Original Article

DOI: 10.7860/JCDR/2026/79366.23612

Orthopaedics Section

Evaluation of Plantar Fasciitis using Ultrasonography and its Clinical Correlation: A Prospective Observational Study

RS MONISH ANAND[1], E DILIP KUMAR NAIDU[2], B VIJAY ANAND[3], C RISHAB[4], R SABARI[5]

ABSTRACT

Introduction: Heel pain is a frequent musculoskeletal complaint that impairs daily functioning and quality of life. Plantar Fasciitis (PF) is the most common cause, particularly among adults. Despite its prevalence, the utility of Ultrasonography (USG) for diagnosis and its correlation with clinical and demographic features remain underexplored in the South Indian population.

Aim: To evaluate ultrasonographic features of the plantar fascia in patients with PF and correlate these findings with clinical symptoms and demographic factors.

Materials and Methods: The present prospective observational study was performed in the Department of Orthopaedics at SRM Medical College Hospital & Research Centre, Chennai, Tamil Nadu, India, from August 2024 to October 2024. About 42 patients between the ages of 26 and 58 years who had unilateral heel pain and a PF diagnosis were included. Radiological assessment included weight-bearing anteroposterior and lateral X-rays of both feet to measure the Angle of the Medial Arch (AMA) and the First Metatarsophalangeal Angle (FMTPA). Demographic data, duration of symptoms, or pain severity utilising Visual Analog Scale (VAS) was recorded. Ultrasonographic parameters, encompassing plantar fascia or heel pad thickness, were assessed. Statistical analysis was conducted utilising Statistical Package for Social Sciences (SPSS) version 21.0. Pearson's correlation or Receiver Operating Characteristic (ROC) curve analysis was utilised, with $p<0.05$ being statistically significant

Results: The mean age of participants was 42.3 years, with 57.1% being female. The average plantar fascia thickness in the affected foot was 6±0.6 mm, significantly higher than 3±0.6 mm in the unaffected foot. A significant correlation was found between plantar fascia thickness and VAS pain scores ($r=0.316$, $p=0.041$). The ROC analysis of heel pad thickness showed an Area under the Curve (AUC) of 0.895 ($p<0.001$), with a cut-off value of 17.9 mm yielding 91.3% sensitivity and 68.4% specificity.

Conclusion: USG is an effective, non-invasive modality for diagnosing PF, with strong correlation to clinical symptom severity. It holds promise as a primary imaging tool in early diagnosis and symptom monitoring. Further longitudinal studies are warranted to confirm its role in prognostication and treatment follow-up.

Keywords: Foot disorders, Heel pad thickness, Musculoskeletal heel pain, Visual analog scale

INTRODUCTION

The most prevalent cause of heel pain in adults, which has a significant negative impact on quality of life, is PF [1,2]. In the forefoot, a connective tissue called the plantar fascia runs from the calcaneus to the metatarsal heads. It is essential for maintaining the arch of the foot and enabling the distribution of weight when moving. The PF symptoms include inflammation and pain in the plantar fascia [3,4].

The incidence of PF was found to be 3.83 cases per 1,000 patient years, with a higher occurrence noted among females [2]. The lifetime incidence is estimated to be around 10% [5]. Notably, PF can present bilaterally in approximately One -third of cases [6]. The prevalence of PF among runners ranges between 3.6% and 7% [7,8]. Additionally, it accounts for roughly 11-15% of all foot-related problems that necessitate medical intervention in adults [9]. The condition is often seen in individuals with both active and sedentary lifestyles, and its prevalence increases with factors such as obesity, prolonged standing, and inappropriate footwear [10-12]. Symptoms, primarily manifesting as stabbing pain in the heel, are usually most painful with the first few steps in the morning or after long periods of rest [13].

The PF is often diagnosed clinically, but the lack of a reliable, objective diagnostic test presents challenges for clinicians [14]. While no definitive test exists, USG serves as a dependable and cost-effective alternative to Magnetic Resonance Imaging (MRI) for assessing heel pain and identifying key features such as thickened plantar fascia or tissue abnormalities [15-17]. USG is favoured for its non-invasive nature and superior spatial resolution [16,18].

Despite growing interest in using USG for diagnosing PF, there is a significant lack of comprehensive studies linking USG findings with clinical symptoms and demographic factors, particularly in the South Indian population. Existing research primarily focuses on descriptive imaging features, with limited exploration into how these characteristics correlate with symptom severity and clinical assessments [3,16,19]. Additionally, the influence of variables like age, Body Mass Index (BMI), lifestyle, or occupation on USG results in PF is insufficiently studied.

The research aimed to evaluate ultrasonographic characteristics of the plantar fascia in patients with PF and to correlate these imaging findings with clinical symptom severity, as assessed through the VAS, and patient demographic variables, to enhance diagnostic accuracy and support more effective management strategies.

MATERIALS AND METHODS

The present prospective observational study was conducted in the Department of Orthopaedics at a tertiary care setting in Chennai, Tamil Nadu, India, from August to October 2024.

Inclusion and Exclusion criteria: Patients between the ages of 26 or 58 who have been clinically diagnosed with PF and presenting with unilateral heel pain were involved in the research population. Patients having history of foot surgery, recent foot trauma, or heel

injections of steroid or platelet-rich plasma were not included. Other exclusion criteria included systemic inflammatory diseases

(including rheumatoid arthritis) and spinal pathologies such as intervertebral disc herniation or lumbosacral radiculopathy that could cause referred pain to the lower limb.

The SRM Medical College Hospital and Research Center's Institutional Ethics Committee approved the study (IEC No: SRMIEC-ST0724-1407), and each participant provided written informed consent.

Sample size calculation: The sample size was calculated based on the study conducted by Aradhya S et al., (2023) in Nagpur, which considered the sensitivity of heel pad thickness in identifying PF as 0.90 with the relative precision of 10%. The level of significance was taken as 5%, resulting in a total of 42 patients [3]. Participants who met the inclusion requirements have been chosen for the study utilising simple random sampling method.

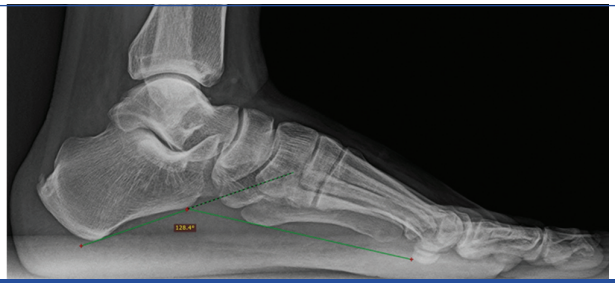
Study Procedure

Data collection consisted of a combination of clinical assessment and radiological imaging. Demographic and clinical information, including the patient's name, age, sex, BMI, occupation, duration of symptoms, and footwear preferences, were recorded. Body Mass Index (BMI) was further categorised as underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), and obese (≥30 kg/m^2) according to the World Health Organisation classification [20].

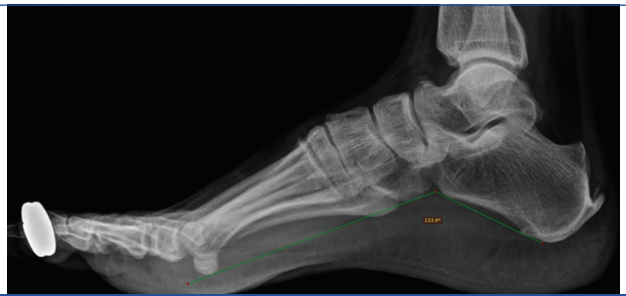
A sedentary lifestyle was defined as engaging in <150 minutes of moderate-intensity physical activity per week and primarily performing tasks involving prolonged sitting or low physical exertion. An active lifestyle is characterised by participating in a minimum of 150-min of moderate or 75-min of vigorous physical activity weekly, as per the WHO physical activity guidelines [21].

Clinical assessment: VAS was utilised to assess the clinical degree of pain, with patients rating their pain on a 0-10 scale. The physical examination involved palpating for tenderness at the anteromedial calcaneus and conducting the Windlass test, considered positive when heel pain occurred by forced dorsiflexion of the toes with the ankle stabilised [22].

Radiological assessment: The FMTPA and the AMA was measured employing weight-bearing anteroposterior or lateral X-rays of both feet [22]. The normal AMA is shown in the lateral view of the unaffected foot [Table/Fig-1], whereas an increased AMA along with a calcaneal spur is demonstrated in the affected foot [Table/Fig-2].

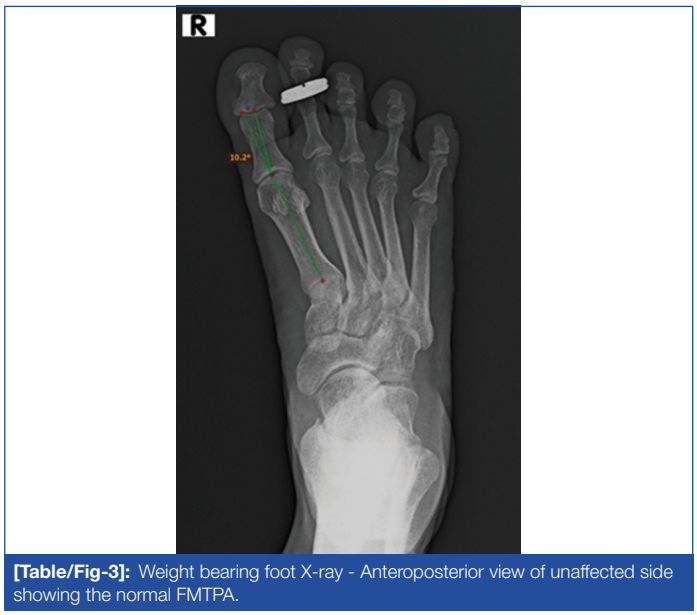


[Table/Fig-1]: Weight bearing foot X-ray - lateral view of unaffected side showing the normal angle of medial arch (AMA).

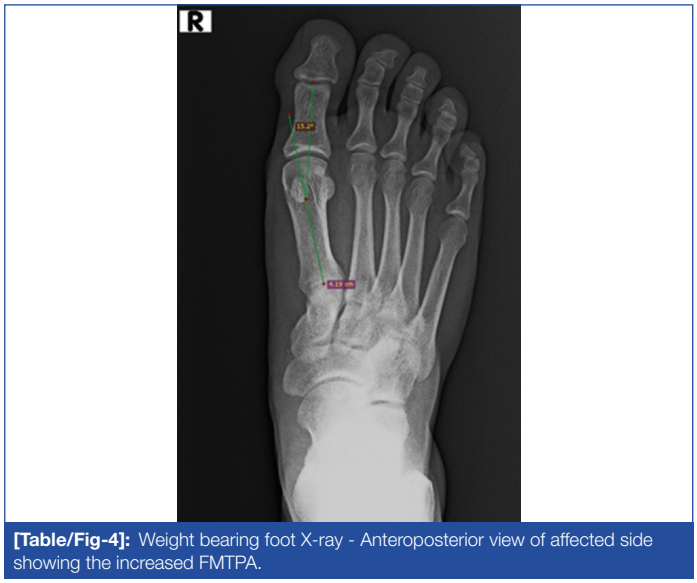


[Table/Fig-2]: Weight bearing foot X-ray - lateral view of affected side showing the increased Angle of Medial Arch (AMA) along with the calcaneal spur.

Similarly, the normal FMTPA is shown in the anteroposterior view of the unaffected foot [Table/Fig-3], and the increased FMTPA is evident in the affected foot [Table/Fig-4].



[Table/Fig-3]: Weight bearing foot X-ray - Anteroposterior view of unaffected side showing the normal FMTPA.



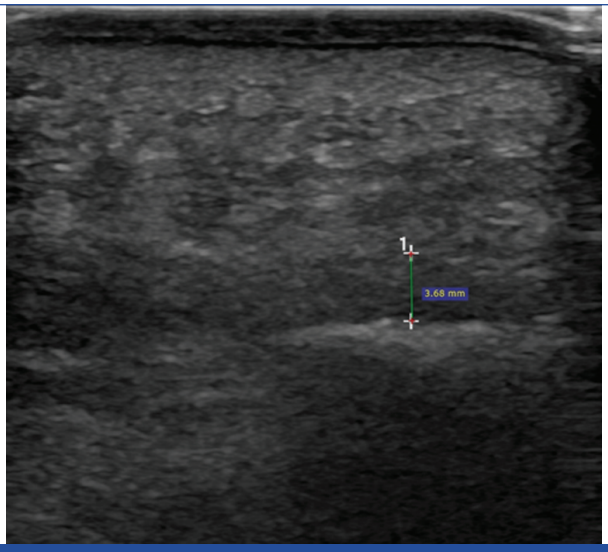
[Table/Fig-4]: Weight bearing foot X-ray - Anteroposterior view of affected side showing the increased FMTPA.

These radiological findings were taken to correlate with USG findings as well which compares the radiological characteristics including AMA and FMTPA between the affected and unaffected foot.

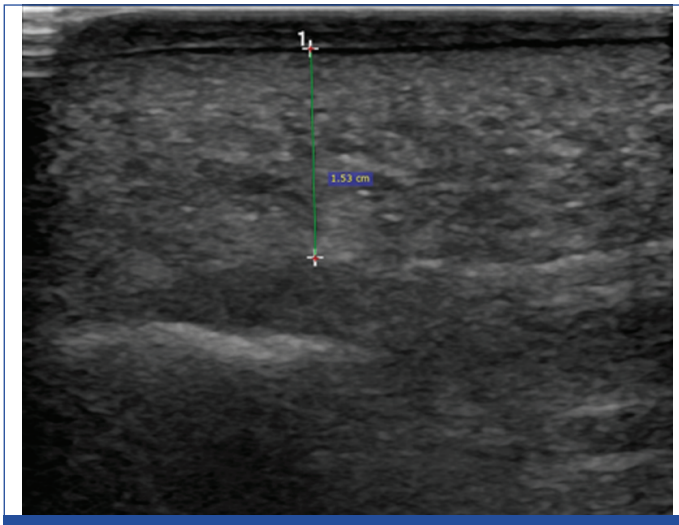
Ultrasonography (USG): The USG of both heels was performed using a GE VOLUSON S8 ultrasound machine with a 12 MHz linear probe. During the patient's prone position, foot was resting on the toes. Without pressing the probe, thickness of the plantar fascia or heel pads has been measured.

Heel pad thickness has been evaluated from the sole to the calcaneum surface. The thickness of the plantar fascia has been assessed within 2 cm of attachment to the calcaneum, following established sonographic measuring methods [23]. It was also recorded any associated findings, like the presence of a calcaneal spur. Normal plantar fascia thickness or heel pad thickness is demonstrated in the unaffected foot [Table/Fig-5,6], respectively, while increased plantar fascia or heel pad thickness in affected foot are shown in [Table/Fig-7,8], respectively.

Normal plantar fascia thickness, as measured by ultrasound, typically falls within a range of 2 to 3 mm. However, a plantar fascia thickness greater than 5.0 mm is considered diagnostic of PF, especially when fluid collection is present. On ultrasound, the plantar fascia is visualised as a "hyperechoic band with linear fibres" against a hypoechoic matrix [23,24].



[Table/Fig-5]: USG of unaffected foot showing the normal plantar fascia thickness.



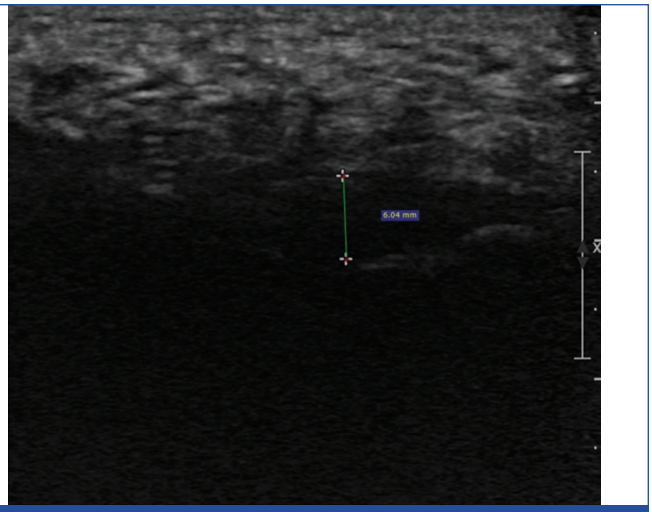
[Table/Fig-6]: USG of unaffected foot showing the normal heel pad thickness.

STATISTICAL ANALYSIS

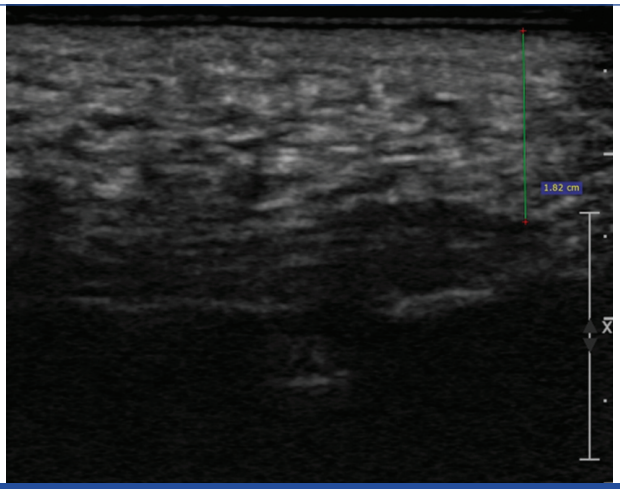
Data were gathered in Microsoft Excel and analysed utilising Statistical Package for Social Sciences (SPSS) version 21.0. Examples of descriptive statistics used were mean or Standard Deviation (SD) for continuous variables, and frequencies (%) for categorical variables. Inferential statistics, such as Pearson's correlation, have been used to examine the relationship among and clinical features and ultrasonographic findings. A paired t-test was used to compare the radiological characteristics between the affected and unaffected foot. A paired t-test was employed to compare the radiological features of the affected and unaffected feet. If the p-value was less than 0.05, it was considered statistically significant. The ROC curve was used to evaluate the sensitivity and specificity of USG characteristics in patients clinically diagnosed with PF.

RESULTS

The study population exhibited a mean age of 42.3 years, with SD of 11.1 years, consisting of 24 (57.1%) females and 18 (42.9%) males. Occupations varied, with the highest representation of housewives 14 (33.3%), followed by office workers13 (31%), field workers 8 (19%), and teachers 7 (16.7%). Lifestyle assessments revealed that most of the patients 29 (69%) led an active lifestyle, while 13 (31%) were sedentary. Regarding BMI, 2 (4.8%) were underweight, 15 (35.7%) had normal weight, 14 (33.3%) were overweight, and 11 (26.2%) were classified as obese. The person's average VAS pain intensity score was 6±2, suggesting moderate pain levels, and their average duration of symptoms was 12.8 months with SD of 5.3 months. The details are depicted in [Table/Fig-9].



[Table/Fig-7]: USG of affected foot showing the increased plantar fascia thickness.



[Table/Fig-8]: USG of affected foot showing the increased heel pad thickness.

Characteristics		Frequency (%) or Mean±SD
Age (in years)		42.3±11.1
Gender	Female	24 (57.1%)
	Male	18 (42.9%)
Occupation	Fieldwork	8 (19%)
	Housewife	14 (33.3%)
	Office work	13 (31%)
	Teacher	7 (16.7%)
Lifestyle	Active	29 (69%)
	Sedentary	13 (31%)
BMI	Underweight	2 (4.8%)
	Normal	15 (35.7%)
	Overweight	14 (33.3%)
	Obese	11 (26.2%)
Duration of symptoms (months)		12.8±5.3
VAS		6±2

[Table/Fig-9]: Distribution of demographic and clinical characteristics of study participants.

[Table/Fig-10] shows the preference for footwear. In the study, of footwear preferences among 42 participants, (54.8%) reported a preference for slippers. Casual and formal shoes were equally represented, each accounting for 14.3% of preferences, while safety shoes comprised 11.9%. Only 4.8% of participants favoured sports shoes.

The comparison of radiological characteristics between affected and unaffected feet revealed significant differences in all measured parameters, with p-values <0.001 illustrating statistical significance.

The affected foot exhibited greater heel pad thickness (18.3±0.9 mm) compared to the unaffected foot (16.1±1.2mm). Similarly, plantar fascia thickness was notably higher in the affected foot (6±0.6 mm) versus the unaffected foot (3±0.6 mm). Additionally, the angular measurements demonstrated a significant increase in the AMA in the affected foot (133±0.6 degrees) compared to the unaffected foot (124.9±3.3 degrees). The FMTPA also showed a marked increase in the affected foot (15.2±2 degrees) versus the unaffected foot (9.5±0.8 degrees). The details are presented in [Table/Fig-11].

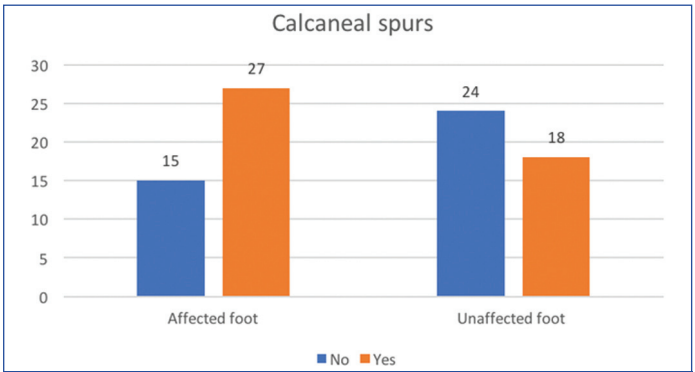
Footwear preference	Frequency N=42	Percent (%)
Casual shoes	6	14.3
Formal shoes	6	14.3
Safety shoes	5	11.9
Slippers	23	54.8
Sports shoes	2	4.8

[Table/Fig-10]: Footwear preferences of study participants.

Radiological characteristics	Affected foot	Unaffected foot	p-value
Heel pad thickness (mm)	18.3±0.9	16.1±1.2	<0.001*
Plantar fascia thickness (mm)	6±0.6	3±0.6	<0.001*
AMA (degrees)	133±0.6	124.9±3.3	<0.001*
FMTPA (degrees)	15.2±2	9.5±0.8	<0.001*

[Table/Fig-11]: Comparison of radiological characteristics between affected and unaffected foot.

The occurrence of calcaneal spurs in both affected and unaffected feet is illustrated in [Table/Fig-12] Among the 42 participants, 27 (64.3%) of the affected feet exhibited calcaneal spurs, while 15 (35.7%) did not have the calcaneal spur. In contrast, 18 (42.9%) of the unaffected feet showed calcaneal spurs, indicating a higher prevalence in the affected feet, with 24 (57.1%) of these feet lacking calcaneal spurs.



[Table/Fig-12]: Comparison of calcaneal spurs between affected and unaffected foot.

The correlation analysis between ultrasound-guided PF thickness and various demographic and clinical characteristics is presented in [Table/Fig-13]. A significant positive correlation was found in the affected foot between PF thickness and VAS scores (r=0.316, p=0.041*), suggesting that greater pain intensity is associated with increased PF thickness. Additionally, there was a no significant positive correlation between PF thickness and the duration of symptoms (r=0.292, p=0.061). In contrast, the unaffected foot showed a significant positive correlation with the duration of symptoms (r=0.347, p=0.024*) and VAS scores (r=0.345, p=0.025*), indicating that these clinical features are also relevant for the unaffected side.

The correlation analysis of ultrasound-guided heel pad thickness with demographic and clinical characteristics is shown in [Table/Fig-14]. In the affected foot and unaffected foot, there were no significant correlation between the heel pad thickness with age, BMI, duration of symptoms or VAS scores, since the p-value exceeds 0.05.

Demographic/clinical characteristics	Affected foot		Unaffected foot	
	Pearson correlation	p-value	Pearson correlation	p-value
Age (years)	-0.053	0.740	0.143	0.365
BMI (kg/m²)	-0.074	0.644	0.256	0.101
Duration of Symptoms (Months)	0.292	0.061	0.347	0.024*
VAS Score	0.316	0.041*	0.345	0.025*

[Table/Fig-13]: Correlation of USG PF thickness with demographic and clinical features.

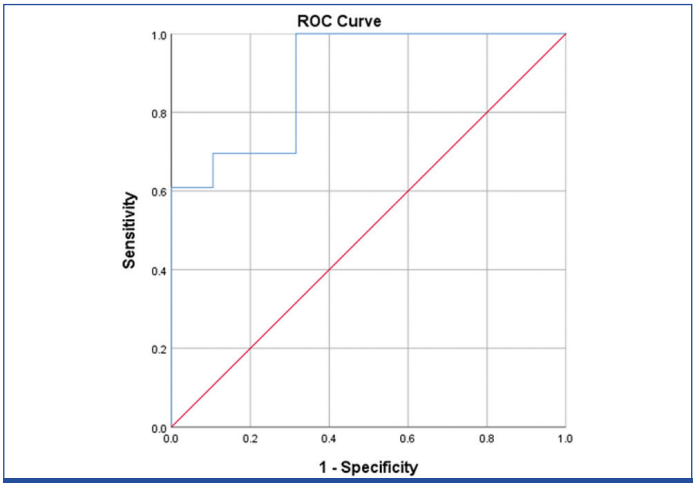
Demographic/clinical characteristics	Affected foot		Unaffected foot	
	Pearson correlation	p-value	Pearson correlation	p-value
Age (years)	0.121	0.446	-0.043	0.786
BMI (kg/m²)	0.078	0.625	-0.114	0.474
Duration of Symptoms (Months)	-0.013	0.934	0.099	0.533
VAS Score	0.035	0.826	0.039	0.806

[Table/Fig-14]: Correlation of USG heel pad thickness with demographic and clinical features.

[Table/Fig-15,16] depict the predictive accuracy of heel pad thickness measured via ultrasound. An area under the ROC curve of 0.895, which indicates excellent discriminative ability in diagnosing PF (p<0.001**). The 95% confidence interval for this area ranged from 0.801 to 0.988. The optimal cut-off value for heel pad thickness was determined to be 17.900 mm, with a sensitivity of 91.30%, suggesting that this measurement correctly identifies a high proportion of true positives. However, the specificity was 68.40%, indicating a moderate rate of false positives.

Area	p-value	Asymptotic 95% Confidence Interval		Cut-off value	Sensitivity	Specificity
		Lower bound	Upper bound			
0.895	<0.001*	0.801	0.988	17.900	91.30%	68.40%

[Table/Fig-15]: Predictive accuracy of heel pad thickness Using USG for diagnosing Plantar Fasciitis (PF).



[Table/Fig-16]: ROC Curve indicating excellent discrmininative ability in diagnosing PF.

DISCUSSION

The present prospective observational study evaluated 42 patients with unilateral PF to assess ultrasonographic features (plantar fascia and heel pad thickness) and their correlation with clinical symptoms, radiographic parameters (AMA and FMTPA), and demographic factors. The study found that plantar fascia thickness correlated significantly with pain severity (VAS scores), while heel pad thickness showed excellent diagnostic accuracy (AUC=0.895; sensitivity=91.3%, specificity=68.4%).

The average age of participants in this study was 42.3 years, which is similar to studies done by Khatiwada P et al., who found more cases among people aged 40 to 60 years [16]. Most of the participants in the present study were women (57.1%), which also matches findings from earlier studies that show PF tends to affect women more often [3,23-25].

The current study revealed that over half of the participants regularly wore slippers, which usually offer little support to the arch of the foot. This could be one of the reasons for the development of PF [5,25]. A minimal number of people used supportive shoes like sports footwear. This shows that poor footwear choices may be an important factor contributing to heel pain, especially in people who spend a lot of time on their feet.

Many participants were either overweight or obese (59.5%), with an average BMI of 27 kg/m^2. This supports earlier research suggesting that excess body weight puts more strain on the plantar fascia, increasing the risk of PF [12,25].

On average, participants had been experiencing symptoms for about 13 months and had moderate pain levels based on the VAS. These results are consistent with Sabir N et al., study that patients with PF had significantly thicker plantar fascia (mean 5.2±1.1 mm) compared to healthy individuals (mean 2.7±0.6 mm), and that greater thickness correlated with higher pain intensity and longer duration of symptoms [19]. Heel pad thickness was also found to increase significantly with pain duration (p=0.021), further supporting association among ultrasonographic findings or the severity and chronicity of heel pain.

Ultrasound imaging illustrated that the plantar fascia or heel pad was thicker in the painful foot. The thickness measurements in the current research are similar to Aradhya S et al., although slightly higher than values seen in the research by Khatiwada P et al., [3,16]. The present research also found that two important angles seen on X-rays the AMA and the FMTPA have been higher in the painful foot, which aligns with the results of Belhan O et al., who stated significantly increased AMA (122.56° vs. 120.60°, p<0.05) and FMTPA (14.72° vs. 14.40°) in painful feet compared to the contralateral side, along with a thinner heel pad (19.45 mm vs. 19.94 mm, p<0.05), indicating that reduced heel cushioning and subtle medial arch flattening may contribute to PF [25].

Correlation analysis showed a moderate positive correlation between ultrasound-measured plantar fascia thickness and VAS scores in the affected foot (r=0.316, p=0.041), indicating that individuals with thicker fascia reported higher pain levels. This finding is consistent with several studies suggesting that increased plantar fascia thickness is associated with greater pain intensity in PF [3,19].

There was also a weak positive correlation between plantar fascia thickness and symptom duration in the affected foot (r=0.292), but this was not statistically significant (p=0.061), and therefore no conclusive relationship can be established. In the unaffected foot, moderate and statistically significant correlations were observed between plantar fascia thickness, symptom duration (r=0.347, p=0.024), and VAS scores (r=0.345, p=0.025). These findings in the asymptomatic foot may have limited clinical value and could reflect subclinical or early structural changes.

Heel pad thickness, on the other hand, did not show any statistically significant correlations with age, BMI, symptom duration, or VAS scores in either foot (p>0.05), suggesting it may not be a reliable marker for symptom severity in PF.

However, when evaluated through ROC curve analysis, heel pad thickness demonstrated excellent diagnostic accuracy, with an AUC of 0.895. A cut-off value of 17.9 mm yielded a sensitivity of 91.3% and specificity of 68.4%, indicating its usefulness in distinguishing affected individuals. These results support previous findings on the diagnostic value of USG in PF [3,19,26-28].

Limitation(s)

The limitations of this research include its observational design, which limits the capacity to establish causal relationships between ultrasonographic findings or clinical symptoms. Furthermore, the use of the VAS for subjective pain assessment may lead to variability in the reported outcomes, as individual differences in pain perception and reporting can influence results. Additionally, there are potential confounding variables such as occupational activity, lifestyle habits, and footwear type that may not have been accounted for, and the operator dependency in ultrasound assessments could impact the precision and applicability of the findings.

CONCLUSION(S)

The present study highlights that PF is more common in middle-aged South Indian women and shows a clear correlation among plantar fascia thickness or pain severity. It reinforces the importance of early diagnosis, appropriate footwear, and weight management. Ultrasound, particularly heel pad thickness measurement, proves to be a useful diagnostic tool. Further longitudinal studies are recommended to evaluate treatment outcomes and lifestyle factors in PF.

Acknowledgement

We would like to thank the Department of Orthopaedics at SRM Medical College Hospital and Research Centre, as well as the participants, for their contributions to this research.

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PARTICULARS OF CONTRIBUTORS:
1. Postgraduate Student, Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Thanjavur, Tamil Nadu, India.
2. Professor and Unit Chief, Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Thanjavur, Tamil Nadu, India.
3. Head, Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Thanjavur, Tamil Nadu, India.
4. Assistant Professor, Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Thanjavur, Tamil Nadu, India.
5. Assistant Professor, Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Thanjavur, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. RS Monish Anand,
Postgraduate Student, Department of Orthopaedics, SRM Medical College Hospital and Research Centre, Thanjavur, Tamil Nadu, India.
E-mail: rsmonishanand.17@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Mar 15, 2025
- Manual Googling: Oct 18, 2025
- iThenticate Software: Oct 21, 2025 (12%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Mar 14, 2025**
Date of Peer Review: **Jul 16, 2025**
Date of Acceptance: **Oct 24, 2025**
Date of Publishing: **Jun 01, 2026**