Prognostic Value of Diagnostic Sonography in Patients With Plantar Fasciitis

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Objectives—The primary objective of this study was to determine whether the sonographic appearance of the plantar fascia is predictive of the treatment (ie, pain) response in patients receiving supportive therapy for proximal plantar fasciitis. This study was a secondary analysis of data obtained from a randomized controlled trial of ambulatory adults, which examined the efficacy of 3 different foot supports for plantar fasciitis.

Methods—Participants underwent diagnostic sonographic examinations of their heel at baseline and again at 3 months by a single experienced foot and ankle surgeon. Quantitative (eg, thickness) and qualitative (eg, biconvexity) characteristics of the fascia were recorded according to a standard protocol. Logistic regression models were used to identify predictors of the pain response.

Results—Seventy patients completed a baseline evaluation, and 63 patients completed a 3-month follow-up assessment. The pain response was not associated with the type of foot support ($P > .05$). The only significant indicator of an unfavorable response in the univariate and multivariate analyses was biconvexity of the plantar fascia on sonography at presentation (multivariate odds ratio, 4.76 [95% confidence interval, 1.16–19.5; $P = .030$]). Furthermore, changes in self-reported pain over the 3-month study period were not accompanied by alterations in plantar fascia thickness over this time ($r = .056$; $P = .671$).

Conclusions—We conclude that patients who present with biconvexity of the plantar fascia may be less responsive to tier 1 treatment regimens that center around mechanical support of the plantar fascia. Furthermore, follow-up measurements of the fascia in this population should not weigh heavily in decisions such as return to play.

Key Words—biconvexity; heel pain; musculoskeletal ultrasound; plantar fascia; predictors; sonography

Plantar fasciitis is one of the most common causes of foot pain in adults. The lifetime risk of developing plantar heel pain is 10%, and more than 1 million outpatient visits annually can be attributed to the condition.[1] Plantar fasciitis is usually diagnosed clinically by the presentation of pain in the plantar heel that is worse when initiating walking. Local point tenderness is also frequently present when palpating along the fascia and medial calcaneal tubercle. However, radiographic studies are sometimes required to establish the diagnosis when there is uncertainty and in patients presenting with persistent plantar heel pain.

In patients suspected of having plantar fasciitis, the primary indication for imaging is to rule out other competing disorders that can also cause heel pain, such as calcaneal stress fractures, benign bone tumors, and infracalcaneal bursitis. However, diagnostic sonography also provides the examiner with additional insight, such as plantar fascia thickness, morphologic characteristics of the fascia, echo texture of the fascia, and whether perifascial fluid is present.[2,3] Musculoskeletal sonography has grown in popularity during the past 2 decades, primarily because it offers the potential for noninvasive, cost-effective, point-of-care testing.[4–6] Although sonography is now generally accepted as an effective diagnostic tool for plantar fasciitis, it is unclear whether the sonographic appearance of the fascia can provide any further insight into disease severity and, most importantly, disease prognosis. Our study therefore had 2 aims: (1) to determine whether sonographic characteristics of the plantar fascia were associated with pain magnitude and disability in patients with proximal plantar fasciitis; and (2) to determine whether certain sonographic characteristics of the plantar fascia were predictive of the short-term treatment response in patients treated primarily with supportive (tier 1) therapies.

Materials and Methods

Participants and Procedures

This study represents a secondary analysis of data obtained from a prospective, double-blind randomized clinical trial that evaluated the efficacy of 3 different mechanical supports for treatment of proximal plantar fasciitis (ClinicalTrials.gov identifier NCT00765843).[7] In this study, ambulatory adult men and women with heel pain for less than 12 months were recruited from 2 high-volume foot and ankle specialty clinics in the greater Chicago area. Participants were randomly assigned to 1 of 3 treatment groups: custom foot orthoses, prefabricated over-the-counter insoles, or sham insoles. Participants also received athletic shoes and instructions for daily icing and were asked to perform daily calf stretches. Compliance was evaluated by a self-reported questionnaire at 3 months.

Eligible patients had to present with pain at the plantar fascial attachment to the calcaneal tubercle, have poststatic dyskinesia, and have a diagnosis of proximally based plantar fasciitis. Furthermore, included patients had to have symptoms for no greater than 1 year and could not have had heel spur injections in the prior 6 months. Patients who were unable to wear supportive closed-toed shoes and patients using gait-assistive devices were excluded from the study, as were patients with other proximal musculoskeletal disorders such as hip or knee arthritis, sciatica, and substantial limb length discrepancy. The history, foot radiography, and diagnostic sonography were used to rule out other etiologies of heel pain, including arthritis, a heel spur, or a stress fracture. The study received approval from the Institutional Review Boards at Rosalind Franklin University of Medicine and Science and Advocate Health Care. All participants were treated in accordance with the Declaration of Helsinki.

Outcome measures examined at baseline, 1 month, and 3 months included an ordinal 10-point pain scale for first-step pain and end-of-day pain. The revised Foot Function Index (FFI-R)[8,9] and 36-Item Short-Form Health Survey questionnaire[10] were also used to evaluate the level of pain and disability. Participants received a diagnostic sonographic examination of their plantar fascia at baseline and again at a 3-month follow-up. Examinations were performed by a single foot and ankle surgeon (A.E.F.) with greater than 5 years of experience in performing dedicated foot and ankle sonographic examinations. The standardized examination consisted of evaluation of the study and nonstudy heels by an 8.0-MHz linear array transducer (Aquila LA 30C/40 MM; Biosound Esaote, Indianapolis, IN). Evaluation was made with the patient supine, in full knee extension and 90° of ankle dorsiflexion. The thickness of the plantar fascia was measured at 2 points on a longitudinal view of the heel. The first measurement was taken from the anterior edge of the inferior calcaneal border to the inferior border of the sonographic abnormality and the second from a point 1 cm distal to that location.[6,11] Measurements were taken from the region of maximal thickness, which usually corresponded to the medial plantar fascial band or medial portion of the central plantar fascial band. Qualitative changes, such as low echogenicity, a biconvex shape, perifascial fluid, and subcutaneous edema, were also recorded (yes/no). Biconvexity was defined simply as a circular appearance within the fascia occurring at the infracalcaneal origin (Figure 1).

Statistical Analysis

To analyze the first study aim, the relationships between continuous sonographic characteristics and pain level (including pain [morning, evening, and the average of morning and evening values] and the pain subscale of the FFI-R), and disability (total FFI-R score and the remaining 4 subscales) were graphically explored by using scatterplots. Assessment of a linear correlation was determined by the Pearson correlation coefficient (r). Dichotomous sonographic characteristics were tested for their association with foot pain and function by using an independent t test and simple regression.

For the second study aim, patient demographics (body mass index [BMI], age, sex, etc) and baseline characteristics (laterality of heel pain, type of mechanical control, duration of heel pain, magnitude of heel pain, etc) were stratified by the pain response: favorable versus unfavorable. A favorable response was considered as a 50% or greater reduction in self-reported pain by the 3-month follow-up (using an average of the pain scores for morning and evening pain levels). Missing values were imputed with mean or median values for the study population. Baseline sonographic characteristics were examined for their association with the treatment response by using univariate logistic regression, with the strength of the association reported as odds ratios and 95% confidence intervals. Potentially important sonographic, demographic, and other baseline characteristics ($P < .25$) were then entered into a multivariable logistic regression analysis to determine the best predictor model for the treatment response. The final multivariate model was determined by using stepwise logistic regression with $P < .05$ as the criterion for model entry and $P \geq .05$ for removal. Age and BMI were automatically retained in the final model because of their clinical relevance. The final model was tested for goodness of fit by using the Hosmer-Lemeshow test. Statistical analyses were conducted with SAS version 9.2 software (SAS Institute, Inc, Cary, NC; and Microsoft Corporation, Redmond, WA). All tests of significance were 2 tailed, with $P < .05$ considered significant.

Results

There were 2 missing values: 1 for height and another for the self-reported time spent standing per day. These values were imputed with the mean value for the study population.

Figure 1. **a**, Longitudinal sonogram from a patient with plantar fasciitis showing diffuse thickening and hypoechogenicity of the plantar fascia (pF) at the infracalcaneal origin (calc), without biconvexity. **b**, The box indicates that the superior and inferior plantar fascial borders are relatively parallel to one another. **c** and **d**, Longitudinal sonograms from a patient with plantar fasciitis showing focal thickening and rounding of the plantar fascia at the infracalcaneal origin, consistent with biconvexity. This feature was originally described by Akfirat et al.[6]
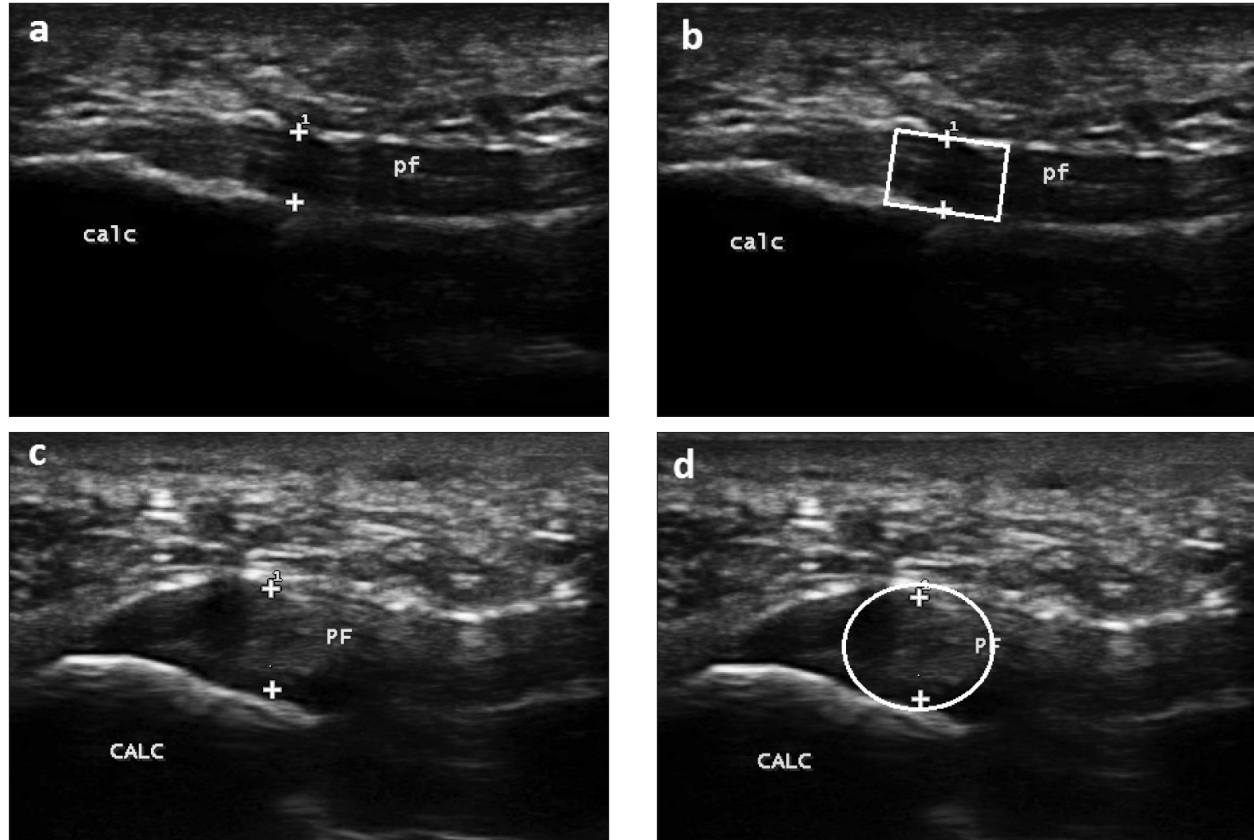
There were 70 patients who had completed baseline evaluation and testing for inclusion in this analysis and 63 patients who had completed a 3-month follow-up assessment that could be used in the second aim of the study. Two patients who completed the 3-month follow-up did not receive a closeout sonographic examination of the heel. The mean age and BMI of the population ± SD were 49 ± 12 years (range, 25–75 years) and 32 ± 7.2 kg/m² (range, 19.5–60.8 kg/m²), respectively. The mean duration of heel pain and self-reported standing time during a typical day were 5.6 ± 3.2 months and 3.3 ± 3.1 hours, respectively. The mean baseline score for morning pain was 6.8 ± 2.2 (range, 2–10), and the mean baseline score for afternoon pain was 5.9 ± 2.4 (range, 1.5–10). Twenty-six patients had bilateral heel pain, and 44 presented with unilateral symptoms. There were no differences in compliance among favorable and unfavorable groups for shoe gear/insole use, icing, or stretching (all $P > .05$). Furthermore, the pain response was not associated with the type of foot support ($P > .05$).

Aim 1: Are Demographic or Sonographic Findings Associated With the Magnitude of Heel Pain or Disability?

Biconvexity of the fascia, perifascial fluid, and edema within the heel pad were not associated with quality of life, level of disability, or self-reported pain (all $P > .05$). Similarly, the absolute plantar fascia thickness at the infracalcaneal origin and relative thickness at the origin compared to the contralateral foot showed no association with pain magnitude or amount of disability ($P > .05$). However, in patients presenting with unilateral symptoms, the ratio of plantar fascia thickness at a point 1 cm distal to the origin in the symptomatic heel compared to the same measurement from the patient's contralateral asymptomatic heel showed a moderate positive association with pain magnitude according to the total score ($r = 0.309$; $P = .041$; n = 44). In other words, thicker fascia measurements taken at a point slightly distal to the origin were associated with higher self-reported pain scores on average.

Age showed a moderate negative association with mean pain ($r = -0.251$; $P = .036$). Body mass index showed a moderate positive association with both mean pain ($r = 0.278$; $P = .020$) and disability determined by FFI-R ($r = 0.324$; $P = .006$). Laterality of symptoms (right versus left), the duration of symptoms, and the self-reported standing time were not associated with the magnitude of pain or disability (all $P > .05$). However, patients of Hispanic ethnicity (n = 11) tended to report higher pain levels on average compared to non-Hispanic patients (mean score, 7.9 versus 6.0, respectively; $P = .001$).

Age also showed a weak positive trend with plantar fascia thickness in the symptomatic heel ($r = 0.218$; $P = .06$). However, sonographic characteristics of the plantar fascia were not found to correlate with the BMI, duration of symptoms, or mean standing time (hours) during the day (all $P > .05$).

Aim 2: Are Demographic or Sonographic Characteristics Predictive of the Treatment Response?

The demographics, pain and disability scores, and sonographic characteristics of the study population at baseline are provided in Table 1. Of the variables examined in the univariate analysis, only biconvexity of the plantar fascia was associated with an unfavorable response to mechanical treatment of plantar fasciitis (univariate odds ratio, 4.3 [95% confidence interval, 1.08–16.9]; $P = .038$). Other potentially important variables that were tested in the multivariate analysis included Hispanic ethnicity (Fisher exact $P = .096$), laterality of symptoms ($P = .198$), use of a sham insole ($P = .167$), and use of a prefabricated insole ($P = .202$). The only significant predictor of an unfavorable treatment response in the final multivariable analysis was biconvexity of the plantar fascia (Table 2).

Discussion

The primary finding of this study was that sonographic characteristics, namely the appearance of biconvexity, helped identify those who were likely (and unlikely) to report pain relief with a supportive treatment regimen for proximal plantar fasciitis. The sonographic feature of biconvexity was originally described by Akfirat et al[6] using a case-control study design. In their work, the authors included patients with symptomatic heels and control participants without plantar heel pain and found that increased biconvexity of the plantar fascia was evident in most patients with plantar fasciitis (19 of 21), whereas it was present in only 1 control participant (1 of 30). The authors concluded that the finding of biconvexity is suggestive of plantar fasciitis when it is present. Our work has now expanded on this original observation and suggests that when biconvexity is present, there may be a poorer prognosis for achieving pain relief with supportive tier 1 therapies in patients with plantar heel pain.

One widely referenced treatment algorithm for plantar fasciitis, endorsed by the American College of Foot and Ankle Surgeons, places stretching, shoe gear recommendations, icing, and insoles in the "initial tier" and suggests that these modalities should be used for 6 weeks before progressing onto tier 2 modalities (eg, prescription physical

therapy and a greater emphasis on corticosteroid injection therapy).[12] The algorithm further suggest that noninvasive extracorporeal shock wave therapy, a tier 3 therapy, is not typically performed earlier than 6 months into treatment.[12] This treatment philosophy involves grouping patients by general condition while gradually, and in some ways blindly, working one's way up the treatment ladder until arriving at the desired therapeutic response. However, as the health care environment in the United States continues to move away from procedurally based payments for physician services and more toward outcomes-based reimbursement arrangements, it will be increasingly more important to tailor treatment programs to individual patients. In this way, it may helpful to begin risk stratifying patients early, perhaps even during the initial visit, to better identify who is likely to respond and who is not by using standard protocols so that we can better provide the "proper measure" of therapy for our patients right from the start. Based on the results of our study, it is possible that patients with biconvexity may be best served with corticosteroid injections and advanced therapies[12,13] earlier in the course of care. However, future work will be needed in this area to fully support or refute the value of such an approach.

In this study, it was interesting to learn that plantar fascia thickness at initial presentation was not helpful in predicting the treatment response (odds ratio, 0.74; $P = .318$), but, rather, biconvexity alone was. Although it is unclear what is causing biconvexity and rounding of the plantar fascia, it likely represents more advanced fasciitis within the heel. It is possible that patients with biconvexity have sustained greater soft tissue injury in the form of microtearing, and the resulting focal enlargement represents a greater and perhaps less organized reparative tissue response. It is unlikely, however, that biconvexity suggests a longer-standing or more chronic condition, as biconvexity was not related to the duration of symptoms in this study. Further

Table 1. Baseline Characteristics of the Study Population Stratified by Treatment Response (n = 63)

Characteristic	Favorable Response (n = 38)	Unfavorable Response (n = 25)	P
Demographics			
Age, y	50.4 ± 11.1	49.6 ± 13.8	.780
Female	24/38 (63)	17/25 (68)	.693
BMI, kg/m^2	31.6 ± 6.3	32.2 ± 8.4	.743
Race/ethnicity	0.68/0.13/0.11/0.08	0.64/0.04/0.28/0.04	.493
Right study foot	15/38 (39)	14/25 (56)	.198
Bilateral symptoms	13/38 (34)	11/25 (44)	.434
Duration of heel pain, mo	5.3 ± 3.4	5.7 ± 2.7	.564
Standing time/d, h	3.1 ± 3.3	2.7 ± 1.9	.595
Mechanical support			
Sham insole	9/38 (24)	10/25 (40)	.167
Prefabricated insole	15/38 (39)	6/25 (24)	.202
Custom orthotic	14/38 (37)	9/25 (36)	.946
Pain/disability score			
Morning pain	7.0 ± 2.2	6.3 ± 2.3	.224
Evening pain	5.8 ± 2.4	5.8 ± 2.4	.954
FFI-R pain subscale	37.0 ± 9.3	34.3 ± 12.4	.327
FFI-R total	166 ± 45.8	164 ± 43.3	.863
SF-36 score	100 ± 5.6	99.3 ± 7.5	.619
Sonographic characteristics of fascia			
Thickness at origin, mm	5.5 ± 1.1	5.1 ± 0.96	.163
Thickness at 1 cm, mm	3.8 ± 0.9	3.4 ± 0.94	.197
Thickness ratio 1	1.54 ± 0.38	1.58 ± 0.38	.764
Thickness at origin, opposite foot, mm	4.2 ± 1.0	4.1 ± 1.0	.715
Thickness ratio 2	1.35 ± 0.26	1.31 ± 0.30	.475
Biconvex shape	24/38 (63)	22/25 (88)	.042
Perifascial fluid	6/38 (16)	2/25 (08)	.461
Edema within heel pad	14/38 (37)	6/25 (24)	.284

Values are displayed as mean ± SD or frequency (percentage of column total) where applicable; race/ethnicity is presented as percentage of column total only for white/African American/Hispanic/other. A *t* test or Wilcoxon rank sum test was used for comparisons of continuous variables; a χ^2 or Fisher exact test was used for comparisons of categorical variables. SF-36 indicates 36-item Short-Form Health Survey; thickness ratio 1, thickness at origin in the study heel/thickness at 1 cm in the study heel; and thickness ratio 2, thickness at origin in the study heel/thickness at origin in the nonstudy heel.

research will be needed to provide a more sophisticated answer to this question.

Another important finding in this study was that plantar fascia thickness did not seem to correlate well with the magnitude of symptoms or degree of disability. Furthermore, changes in the self-reported pain level over the 3-month study period were unrelated to changes in plantar fascia thickness over this time ($r = 0.056$; $P = .671$; Figure 2). This observation is on the surface quite contrary to what has been reported in the literature to this point.[14–21] Previous studies have shown a reduction in plantar fascia thickness as patients responded positively to treatment: anywhere from 14% improvement in thickness over a 3-month period[14] to as much as 60% over as little as 1 week.[18] However these studies all used corticosteroid injections or extracorporeal shock wave treatments, which likely explains the apparent disagreement with our work, in which only supportive treatment was used. The catabolic effects of local corticosteroid injections could certainly account for the observed "thinning" of the plantar fascia seen in previous studies. Based on our findings, it appears that sonographic findings in return patients who have received supportive therapy alone should not weight heavily in clinical decisions such as return to play.

In conclusion, our study indicates that patients with biconvexity of the plantar fascia on sonography are less likely to respond to supportive therapy than those without this feature. Future studies may want to determine whether patients with a biconvex plantar fascia on initial examination respond more favorably to a treatment approach that uses earlier advancement onto tier 2 and 3 therapies.

Table 2. Final Model for Predicting an Unfavorable Response to Mechanical Support (n = 63)

Risk Factor[a]	Regression Coefficient	OR	95% CI	*P*
Intercept	–1.155	NA	NA	.500
Age	–0.017	0.98	0.94–1.03	.453
BMI	0.012	1.01	0.94–1.09	.745
Plantar fascia biconvexity	1.561	4.76	1.16–19.5	.030

The area under the receiver operating characteristic curve for this model was 0.655 (Hosmer-Lemeshow goodness-of-fit test, 5.146; $P = .742$). CI indicates confidence interval; NA, not applicable; and OR, odds ratio.
[a]Observations at baseline (patient's initial presentation).

Figure 2. Scatterplot showing the lack of association between change in plantar fascia thickness and change in heel pain symptoms during the 3-month follow-up ($r = 0.056$; $P = .671$; n = 61). Pain response (y-axis) refers to the change in self-reported pain at 3 months using the participant's average score for morning and evening pain. Positive values indicate an increasing level of pain, whereas negative values indicate a decreasing level of pain. RMSE indicates root mean squared error; and USPFT, sonographic plantar fascia thickness.

Pain Response = -3.5965 + 0.1714 USPFT Response
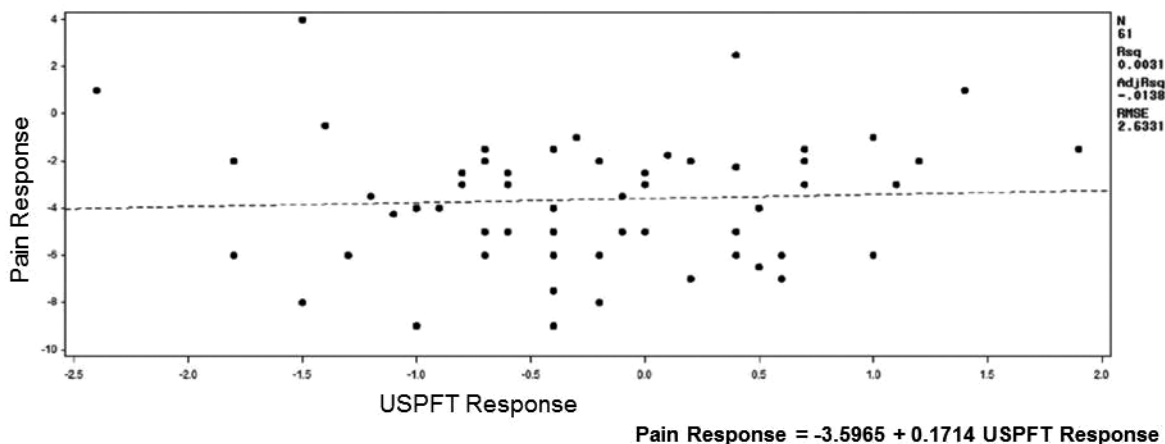
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