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Radiological Evaluation of the Relationship Between Plantar Fasciitis and Foot Arch Angles in Adults

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Abstract

Objective: The foot arch deformation increases plantar fasciitis (PF) and plantar calcaneal spur (PCS) formation. As a result, the heel fat pad becomes thinner. This study investigated the relationship between plantar fasciitis and foot arch angles.

Methods: We performed a retrospective review of patients who had PF patients (n = 53) and healthy individuals (n = 71) without PF. We have evaluated the presence of PCS and heel fat pad thickness measurements on magnetic resonance imaging (MRI), and the lateral talus-first metatarsal angle (Meary's angle), lateral talocalcaneal angle, and calcaneal inclination angle measurements were performed on X-ray images.

Results: The mean age of the PF group was significantly higher than the control group (p = 0.001). The degrees of Meary's angle and calcaneus inclination angle were significantly higher in the PF group (p < 0.001 and p = 0.026, respectively) than in the control group. The incidence of PCS was significantly higher in the PF group (p = 0.028). In the binary logistic regression analysis model, high Meary's angle and calcaneal pitch angle were found to be associated with the risk of PF. There was also a significant association between age and the presence of PCS and PF.

Conclusion: Changes in Meary's angle and calcaneal pitch angle were significant risk factors for PF.

Key words: Plantar fasciitis, heel fat pad, calcaneal spur, Meary's angle, lateral talo-calcaneal angle, calcaneal inclination angle

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INTRODUCTION

The foot is an integral component of the skeletal system in the human body and plays an important role in walking (1). Feet not only support body weight but also maintain the balance of the body against external forces. Moreover, for each step the foot takes, it simultaneously receives the pressure of approximately 80% of the bodyweight (2). The arc of the foot helps the foot adapt to a variety of surfaces and absorbs the forces exerted on the foot when performing activities in a closed kinematic chain. In addition to the above-mentioned function, the arch of the foot also acts as a solid lever during walking (3).

Plantar fasciitis is known as the most common cause of plantar heel pain (4). This problem affects approximately 10% of people at any point of time in their lives (5). With the deterioration of the arch angles of the feet, the anatomical contact of the foot with the ground is impaired; furthermore, excessive foot pronation is particularly an important risk factor for the development of plantar fasciitis. Increased plantar fascia thickness and abnormal soft tissue findings support the diagnosis of plantar fasciitis (6,7). Likewise, the contact of the bodyweight with the ground is impaired following deterioration of the arch angles of the feet (7). Pathological change can also be induced by repeatedly applied stress to the plantar fascia (8). In general, plantar fasciitis (PF) is caused by inflammation from repeated stress placed on the plantar fascia, degenerative changes due to fibrosis, microdamage of the foot heel, and excess biomechanical use such as bearing body weight for extended amounts of time (9,10). Plantar fasciitis is associated with many biomechanical factors such as pes cavus, sudden gain in body weight or obesity, increased running distance or intensity, shoes with poor cushioning, change in the walking or running surface, and tightness of the Achilles tendon (11).

To the best of our knowledge, there is no study in the literature evaluating both the thickness of the unloaded heel fat pad and the arch deformation of the foot in patients with PF. In this study, we purposed to investigate the thickness of the heel fat pad and the angles of the foot arch in patients with PF. We hypothesize that the foot arch deformation increases plantar fasciitis and plantar calcaneal spur formation. As a result, the heel fat pad becomes thinner.

METHODS

This retrospective single-center study was conducted in the Orthopedics and Traumatology Department of our hospital with the contributions of the Radiology Department between March 2020 and May 2021. This research has been approved by the IRB of the authors' affiliated institutions. The study was conducted with the principles of the Declaration of Helsinki. This study was planned with at least 52 patients in each group. The sample size was determined using G-Power with an effect size of 0.8, a power of 0.8, and a significance level of α=0.05.

Our study evaluated the magnetic resonance imaging (MRI) findings of the ankle taken by the radiology clinic between March 2020 and May 2021. Patients diagnosed with plantar fasciitis based on these MRI findings were included in the PF group (n = 53) and those without plantar fasciitis were included in the control group (n = 71). Exclusion criteria included a history of previous foot surgery; foot injury, including any bone pathology or ligament injury; congenital deformity of the lower extremity, and patients with a space-occupying lesion. Patients who could not undergo standard true lateral X-ray and MRI, as well as patients aged under the age of 20 years, were excluded from the study. The lateral radiographs were taken with the tibia neutral on the talus and the x-ray beam centered on the lateral cuneiform and parallel to the weight-bearing surface. Unloaded heel fat pad thickness (UHPT) was measured on MRI in all patients included in the study. Scanning was performed with a 1.5 Tesla Magnetum system (SIEMENS Magnetom Amira, Germany). Sagittal, coronal, and axial images with a section thickness of 4 mm were obtained in all scans. The MRI sequences included sagittal, coronal, axial T1-weighted, and proton-weighted images. UHPT measurements were performed using the sagittal images. This measurement was accomplished by measuring the distance from the calcaneal tuberosity to the outer margin of the skin (Figure 1). The lateral talus-first metatarsal angle (Meary's angle), lateral talocalcaneal angle (LTCA), and calcaneal inclination angle (the calcaneal pitch) measurements were performed using weight-bearing lateral X-ray images of all patients (Figure 2). All measurements were made using the standardized method described by Flores et al., and were conducted using the digital radiographic viewer at our clinic with the picture archiving and communications systems (PACS) (12). The presence of plantar fasciitis and plantar calcaneal spur (PCS) was investigated by MRI. Findings such as thickening of the plantar fascia, increased signal intensity in or around the fascia in fat-suppressed sequences, and limited bone marrow edema within the medial calcaneal tuberosity were evaluated in favor of inflammation (Figure 3) (13). All X-rays and MRI were evaluated by a radiologist and orthopedic and traumatology specialist with at least 5 years of experience. Each observer evaluated the radiographs and MRI—listed differently each time—on a total of 2 occasions. The average of the measurements was recorded. In addition, the age, gender, foot side, and body mass index (BMI) data of all patients were obtained using the digital recording system.

Statistical Analysis

The sample size was based on the literature obtained for the difference observed in the thickness of the plantar fascia in patients with plantar fasciitis. A power of 80% and a confidence level of 95% yielded the sample size. All data were analyzed using the statistical software package SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). A normality check was performed using the Kolmogorov–Smirnov test. The data were presented as mean and standard deviation for continuous variables. The categorical variables were expressed as frequency and percentage and compared using the chi-squared test. The non-normally distributed data were compared using the Mann–Whitney U test. Factors affecting the presence of plantar fasciitis were examined by binary logistic regression analysis. $P < 0.05$ was accepted as a statistically significant level. In addition, the intraclass correlation coefficient (ICC) was used as a statistical analysis to determine interobserver reliability.

RESULTS

The demographic and clinical characteristics of the participants are presented in Table 1. There was no significant difference between the groups in terms of the evaluated foot side, BMI, and gender distribution (p > 0.05). The age of the patients with PF was significantly higher than the control group (p = 0.001). When the patients were evaluated according to their foot arch angles, the Meary's angle and calcaneal inclination angle degrees were significantly higher in the plantar fasciitis group (p<0.001 and p=0.026, respectively) (Table 1). No statistically significant differences were found between the groups regarding lateral talocalcaneal angle and UHPT values (*p* = 0.236 and *p* = 0.231, respectively). PCS was present in 13 (24.53%) of the patients with PF and 7 (9.86%) of the patients in the control group. The incidence of PCS was significantly higher in the PF group (p = 0.028).

Table 1. Demographic and clinical characteristics of the participants

Parameter	Plantar fasciitis (*n* = 53)	Control (*n* = 71)	*p*-value
Gender (Male/Female)	19/34 (35.85%/64.15%)	29/42 (40.85%/59.15%)	0.572[a]
Side (Right/Left)	30/23 (56.60%/43.40%)	41/30 (57.75%/42.25%)	0.899[a]
Age (years)	50.43 ± 11.59	41.92 ± 14.30	**0.001[b]**
Body mass index (kg/m^2)	23.81 ± 1.86	23.21 ± 2.08	0.120[b]
Meary's angle	4.44 ± 4.05	2.62 ± 2.17	**<0.001[b]**
Lateral talocalcaneal angle	26.92 ± 8.14	24.75 ± 5.34	0.236[b]
Calcaneal pitch angle	18.81 ± 5.58	16.60 ± 4.96	**0.026[b]**
UHPT (mm)	14.50 ± 3.00	13.86 ± 2.62	0.231[b]

Data are given as mean ± standard deviation for continuous variables and as frequency (percentage) for categorical variables. [a]Chi-square test; [b]Mann–Whitney U test. UHPT: unloaded heel fat pad thickness

In the binary logistic regression analysis model, high Meary's angle and calcaneal pitch angle were found to be associated with the risk of plantar fasciitis (95% CI: 1.070–1.537; P = 0.007 and 95% CI: 1.056–1.251; p = 0.001, respectively). There was also a significant association between age and the presence of PCS and PF (95% CI: 1.019–1.088; p = 0.002 and 95% CI: 1.092–9.923; p = 0.034, respectively) (Table 2). The measurements of all images showed almost perfect interobserver agreement, and ICC was 0.974

Table 2. Factors associated with the risk of plantar fasciitis.

Variables	Odds Ratio (95% CI)*	p-value
Age	1.053(1.019–1.088)	0.002
Meary's angle	1.282 1.070–1.537)	0.007
Calcaneal pitch angle	1.149 (1.056–1.251)	0.001
Plantar calcaneal spur	3.292 (1.092–9.923)	0.034

DISCUSSION

Plantar fasciitis is a disease frequently encountered and is the most common cause of heel pain in adults (14). Although PF is known as the local inflammation of the plantar fascia due to microtrauma, its exact etiology is yet to be clarified. Our study shows that there is a highly significant relation between PF and PCS. In addition, while changes in Meary's angle and the calcaneal pitch angle result in an increased risk of PF, whereas changes in the lateral talocalcaneal angle have no significant effect on PF. The risk of PF also increases with age.

Although the exact etiology of PF is unknown, many studies investigating its etiology are available in the literature. One of the etiological aspects emphasized the most is the relationship between obesity and PF. Frey et al. investigated the effects of obesity on foot and ankle pathologies and showed that overweight or an obese patient has a 1.4 times increased risk of PF (15). Abate et al. investigated the effect of BMI on Achilles' tendon and plantar fascia thickness, they found that the thickness of the plantar fascia increased with increasing BMI (16). They also stated that this increased the risk of PF. Caliskan et al. are demonstrated that female sex, BMI over 30 kg/m^2, higher red cell distribution width, and higher plantar fascia thickness were associated with plantar fasciitis (17). The difference of these studies, although the BMI ratio was higher in the PF group in our study, we did not determine a significant difference between BMI and PF. In addition, the female sex ratio was higher in patients with PF and this finding was consistent with the literature.

Age is among the demographic characteristics studied in the literature regarding the etiology of PF and heel pain, and contradictory results have been obtained in such studies. According to the studies by Rome et al. and Rano et al., the groups of patients with heel pain had significantly higher ages (18, 19). Unlike these studies, Wearing et al. compared the age parameter of the groups with and without PF, no significant difference was found despite the mean age being higher in the PF group (20). In our study, the mean age in the PF group was higher than the control group, and this difference was found to be statistically significant. Additionally, according to our binary logistic regression analysis, we determined that a one-unit increase in age increases the presence of PF by 1.053 times.

In some studies, plantar calcaneal spur has also been shown in asymptomatic patients (21,22). Therefore, it is still unclear whether there is a relation between spur formation and PF. Pasapula et al. showed that calcaneal spurs can be observed in 50% of those with heel pain (21). However, the calcaneal spur can also be observed in 16% of the patients without heel pain. Johal et al. found that the incidence of PCS was 89% in the PF group and 32% in the control group (22). On the other hand, Beytemur et al. investigated the incidence of age-related calcaneal spurs (23). They evaluated the lateral ankle X-rays of 1335 patients and found the incidence of PCS to be 32.2%. In addition, they determined that the incidence of PCS increases with age, and the posterior calcaneal spur is more common in women, and there is no difference between men and women in the incidence of the plantar calcaneal spur. In our study, the incidence of PCS was found to be 24.53% in the PF group, and it was significantly higher than in the control group. This finding is consistent with the literature. In addition, according to the binary logistic regression analysis performed, we found that the presence of PCS increased the presence of PF by 3.292 times. In our study, there were no cases of posterior calcaneal spurs. Besides, 85% of the patients with PCS were female patients.

During the gait cycle, the heel is the first point of contact between the body and the ground and is covered by a special fat pad whose main function is to absorb forces from the ground. In their histological study, Jahs et al. revealed the presence of free nerve endings and Pacinian bodies in the heel fat pad (24). These findings suggest that heel pain might originate from the heel fat pad. According to Belhan et al. who investigated the relationship between heel fat pad thickness and PF using ultrasonography, the fat pad thickness of painful heels was statistically thinner than painless heels (25). In our study, unlike the literature, unloaded heel fat pads were found to be thicker in the PF group; however, this finding was not statistically significant. Hsu et al. determined that the elderly have a thicker and stiffer heel fat pad compared with young people (26). In our study, the higher mean age in the PF group may be the reason for the thicker heel fat pad.

The plantar fascia is the primary structure that stabilizes the medial longitudinal arch (27). Therefore, abnormal arc structure may play a role in the development and progression of PF. Based on this hypothesis, the relation between PF and lower extremity biomechanics has been previously studied in the literature (28,29). In a retrospective study by Taunton et al., pes planus was found in only 19 (12%) and pes cavus in only 11 (7%) of 159 patients with PF (28). When the groups were compared in terms of Meary’s angle in our study, Meary's angle was found to be higher in the PF group than in the control group, and pes planus was present in 15 (28%) of the 53 patients with PF. We did not find cavus deformity in any of our patients. Moreover, in the binary logistic regression analysis conducted, we found that a one-degree increase in Meary’s angle increased the risk of PF by 1.282 times. This finding indicates that pes planus is an important risk factor for PF. In the study by Menz et al. measured calcaneal inclination angle, calcaneal-first metatarsal angle, and navicular height in their study between elderly patients with and without PCS and reported that there was no statistically significant difference between the two groups (29). As a result, they concluded that radiographic measurements were not effective on PCS formation. In our study, we measured the calcaneal inclination angle, LTCA, and Meary’s angle in a group of participants aged over 20 years, including patients with and without PF. In these measurements, we found that the control group had lower values than the PF group in terms of these three angles, and the difference in Meary’s angle and the calcaneal inclination angle was statistically significant. In addition, based on the binary logistic regression analysis performed, we determined that a one-degree increase in Meary’s angle, and the calcaneal inclination angle increased the risk of PF by 1.282 and 1.149 times, respectively.

This study has some limitations. The first limitation relates to the retrospective nature of the study and to the fact that the cases were evaluated only radiologically; therefore, we could not evaluate other factors such as the clinical presentations, professions, daily activities of the patients, as well as for how long they stood per day. A relation can be established between the symptoms and the demographic and radiological characteristics of patients only if such evaluation is performed. The second limitation was that more angles could be measured, such as the calcaneal-first metatarsal angle. Thus, the radiological features of the patients could be evaluated from a wider perspective and more objective results could be obtained. The third limitation was that since it is a retrospective study, the mean age was different between the groups. Age-related degenerative changes in bones may affect angle measurements.

CONCLUSION

In conclusion, patients with high foot arch on X-rays have MRI changes in PF more often. In this study, we determined that changes in Meary's angle and the calcaneal inclination angle increased the risk of PF. In addition to improving current treatment strategies for PF, there is a need to prevent the onset of inflammation in the plantar fascia. For this reason, it is important to develop screening and treatment programs that will facilitate early diagnosis and treatment of foot arch disorders. The development of such a program will contribute to saving national health expenditures on PF treatment in the future and reducing the loss of the labor force. In addition, studies with larger sample groups will be useful in identifying more risk factors for PF and developing screening programs to this end.

Ethics Committee Approval: Ethics committee approval was received for this study from local ethics committee at Turgut Ozal University with file number 2021/39

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