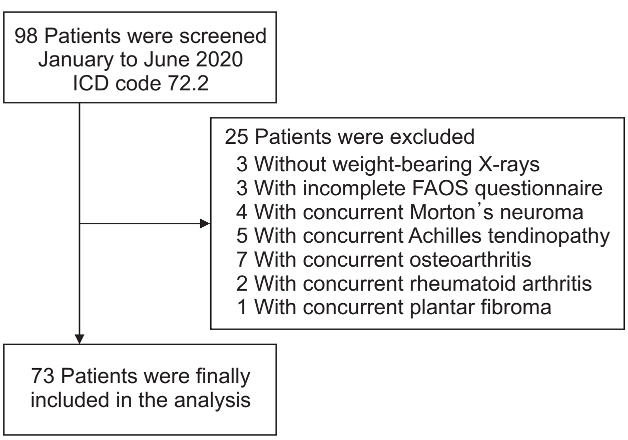

Fig. 1. Flowchart of patients with plantar fasciitis (n = 73) through this study for inclusion and exclusion. ICD: International Classification of Diseases, FAOS: Foot and Ankle Outcome Score.

FAOS Questionnaire

The FAOS is based on a 42-item self-administered questionnaire developed to assess patients' opinions regarding various foot- and ankle-related problems. The FAOS has five subscales: symptoms and stiffness (7 items), pain (9 items), function during daily living (17 items), function during sports and recreational activities (5 items), and quality of life (4 items). Standardized answer options were given on a 5-point Likert scale (0–4). A normalized score (100 indicating no symptom and 0 indicating extreme symptoms) was calculated for each subscale. The patients completed a questionnaire based on the average symptoms of their foot and ankle problems exhibited in the previous week.[12,13)]

Radiographic Measurements

Radiographs of the concerned foot were taken using a DigitalDiagnost X-ray machine (Philips Healthcare, Amsterdam, The Netherlands) according to our protocol. The AP view was obtained with the central beam angled at 15° to the vertical axis and centered between the feet at the level of the midtarsal joint, with the patient standing barefoot. The feet were 10 cm apart with their medial borders

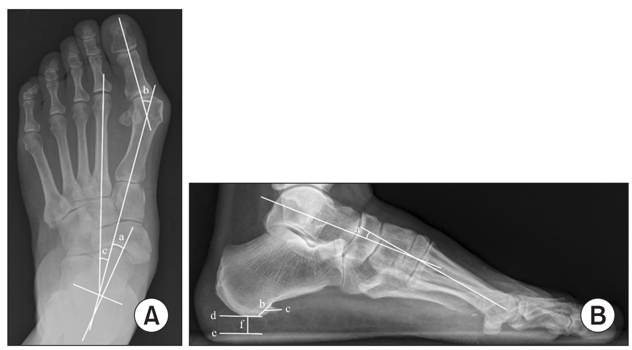

Fig. 2. Radiographic examination of the foot. (A) Weight-bearing anteroposterior foot radiograph. The anteroposterior talo-first metatarsal angle (a) is the angle between the longitudinal axis of the talus and that of the first metatarsal. The hallux valgus angle (b) is the angle between the longitudinal axis of the first metatarsal and that of the first proximal phalanx. The intermetatarsal angle (c) is the angle between the longitudinal axes of the first and second metatarsals. (B) Weight-bearing lateral foot radiograph. The lateral talo-first metatarsal angle (a) is the angle between the longitudinal axis of the talus and that of the first metatarsal. The calcaneal spur size (c) is the distance between the tip of the spur and the midpoint of the spur base demarcating the calcaneal border (b). Soft-tissue thickness of the heel (f) is the distance between the floor (e) and the lowest point of the calcaneal tuberosity (d).

parallel. The lateral radiograph was captured separately for each foot standing with the beam focusing on the medial cuneiform. The radiograph settings were 60 kVp and 10 mAs at a source-to-image distance of 110 cm. All radiographic images were digitally acquired using a picture archiving and communication system (PACS; INFINITT Healthcare, Seoul, Korea), and radiographic measurements were performed using PACS software.

Six radiographic indices were selected and measured: the AP talo-first metatarsal angle, lateral talo-first metatarsal angle, hallux valgus angle, intermetatarsal angle, calcaneal spur size, and heel soft-tissue thickness. The AP talo-first metatarsal angle was defined as the angle between the longitudinal axis of the first metatarsal and that of the talus on the AP radiograph (Fig. 2A).[15] A positive value was defined as abduction of the forefoot. The hallux valgus angle was measured between the longitudinal axis of the first metatarsal and that of the first proximal phalanx on the AP radiograph (Fig. 2A).[16] The intermetatarsal angle was the angle between the longitudinal axes of the first and second metatarsals on the AP foot radiograph (Fig. 2A).[16] The lateral talo-first metatarsal angle was defined as the angle between the longitudinal axis of the first metatarsal and that of the talus on the lateral foot radiograph,[15] and a positive value was defined as a flatfoot (Fig. 2B). The calcaneal spur size was defined as the distance between the tip of the spur and the midpoint of the spur base demarcating the calcaneal border.[17] Soft-tissue thickness of the heel was defined as the distance between the floor and the lowest point of the calcaneal tuberosity on weight-bearing lateral radiographs (Fig. 2B).[18]

After a consensus on the radiographic measurements to be used for the study was reached, interobserver reliability was tested for 36 randomly selected images, which was the number predetermined by a sample size estimation for three observers. Three orthopedic surgeons (KML, WYC, and HSH) with a clinical experience of 19, 5, and 3 years, respectively, conducted the radiographic measurements independently and were blinded to the clinical information of the patients. Following the reliability testing, one of the surgeon with an experience of 5 years (WYC) measured the radiographic indices for all patients.

Statistical Analysis

The intraclass correlation coefficient (ICC) was used for the interobserver reliability of radiographic measurements. The sample size was calculated with an ICC target value of 0.9 and a 95% confidence interval of 0.2, assuming a single measurement and absolute agreement in a two-way mixed effect model.[19]

Descriptive analysis was performed for all datasets and included the mean ± standard deviation for continuous variables and frequency for dichotomous variables. The Kolmogorov-Smirnov test was used to evaluate the normal distribution of data for the continuous variables. The results between the two groups were compared using the Student *t*-test or Mann-Whitney *U*-test, depending on whether data were distributed normally or not. A potential correlation between the variables was analyzed using the Pearson's or Spearman's correlation coefficient. All statistical analyses were performed with IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, US), and a p-value < 0.05 was considered to indicate statistical significance.

Table 1. Demographic and Clinical Characteristics of Patients with Plantar Fasciitis

Characteristic	Value (n = 73)
No. of patients	73
Sex (male : female)	20 : 53
Age (yr)	53.8 ± 10.0
Height (cm)	160.1 ± 8.2
Weight (kg)	66.3 ± 12.4
BMI (kg/m^2)	25.8 ± 3.9
Radiographic measurement	
AP talo-1st MT (°)	10.7 ± 7.3
Lat talo-1st MT (°)	1.7 ± 7.5
IMA (°)	9.2 ± 2.8
HVA (°)	13.7 ± 7.9
Calcaneal spur (mm)	3.2 ± 2.5
Soft-tissue thickness (mm)	8.7 ± 2.0
Foot and Ankle Outcome Score	
Symptom	79.6 ± 13.4
Pain	64.3 ± 17.8
ADL	79.2 ± 17.3
Sports & recreation	65.7 ± 23.8
QoL	41.4 ± 22.7

Values are presented as mean ± standard deviation.
BMI: body mass index, AP talo-1st MT: anteroposterior talo-first metatarsal angle, Lat talo-1st MT: lateral talo-first metatarsal angle, IMA: intermetatarsal angle, HVA: hallux valgus angle, ADL: activities of daily living, QoL: quality of life.

RESULTS

We analyzed the data of 73 patients, 20 men and 53 women, with a mean age of 53.8 ± 10.0 years. The mean body mass index (BMI) was 25.8 ± 3.9 kg/m^2. The mean normalized subscore of the FAOS was highest for the symptoms and stiffness subscale (79.6 ± 13.4) and lowest in the quality-of-life subscale (41.4 ± 22.7). The mean AP talo-first metatarsal angle, hallux valgus angle, calcaneal spur size, and soft-tissue thickness of the heel were 10.7° ± 7.3°, 13.7° ± 7.9°, 3.2 ± 2.5 mm, and 8.0 ± 2.0 mm, respectively (Table 1). All radiographic measurements showed excellent ICCs in interobserver reliability testing (Table 2).

Male patients were significantly younger ($p = 0.028$) and showed a significantly smaller hallux valgus angle ($p = 0.003$) than female patients. Male patients further had a significantly higher normalized score in the function during sports and recreational activities subscale than that of female patients ($p = 0.034$) (Table 3). Age showed a significant positive correlation with the quality-of-life subscale ($r = 0.297$, $p = 0.011$), whereas the BMI correlated negatively with the function during sports and recreational activities subscale ($r = –0.251$, $p = 0.032$). Age and BMI showed a significant correlation with the calcaneal spur size ($r = 0.274$, $p = 0.027$; $r = 0.324$, $p = 0.008$, respectively), and calcaneal spur size was significantly correlated with the pain subscale ($r = –0.348$, $p = 0.004$), function during daily living subscale ($r = –0.410$, $p = 0.001$), and function in sports and recreational activities subscale ($r = –0.439$, $p < 0.001$) (Table 4).

Night pain (P7) ($p = 0.014$), sitting pain (P8) ($p = 0.037$), and difficulty in rising from bed (A10) ($p = 0.032$) were significantly greater in women than in men (Supplementary Table 1). Age was significantly correlated with pain frequency ($r = –0.245$, $p = 0.041$). Patients with a higher BMI reported more pain when walking on a flat surface (P5) ($r = 0.234$, $p = 0.048$) and more difficulty when climbing stairs (A2) ($r = 0.243$, $p = 0.039$). Larger calcaneal spur size was correlated with greater pain when walking on a flat surface (P5) ($r = 0.335$, $p = 0.007$) and going up or down the stairs (P6) ($r = 0.341$, $p = 0.005$), as well as more difficulties in rising from sitting (A3) ($r = 0.408$, $p = 0.001$), walking on a flat surface (A6) ($r = 0.373$, $p = 0.002$), rising from bed (A10) ($r = 0.244$, $p = 0.049$), and sports activities such as squatting (SP1) ($r = 0.351$, $p = 0.004$), running (SP2) ($r = 0.378$, $p = 0.002$), jumping (SP3) ($r = 0.393$, $p = 0.001$), and twisting/pivoting on the foot/ankle (SP4) ($r = 0.367$, $p = 0.003$) (Supplementary Table 2).

Table 2. Interobserver Reliability of Radiographic Measurements

Variable	ICC (95% CI)
AP talo-1st MT	0.889 (0.693–0.950)
Lat talo-1st MT	0.873 (0.750–0.932)
IMA	0.894 (0.815–0.939)
HVA	0.923 (0.869–0.955)
Calcaneal spur	0.932 (0.885–0.961)
Soft-tissue thickness	0.896 (0.536–0.961)

ICC: intraclass correlation coefficient, CI: confidence interval, AP talo-1st MT: anteroposterior talo-first metatarsal angle, Lat talo-1st MT: lateral talo-first metatarsal angle, IMA: intermetatarsal angle, HVA: hallux valgus angle.

Table 3. Comparison of Demographic and Clinical Characteristics between Male and Female Patients with Plantar Fasciitis (n = 73)

Characteristic	Male (n = 20)	Female (n = 53)	*p*-value
Age (yr)	49.7 ± 11.4	55.3 ± 9.0	0.028
Height (cm)	170.3 ± 6.1	156.3 ± 5.0	< 0.001
Weight (kg)	75.7 ± 12.7	62.7 ± 10.4	< 0.001
Body mass index (kg/m^2)	26.0 ± 3.2	25.7 ± 4.2	0.765
Radiographic measurement			
AP talo-1st MT (°)	12.2 ± 5.5	10.1 ± 7.9	0.287
Lat talo-1st MT (°)	4.6 ± 6.0	0.6 ± 7.8	0.047
IMA (°)	8.8 ± 2.1	9.4 ± 3.1	0.443
HVA (°)	10.2 ± 4.2	15.1 ± 8.7	0.003
Calcaneal spur (mm)	2.5 ± 2.6	3.5 ± 2.4	0.168
Soft-tissue thickness (mm)	8.9 ± 1.5	8.6 ± 2.1	0.589
Foot and Ankle Outcome Score			
Symptom	81.3 ± 12.9	79.0 ± 13.7	0.531
Pain	67.3 ± 16.4	63.1 ± 18.3	0.374
ADL	84.0 ± 17.4	77.4 ± 17.0	0.145
Sports & recreation	75.3 ± 21.7	62.1 ± 23.7	0.034
QoL	45.3 ± 24.2	39.9 ± 22.1	0.368

Values are presented as mean ± standard deviation.
AP talo-1st MT: anteroposterior talo-first metatarsal angle, Lat talo-1st MT: lateral talo-first metatarsal angle, IMA: intermetatarsal angle, HVA: hallux valgus angle, ADL: activities of daily living, QoL: quality of life.

Table 4. Correlation Table for the Demographic, Clinical, and Radiographic Variables Investigated in This Study in Patients with Plantar Fasciitis (n = 73)

Variable	Age	BMI	Symptom	Pain	ADL	Sports & recreation	QoL	AP talo-1st MT	Lat talo-1st MT	IMA	HVA	Calcaneal spur
BMI	$r = 0.164$ $p = 0.165$											
Symptom	$r = 0.120$ $p = 0.312$	$r = -0.163$ $p = 0.169$										
Pain	$r = 0.173$ $p = 0.143$	$r = -0.037$ $p = 0.755$	$r = 0.249$ $p = 0.034$									
ADL	$r = -0.071$ $p = 0.553$	$r = -0.223$ $p = 0.057$	$r = 0.175$ $p = 0.138$	$r = 0.713$ $p < 0.001$								
Sports & recreation	$r = -0.030$ $p = 0.800$	$r = -0.251$ $p = 0.032$	$r = 0.314$ $p = 0.007$	$r = 0.558$ $p < 0.001$	$r = 0.832$ $p < 0.001$							
QoL	$r = 0.297$ $p = 0.011$	$r = 0.013$ $p = 0.916$	$r = 0.215$ $p = 0.069$	$r = 0.594$ $p < 0.001$	$r = 0.529$ $p < 0.001$	$r = 0.536$ $p < 0.001$						
AP talo-1st MT	$r = -0.023$ $p = 0.854$	$r = 0.079$ $p = 0.524$	$r = 0.015$ $p = 0.904$	$r = 0.037$ $p = 0.769$	$r = 0.005$ $p = 0.967$	$r = -0.016$ $p = 0.900$	$r = -0.152$ $p = 0.224$					
Lat talo-1st MT	$r = 0.014$ $p = 0.913$	$r = -0.054$ $p = 0.669$	$r = 0.092$ $p = 0.466$	$r = 0.062$ $p = 0.622$	$r = 0.041$ $p = 0.748$	$r = 0.163$ $p = 0.195$	$r = 0.096$ $p = 0.449$					
IMA	$r = 0.051$ $p = 0.684$	$r = -0.177$ $p = 0.152$	$r = 0.020$ $p = 0.870$	$r = 0.027$ $p = 0.831$	$r = -0.113$ $p = 0.363$	$r = -0.193$ $p = 0.117$	$r = -0.084$ $p = 0.504$	$r = 0.152$ $p = 0.221$	$r = 0.495$ $p < 0.001$			
HVA	$r = 0.224$ $p = 0.068$	$r = -0.105$ $p = 0.398$	$r = -0.083$ $p = 0.503$	$r = 0.014$ $p = 0.911$	$r = -0.065$ $p = 0.601$	$r = -0.129$ $p = 0.299$	$r = -0.026$ $p = 0.835$	$r = 0.310$ $p = 0.011$	$r = 0.274$ $p = 0.027$	$r = 0.582$ $p < 0.001$		
Calcaneal spur	$r = 0.274$ $p = 0.027$	$r = 0.324$ $p = 0.008$	$r = -0.007$ $p = 0.957$	$r = -0.348$ $p = 0.004$	$r = -0.410$ $p = 0.001$	$r = -0.439$ $p < 0.001$	$r = -0.210$ $p = 0.096$	$r = 0.175$ $p = 0.163$	$r = -0.203$ $p = 0.104$	$r = 0.073$ $p = 0.563$	$r = -0.044$ $p = 0.729$	
Soft-tissue thickness	$r = 0.187$ $p = 0.135$	$r = 0.282$ $p = 0.023$	$r = 0.070$ $p = 0.581$	$r = -0.090$ $p = 0.474$	$r = -0.164$ $p = 0.191$	$r = -0.052$ $p = 0.683$	$r = 0.024$ $p = 0.850$	$r = -0.141$ $p = 0.263$	$r = 0.079$ $p = 0.532$	$r = -0.100$ $p = 0.430$	$r = -0.009$ $p = 0.945$	$r = 0.144$ $p = 0.253$

BMI: body mass index, ADL: activities of daily living, QoL: quality of life, AP talo-1st MT: anteroposterior talo-first metatarsal angle, Lat talo-1st MT: lateral talo-first metatarsal angle, IMA: intermetatarsal angle, HVA: hallux valgus angle.

DISCUSSION

This study investigated the effects of demographic and radiographic characteristics on the specific symptoms of patients with plantar fasciitis. Based on the FAOS, plantar fasciitis showed a lower normalized score in the quality-of-life subscale than in the symptoms, stiffness, pain, activities of daily living, and function during sports and recreational activities subscales. Among the radiographic measurements, calcaneal spur size was found to be a clinically relevant index that was associated with some of the subscales and symptoms in the FAOS.

Men with plantar fasciitis showed a higher normalized score in their function in sports and recreational activities subscale than that of women. However, we could not conclude whether this was a gender-specific effect because, in our cohort, men and women also had significantly different age, lateral talo-first metatarsal angle, and hallux valgus angle. Age showed a positive correlation with the quality of life, implying that increasing age is associated with higher quality of life in patients with plantar fasciitis. This could be interpreted such that the quality of life of patients is less affected by plantar fasciitis as they become older. A high BMI was correlated with a limited function in sports and recreational activities. Therefore, weight reduction might be recommended for those who want to recover their sports and recreational activities.

Although a previous study reported that the incidence of plantar fasciitis increased with the severity of a hallux valgus deformity,[20] the hallux valgus angle and patient-reported symptoms did not show a significant relationship with plantar fasciitis in our patients. The previous study suggested that an abnormal windlass mechanism in hallux valgus deformity could favor the development of plantar fasciitis,[20] but this needs to be validated in biomechanical or cadaveric studies. A flatfoot has been shown to be a causative factor in the development of plantar fasciitis.[21] However, the radiographic indices for flatfoot deformity, such as the AP and lateral talo-first metatarsal angles, did not correlate with the symptoms of plantar fasciitis in our patients. Whether hallux valgus and flatfoot deformities only contribute to the development but not to the severity of symptoms of plantar fasciitis is not known, and further study is required to clarify this issue. Furthermore, the discrepancies between previous studies and our study might result from different characteristics of the cohort. We had strictly excluded patients with radiographic evidence of foot osteoarthritis and the patients showed somewhat narrow ranges of foot deformities in terms of radiographic measurements.

Calcaneal spur size was found to be significantly associated with patients' self-reported symptoms. The clinical implications of calcaneal spurs have been extensively investigated in patients with and without plantar fasciitis in previous studies.[1,22,23] Calcaneal spurs are commonly found in the general population, and majority of them are silent.[11] Furthermore, a calcaneal spur may be located within the origin of the plantar fascia or plantar muscles.[24] Calcaneal spurs and plantar fascial thickening frequently coexisted in individuals with plantar heel pain.[25] Therefore, a calcaneal spur may represent degenerative changes in the plantar fascia and could aggravate the symptoms in patients with current plantar fasciitis. In our study, calcaneal spur size was correlated with the patients' age and BMI and was also significantly associated with patients' pain, activities of daily living, and sports activities, which supports previous results.[11,26] However, evidence on whether spur excision affects symptoms and recurrence of the condition is inconclusive[27,28] and needs to be investigated in well-designed studies.

Based on each FAOS items, our study results show a correlation of several demographic and radiographic factors with specific symptoms using a validated self-reported questionnaire. Women reported more severe night and sitting pain, as well as more difficulty in rising from the bed than men. Patients with a high BMI reported more pain when walking on a flat surface and more difficulty when climbing stairs. Pain from plantar fasciitis was less frequent in older patients. Patients with larger calcaneal spurs reported more pain when walking on a flat surface and climbing or going downstairs and more difficulty in rising from bed and sports activities. A better understanding of these specific relationships may help clinicians communicate with their patients with plantar fasciitis, set appropriate treatment goals, and evaluate the effectiveness of the treatment.

Our results need to be interpreted within the limitations of this study. First, this was a retrospective file review, and unknown bias might have affected our results. Second, the study was performed at a tertiary referral medical center, and selection bias could not be excluded. Third, due to the cross-sectional investigation, we could not obtain information on the duration or recurrence of plantar fasciitis in our patients. Theoretically, the duration or recurrence of plantar fasciitis could affect the degeneration of the plantar fascia or the development of calcaneal spurs. In fact, a calcaneal spur might be a secondary representation of the quality of the fascia, which makes it more vulnerable to inflammatory processes. More effective clinical markers of symptoms of plantar fasciitis need to be obtained in a future longitudinal study.

Demographic factors were associated with specific symptoms in patients with plantar fasciitis. Calcaneal spur size was the only radiographic parameter correlated with symptoms. Future studies need to focus on the longitudinal course of the disease and the prognostic factors of plantar fasciitis.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY MATERIAL

Supplementary material is available in the electronic version of this paper at the CiOS website, www.ecios.org.

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