Clinical Utility of Sonography in Diagnosing Plantar Fasciitis

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Objective. The purpose of this study was to investigate the efficacy of sonography in the detection of plantar fasciitis (PF) compared with magnetic resonance imaging (MRI) findings in subjects with inferior heel pain. ***Methods.*** Seventy-seven patients with unilateral (n = 9) and bilateral (n = 68) heel pain were studied. Seventy-seven age- and sex-matched asymptomatic subjects served as a control group. Magnetic resonance imaging was used to establish a diagnosis of PF with sagittal T1-weighted, T2-weighted, and short tau inversion recovery sequences. The sonographic appearances of PF were compared with MRI findings. Plantar fascia and heel pad thickness were also measured on both imaging modalities. ***Results.*** Compared with MRI, sonography showed 80% sensitivity and 88.5% specificity in assessing PF. A strong correlation was found between plantar fascia and fat pad thickness measurements done by sonography ($P < .001$; $r = 0.854$) and MRI ($P < .001$; $r = 0.798$). Compared with the asymptomatic volunteers, patients with PF had significant increases in plantar fascia and heel pad thicknesses, weight, and body mass index ($P = .0001$). Heel pad thickness was also significantly increased with pain duration ($P = .021$). ***Conclusions.*** Although MRI is the modality of choice in the morphologic assessment of different plantar fascia lesions, sonography can also serve as an effective tool and may substitute MRI in the diagnosis of PF. ***Key words:*** magnetic resonance imaging; plantar fasciitis; sonography.

Abbreviations
BMI, body mass index; MRI, magnetic resonance imaging; PF, plantar fasciitis; STIR, short tau inversion recovery; TE, echo time; TR, repetition time

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Plantar fasciitis (PF) is the most common cause of inferior heel pain, with poorly understood etiology and confusing terminology.[1] It is known to affect middle-aged women and younger, predominantly male, runners.[2] The role of radiology in the management of PF is to make an accurate diagnosis as early as possible because effective treatment of PF requires precise diagnosis and differentiation from other causes of heel pain.[3] Imaging may also be of value in the follow-up of these patients, particularly athletes, to time appropriate recommencement of physical activity.[4,5] Conventional radiographic studies of patients with painful heel syndrome are often unrewarding,[6] and calcaneal uptake at radionuclide scintigraphy is a frequent but nonspecific finding.[7] Magnetic resonance imaging (MRI) has emerged as an important noninvasive diagnostic imaging technique for assessment of foot conditions, with multiplanar imaging capability and inherent superiority in contrast resolution.[8–11] Sonography has also proved to be an excellent imaging technique for the

assessment of tendon disorders in various parts of the body.[12–15] The plantar aponeurosis, similar to tendons elsewhere, is shown sonographically as a homogeneous echogenic band with internal linear interfaces on longitudinal sections.[16] Sonography has also the advantages of being noninvasive, well tolerated by patients, and inexpensive, and it provides excellent spatial resolution for superficial structures. Previous studies reported that mechanical stress and inflammation result in tendon thickening, with hypoechoic areas within the plantar fascia[17] and, occasionally, peritendon fluid collection,[18] but these studies were done in a limited number of patients. However, this study was performed in a bigger population with inferior heel pain to evaluate the effectiveness of sonography as a primary modality in diagnosing PF. To date, to our knowledge a correlation of sonographic and MRI findings of PF has not been performed. Therefore, in this prospective study, we aimed to test the utility of sonography in the evaluation of PF in patients with inferior heel pain using the MRI findings as a reference standard.

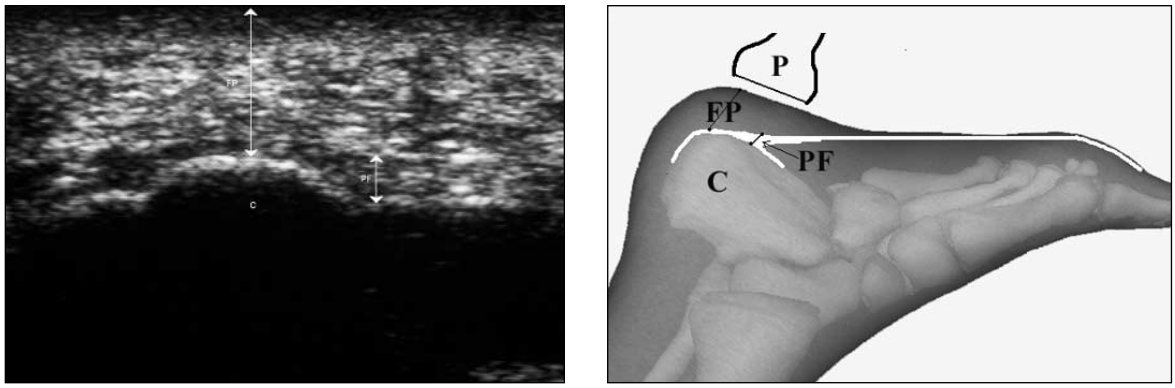
Materials and Methods

Subjects

The study population consisted of 77 patients with heel pain and the physical characteristics of PF. Nine of the study group had unilateral heel symptoms, and 68 had bilateral heel symptoms, giving a total of 145 symptomatic heels. There were 66 women and 11 men with a mean age ± SD of 45.9 ± 11.8 years (range, 26–76 years). Body weight and height of all the subjects were recorded, and, accordingly, the body mass index (BMI; weight/height^2) was calculated. In addition, heels of 77 asymptomatic volunteers were recruited into the study as a control group and were examined to provide a baseline as to the normal appearance of the plantar fascia. The control subjects were age and sex matched to the symptomatic patients and included 63 women and 14 men with a mean age of 42 ± 7.5 years (range, 25–69 years). The local Institutional Review Board approved the study, and informed consent was obtained from each subject imaged under the research protocol. Radiologic evaluation of the changes in the heels of the study and control groups was fulfilled prospectively from April 2003 to March 2004.

Radiologic Examinations

Sonograms and MR images were evaluated independently by 2 different radiologists in a blinded fashion. Magnetic resonance images were interpreted by an experienced musculoskeletal radiologist (N.S.), and sonography was performed by a 4-year radiology resident (S.D.) who had completed a 1-year sonography rotation including 3 months of training in musculoskeletal sonography. Furthermore, before the study, the radiologist was taught how to approach the sonographic examination of the plantar fascia. Both heels were imaged in all patients irrespective of the laterality of the symptoms. There was a maximum of 3 days' duration between sonographic and MRI examinations. Sonographic examinations were performed with a commercially available scanner (LOGIQ 500 PRO; GE Healthcare, Milwaukee, WI) and a 6.0- to 9.0-MHz linear transducer. The subjects lay prone with their feet hanging free over the end of the examination couch and their ankles dorsiflexed to 90°. Care to keep the beam perpendicular to the plantar fascia was taken at all times to avoid anisotropy. Sagittal imaging of the plantar fascia was performed, and its thickness was measured at a standard reference point where the plantar fascia crosses the anterior aspect of the inferior border of the calcaneus (Figure 1). Plantar fascia thickness greater than 4 mm was considered abnormal.[13,19] Heel fat pad thickness was also measured at the same region between the skin–fat pad interface and the fat pad–calcaneal bone interface. Three measurements of the plantar fascia and heel fat pad were taken to avoid error due to transducer obliquity, and the average of the 3 was recorded. Uniform hyperechogenicity of the plantar fascia was considered a normal finding. The changes in the echogenicity of the symptomatic fascia were evaluated as a hypoechoic fascia that stood in contrast to the adjacent hyperechoic fat of the heel pad. Sonographic findings of PF were assessed as thickening of the plantar fascia, reduced echogenicity of the plantar fascia (Figure 2), and loss of the fascia edge sharpness (Figures 3 and 4). Because solitary or combinations of findings could be seen in the same patient, patients were analyzed according to the number of the displayed sonographic findings. According to the localization of the sonographic findings within the plantar fascia and the subclassification that was used in MRI,[20] PF was subclassified into



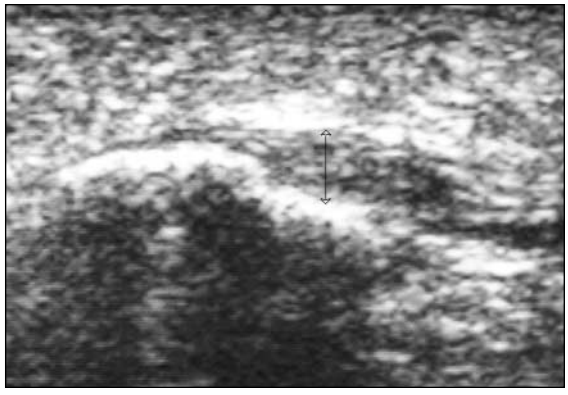
A B

Figure 1. A, Longitudinal sonogram from a 41-year-old woman, inferior calcaneal region, plantar aspect of the foot, showing the normal internal longitudinal fibrillar pattern within the plantar fascia (arrows). **B**, Diagram showing the location and the obtained measurements both for the plantar fascia (PF) and the heel fat pad (FP). C indicates calcaneus; and P, probe.

enthesopathy, musculoaponeurositis, and rupture. Enthesopathy was diagnosed when the above-mentioned sonographic findings were seen at the site of insertion of the plantar fascia. However, musculoaponeurositis was considered when the sonographic findings were seen over many centimeters extending through the central part/body of the plantar fascia. Rupture was identified when there was loss of an internal longitudinal fibrillar pattern with thickening, blurring of the edges, and an anechoic area in the plantar fascia.[14,17]

Magnetic resonance imaging was performed with a 1.5-T unit (Gyroscan Intera-Power; Philips Medical Systems, Eindhoven, the Netherlands) with a superconductive system using an extremity coil. Sagittal T1-weighted (repetition time [TR], 500 milliseconds; echo time [TE], 18 milliseconds) spin echo, T2-weighted (TR, 3881 milliseconds; TE, 120 milliseconds) gradient echo, and short tau inversion recovery (STIR; TR, 2414 milliseconds; TE, 60 milliseconds; inversion time, 160 milliseconds) sequences were taken. T1-weighted sagittal sections after intravenous administration of gadolinium diethylenetriaminepentaacetic acid (Magnevist; Schering AG, Berlin, Germany) were also obtained. The plantar fascia is normally of homogeneous low signal intensity with either uniform or minimal tapering along its course. The thickness of the plantar fascia was measured at a point just anterior to the calcaneal insertion. Heel pad thickness was also taken by measuring the thickness of the subcutaneous tissue at a point between the calcaneal insertion of the plantar fascia and the skin (Figure 1). Care was taken to do all the measurements at the same location on MRI as taken on sonography. The pathologic appearance of the plantar fascia was evaluated according to the morphologic findings, namely, enthesopathy, musculoaponeurositis, and rupture.[20] Enthesopathy was diagnosed when there was a thickened plantar fascia at its origin on T1-weighted images (Figure 5A) and abnormal high intersubstance signal intensity on T2-weighted and STIR images (Figure 5C). Contrast enhancement of the thickened plantar fascia on the T1-weighted sequence was regarded as reflecting an active inflammatory process (Figure 5B). Musculoaponeurositis was diagnosed when there was a thickened fascia over several centimeters in the central part of the plantar fascia, usually irregular but continuous. It generated a low-intensity signal on T1- and T2-weighted images (Figure 6) because of minimal

Figure 2. Sagittal sonogram of the inferior calcaneal region from a 43-year-old woman showing prominent thickening, measuring 7.3 mm (arrows), and hypoechogenic changes in the plantar fascia.



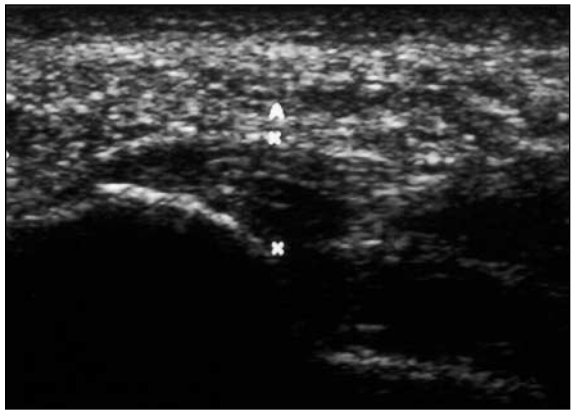


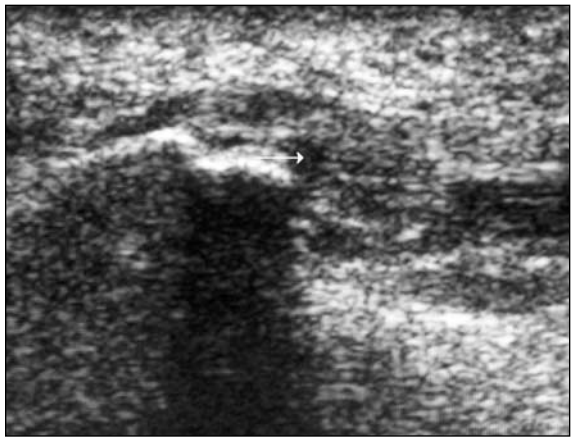
Figure 3. Sagittal heel sonogram from a 39-year-old man showing enthesopathic changes as a grossly thickened hypoechoic plantar fascia measuring 8.1 mm with loss of edge sharpness.

inflammatory reactions; no contrast enhancement was seen on postcontrast T1-weighted images. Rupture of the plantar fascia was another morphologic entity that was displayed as a disruption of plantar fascia continuity with abnormal loss of its low signal intensity on T1-weighted MR images at the site of the rupture and a considerable amount of enhancement.

Statistical Analysis

Findings related to PF from both imaging modalities were compared. Mean values, SDs, and ranges of age, weight, height, BMI, and sonographic and MRI measurements of plantar fascia and heel fat pad thicknesses were calculated. The Pearson correlation test was used to correlate plantar fascia thickness with fat pad thickness measured by both sonography and MRI. The sensitivity, specificity, and positive and negative predictive values of sonographic findings were assessed. The significance of differences between the control group and patients with PF was determined by an independent samples *t* test. A linear regression test was computed between plantar fascia and heel fat pad thicknesses, weight, height, and BMI.

Figure 4. Sagittal heel sonogram from a 45-year-old woman showing thickening, reduced echogenicity, and fluid collection in the paratenon (arrow).



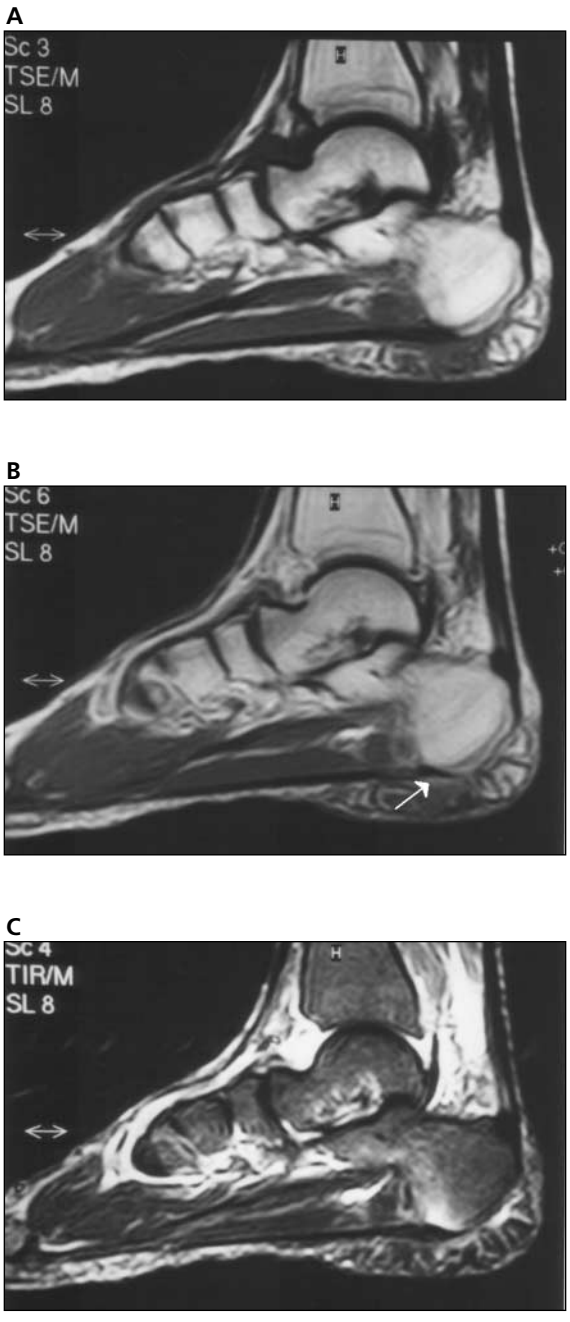
Results

Table 1 shows the significant increase in plantar fascia thickness, heel fat pad thickness, weight, and BMI in patients with PF in relation to the control group ($P = .0001$). In 77 patients with pain, a total of 145 heels were assessed by both sonography and MRI. Evidence of PF was observed in 66 (45.5%) of 145 (60 bilateral and 6 unilateral) heels by sonography and 68 (46.9%) of 145 heels (62 bilateral and 6 unilateral) by MRI.

Plantar fasciitis was subclassified, and we found that 42 (28.9%) of 145 heels had enthesopathy by sonography, compared with 46 (31.7%) of 145 by MRI. Musculoaponeurositis was diagnosed in 11 (7.5%) of 145 by sonography and in 20 (13.8%) of 145 by MRI. Only 2 (1.3%) of 145 had rupture shown on both sonography and MRI. Seventy-nine (54.4%) and 77 (53.1%) of 145 symptomatic heels showed no evidence of PF findings on sonography and MRI, respectively (Table 2).

Sonographic findings of PF were seen particularly in cases of enthesopathy, in which the mean thickness of the plantar fascia was 4.9 ± 0.9 mm. Sonographic findings of PF were identified mainly as thickening of the plantar fascia in 62 (42.7%) of 145 heels, reduced echogenicity of the plantar fascia in 56 (38.6%) of 145 heels, and loss of the fascia edge sharpness in 42 (28.9%) of 145 heels (Figures 2 and 3A). All the sonographic findings were seen in 41 of 145 heels, whereas at least 2 sonographic findings were seen in 12 of 145 heels, and only 1 finding was seen in 13 of 145 heels. The other additional findings were perifascial fluid, seen in 5 (3.4%) of 145 heels (Figure 4), and intratendinous calcification, seen in 2 (1.3%) of 145. Correlating with MRI findings as a reference standard in this study, sonography showed 80.9% sensitivity (55 of 68) and 85.7% specificity (66 of 77) in assessing PF

Figure 5. Enthesopathy of the plantar fascia. **A** and **B**, T1-weighted precontrast (**A**) and postcontrast (**B**) sagittal MR images showing a thickened plantar fascia at its calcaneal origin and signal intensity changes reflecting edema in perifascial soft tissues. Contrast enhancement of the plantar fascia and perifascial soft tissue is shown in **B** (arrow). **C**, Sagittal STIR image showing reveals the increased intrasubstance signal intensity of the thickened plantar fascia with surrounding hyperintense perifascial soft tissue edema. The abnormal high marrow signal intensity at the calcaneal insertion is also shown. Achilles tendinitis is also shown, suggesting a common stress mechanism.



However, sonography revealed higher sensitivity in diagnosing PF in patients with enthesopathy than in those with musculoaponeurosis (91.3% versus 55%). In the symptomatic heels, sonographic findings showed an 83.3% positive predictive value and an 83.5% negative predictive value. There was a strong correlation between plantar fascia thickness and fat pad thickness measured both by sonography (P = .0001; r = 0.854) and MRI (P = .0001; r = 0.798). The linear regression test also revealed that fat pad thickness inversely affected plantar fascia thickness (t = –2.755; P = .007).

Discussion

The results of this study show that sonography can be used to diagnose PF confidently in most cases. In our study, PF was considered present when the plantar fascia thickness was greater than 4 mm with reduced echogenicity, loss of definition of the borders of the fascia distal to the anteroinferior border of the calcaneus, or both.[13,20] Many previous studies also used these criteria as diagnostic parameters in PF.[15,17,18,21] However, most of the studies were performed in a smaller study population, and, to our knowledge, no study subclassified PF with sonography or correlated sonographic findings with MRI. We also analyzed the presence of different sonographic findings of PF, namely, a thickened fascia, reduced echogenicity, and loss of definition in the fibrillar echo texture, in the same patient. The thickening and hypoechoic changes of the fascia were frequent findings in our study. These findings were in accordance with those of

Figure 6. Musculoaponeurositis. T1-weighted sagittal MR image of the plantar fascia shows thickening and irregularity of the body of the plantar fascia (arrow).

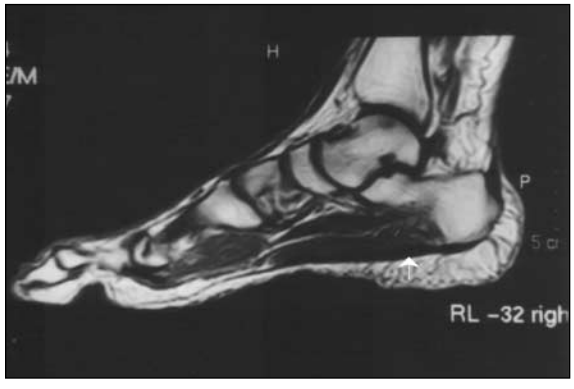


Table 1. Independent Samples *t* Test Showing the Difference Between the Patients With PF and the Control Group

Subjects	Weight, kg	Height, cm	BMI, kg/m²	Plantar Fascia Thickness, mm		Heel Pad Thickness, mm	
				MRI	Sonography	MRI	Sonography
PF (n = 68)	86.5 ± 18.4	159.1 ± 7.5	34.2 ± 6.6	5.6 ± 1.3	4.9 ± 0.9	17.6 ± 2.6	16.1 ± 2.1
Control (n = 154)	72.1 ± 10.6	169 ± 9.2	25.2 ± 3.1	3.0 ± 0.5	3.2 ± 0.4	17.1 ± 1.6	15.4 ± 1.6

Values are mean ± SD. All variables were significant ($P = .0001$).

Cardinal et al[17] and Akfirat et al.[13] However, the hypoechoic changes were not constant features in a report by Gibbon and Long.[18] Among the other sonographic features of fasciitis shown in our study were perifascial edema, seen as loss of edge sharpness in 42 (29.9%) of 145 heels, and perifascial fluid, seen in 5 (3.4%) of 145. Perifascial edema and collection of fluid were reported by Gibbon and Long[18] (5%) and by Akfirat et al[13] as 10%. This finding is not in accordance with our result because we considered edema a different finding from fluid collection; however, both are part of fascial and perifascial inflammation resulting from repetitive microtears attributed to mechanical stress on the plantar fascia.[11,21] The plantar fascia is similar to the Achilles and patellar tendons in having a paratenon rather than a tendon sheath.[18] Fluid distension of the paratenon is usually associated with perifascial edema, which clearly explains the change in echogenicity and loss of the edge sharpness of the plantar fascia. Sonography showed all 3 findings in 41 of 145 heels, whereas at least 2 sonographic findings were seen in 12 of 145 heels, and only 1 finding was seen in 13 of 145 heels. Therefore, we think that sonography can be helpful in making the diagnosis of PF with even 1 available sonographic finding; however, the combination of findings will give more confidence to the diagnosis and reflect symptom severity. Sonography showed findings of PF in 55 of 68 heels diagnosed as PF by MRI, giving sensitivity of 80.9%; conversely, sonographic findings were negative in 66 of 77 heels normally having a positive MRI diagnosis, giving specificity of 85.7%.

The morphologic changes in the plantar fascia were determined by both imaging modalities at the calcaneal insertion and in the central component of the fascia, and, accordingly, PF was subclassified into enthesopathy, musculoaponeurositis, and rupture of the plantar fascia (Table 2). The results of subclassification in both modalities were correlated. The subclassification of PF can be important for enabling a sufficiently fine analysis to describe the lesion precisely as well as to clearly differentiate the chronic and diffuse forms of the condition as musculoaponeurositis from the acute forms of enthesopathy and rupture, for which surgery may be indicated to alleviate a major functional loss.

In correlating sonographic and MRI findings of PF, sonographic findings were positive in 11 symptomatic heels, whereas MRI gave negative results. This may be due to inaccurate positioning of the patient's foot inside the extremity coil, which sometimes even needed to be supported by foam pads, or it might be due to improper image plane positioning. However, sonography was shown to be easier in manipulating and examining the patient. Acutely, the pain and tenderness of PF are localized deep in the heel pad along the insertion of the plantar aponeurosis at the medial calcaneal tuberosity. For this, localized tenderness without swelling can also be present over the anteromedial portion of the plantar surface of the calcaneus during examination with the ultrasound probe, which can help in directly correlating sonographic findings with patient symptoms. Conversely, MRI findings were positive in

Table 2. Sonographic and MRI Positive and Negative Findings of PF and Its Subtypes in 145 Symptomatic Heels

Sonographic Findings	MRI Findings								
	Enthesopathy		Musculoaponeurositis		Rupture		Overall		
	+	–	+	–	+	–	+	–	Total
+	42	7	11	4	2	0	55	11	66
–	4	92	9	121	0	143	13	66	79
Total	46	99	20	125	2	143	68	77	145

13 symptomatic heels, whereas sonography revealed negative findings. This might be due to the somewhat low sensitivity of sonography in diagnosing musculoaponeurotic types of PF that affect mostly the central part of the plantar aponeurosis, whereas the proximal part of the plantar fascia and, especially, the site of the calcaneal attachment are more clearly displayed.

Magnetic resonance imaging can be accepted as a standard for an imaging technique that is sufficiently sensitive to identify the disease process and the morphologic changes affecting the plantar fascia.[22–24] Care must be taken in the diagnosis of PF to rule out other similar clinical findings such as subcalcaneal bursitis, calcaneal stress fracture, tarsal tunnel syndrome, and calcaneal osteomyelitis.[25] Moreover the perifascial soft tissue edema and enhancement of the inflamed plantar fascia were explained as a reflection of an active inflammatory phase secondary to degeneration or tearing of the fascia. Limited bone marrow edema in the subperiosteal part of the medial calcaneal tuberosity may also be observed. Conversely, the prominent thickening of the plantar fascia and mild thickening of the adjacent heel fat pad, measured both by MRI and sonography, reflects the soft tissue involvement secondary to stress due to repetitive trauma from excessive job-related standing and walking, changes in footwear, athletic activities, and obesity. In these conditions, microtears occur, mainly in the origin of the plantar fascia, and draw out a local inflammatory reaction.

The heel fat pad cushions heel strikes and allows the skin to resist forces during different physical activities. The thickness of this adipose tissue decreases after the age of 40 years, with loss of shock absorbency.[26,27] The mild thickening of the heel fat pad, measured both by MRI and sonography, in the symptomatic group of this study might also be due to the local inflammatory process affecting the area. The significant correlation of BMI with the thickness of the plantar fascia and heel fat pad was explained as a result of a stress mechanism due to the increase in vertical forces, which may lead to increased plantar pressure and gradual collapse of the medial longitudinal arch of the foot.[28] We agree that aging and being overweight, in addition to chronic overuse situations, result in a weakening of the ligamentous support and increase the stress on the plantar fascia, which is the most important structure for dynamic arch support. Conversely, the inverse effect of heel fat pad thickness on plantar fascia thickness could be interpreted by the fact that aging and being overweight decrease the heel fat pad shock absorbance function, which in turn increases the stress factor over the plantar fascia.

Our study confirmed that sonography is as promising a tool as MRI in diagnosing PF. The greater spatial resolution of sonography for superficial structures, ease of patient manipulation, and real-time capability to correlate findings directly to patient symptoms provide advantages over MRI in the assessment of patients with PF. In subclassifying PF, sonography was more sensitive (91.3%) in diagnosing enthesopathy than musculoaponeurositic changes of the plantar fascia, for which the sensitivity fell to 55%. This can be accepted as a limitation of this study, which could be overcome in the future by use of a higher-frequency probe. Also, this study included only 2 cases of rupture of the PF, which were shown on both sonography and MRI; more rupture cases should be evaluated to improve the specificity of sonography in this entity. Nevertheless, sonography is noninvasive, less expensive, readily available, easier, and faster than other imaging modalities in the diagnosis of PF and can also be performed at the bedside. These all suggest that sonography is capable of confirming or excluding PF and can be as valuable as MRI in treating patients with heel pain.

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