Section: Orthopaedics

Original Research Article

ULTRASONOGRAPHIC CORRELATION OF BODY MASS INDEX WITH PLANTAR FASCIA THICKNESS AND HEEL FAT PAD THICKNESS IN SYMPTOMATIC HEEL PAIN: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Heel pain attributable to plantar fasciopathy and heel fat pad pathology is a leading cause of lower extremity disability in working-age adults. Elevated body mass index (BMI) has repeatedly been linked to altered plantar soft tissue morphology, yet simultaneous ultrasonographic quantification of plantar fascia thickness (PFT) and heel fat pad thickness (HPT) in symptomatic patients is rarely reported. This investigation sought to determine how closely BMI correlates with sonographically obtained PFT and HPT values in a hospital-based cohort presenting with heel pain. **Materials and Methods:** Eighty-five skeletally mature patients with clinically confirmed heel pain were recruited over an 18-month period at a single tertiary orthopaedic unit. Height and weight were recorded to derive BMI. Pain intensity was graded using the Visual Analog Scale (VAS). A trained radiologist performed standardised high-frequency musculoskeletal ultrasonography to obtain PFT at the calcaneal enthesis and HPT at the heel centre. Pearson's r was computed to evaluate the magnitude of association between BMI and each sonographic variable. **Result:** Participant mean age was 43.54 ± 14.46 years; men outnumbered women (62.4% vs. 37.6%). Group mean BMI was 26.68 ± 6.06 kg/m². Ultrasonography yielded a mean PFT of 5.00 ± 0.34 mm and a mean HPT of 20.96 ± 3.82 mm. BMI and PFT were strongly correlated ($r = 0.839$, $p < 0.001$); the BMI–HPT relationship was even more pronounced ($r = 0.961$, $p < 0.001$). **Conclusion:** A robust, statistically significant association exists between BMI and the sonographic dimensions of both major heel soft tissue structures. These data support the routine use of BMI-directed weight reduction as a cornerstone of conservative heel pain management, and establish musculoskeletal ultrasonography as an objective monitoring tool for tracking structural change over time.

INTRODUCTION

Heel pain is one of the most frequently encountered musculoskeletal presentations in both outpatient orthopaedic and general medical practice. Although the differential diagnosis encompasses several entities, plantar fasciopathy and heel fat pad syndrome together account for the overwhelming majority of cases. These conditions generate a considerable burden of work-related absence, restricted ambulation, and diminished health-related quality of life.[1,2]

Two anatomical structures lie at the centre of this problem. The plantar fascia—a robust fibrous band originating from the medial process of the calcaneal tuberosity and radiating toward the metatarsal heads—functions as the primary tensile stabiliser of the medial longitudinal arch during the propulsive phase of gait via the windlass mechanism.[3] Beneath the calcaneus, the heel fat pad is architecturally unique: specialised adipose lobules are enclosed within a scaffold of fibrous septa arranged in a honeycomb pattern that confer viscoelastic shock-absorption during initial contact.[4] Disruption or morphological alteration of either structure precipitates the characteristic pain syndrome.

Of the recognised predisposing variables—including prolonged weight-bearing, intrinsic foot deformity, and reduced ankle dorsiflexion—BMI has attracted particular scientific attention because it is both highly prevalent and amenable to intervention. The mechanistic rationale is straightforward: additional

body mass linearly amplifies the load imposed on plantar structures with each step, accelerating microdamage accumulation beyond the tissues' reparative capacity.[5,6] The evidence base was consolidated by a large meta-analysis that identified a BMI threshold above 27 kg/m² as the single most robust clinical predictor of plantar fasciopathy in non-athletic adults, associated with a nearly fourfold increase in odds.[7]

Real-time musculoskeletal ultrasonography has progressively supplanted plain radiography as the preferred first-line imaging modality for heel soft tissue assessment, offering dynamic evaluation without ionising radiation. Sonographic PFT measurement at the calcaneal insertion is well validated, and a value exceeding 4 mm is widely accepted as consistent with plantar fasciitis.[8,9] HPT quantification by ultrasound likewise correlates well with MRI-derived measurements.[4]

Despite the extensive literature on individual BMI–PFT or BMI–HPT associations, contemporaneous sonographic assessment of both parameters within a single symptomatic cohort remains sparsely reported. The current study was therefore designed to quantify the Pearson correlation between BMI and each of PFT and HPT in patients attending a tertiary orthopaedic unit with heel pain.

MATERIALS AND METHODS

Study Design, Setting, and Ethics: This was a hospital-based, cross-sectional observational study conducted between April 2024 and September 2025 in the Department of Orthopaedics at Rajarajeswari Medical College and Hospital, Bengaluru, India. Institutional Ethics Committee approval was secured before the commencement of recruitment. Written informed consent was obtained from every participant in their preferred language.

Sample Size Calculation: Enrolment targets were computed via Yamane's proportional formula: $n = N \div [1 + N(e^2)]$, where N represented the estimated annual eligible pool (108 individuals, derived from retrospective audit showing 5–6 qualifying attendees per month) and e = 0.05 denoted the tolerated margin of error. This yielded a minimum requirement of 85 participants, all of whom were enrolled consecutively.

Eligibility Criteria

Inclusion: Any skeletally mature individual presenting with unilateral or bilateral heel pain of any duration.

Exclusion: Patients were excluded if they had undergone prior ipsilateral foot or ankle surgery, sustained a foot injury within the preceding three months, had congenital or developmental lower-limb deformities, or had received local corticosteroid therapy in the affected heel at any time.

Clinical and Anthropometric Assessment: A standardised proforma captured age, sex, smoking habit, presence of comorbid diabetes mellitus and thyroid dysfunction, pain chronicity, and occurrence of first-step morning pain. Body weight (kg) was recorded with a calibrated digital platform scale and standing height (cm) with a wall-mounted stadiometer. BMI was calculated as weight (kg) divided by height squared (m²) and classified per WHO criteria: underweight (< 18.5), normal (18.5–24.9), overweight (25.0–29.9), obese (≥ 30.0 kg/m²). Pain severity was rated on a Visual Analog Scale (VAS), categorised as mild (1–3), moderate (4–6), or severe (7–10).

Ultrasonographic Protocol: All sonographic examinations were performed by a single experienced musculoskeletal radiologist using a linear array transducer at 7.5–15 MHz, with the patient prone and the ankle in the neutral resting position. PFT was measured at the calcaneal insertion in a standardised longitudinal plane as the perpendicular distance between the superior and inferior fascial margins. HPT was measured perpendicularly from the external skin surface to the calcaneal periosteum at the weight-bearing heel centre. Three readings per parameter were averaged to yield the final measurement.

Statistical Methods: Data were processed with IBM SPSS Statistics v.23 and Microsoft Excel 2019. Continuous variables are summarised as mean ± SD; categorical data as counts and proportions. Pearson's correlation coefficient (r) quantified the linear association between BMI and each ultrasonographic outcome. A two-tailed $p < 0.05$ was considered statistically significant.

RESULTS

Demographic and Clinical Profile: The study enrolled 85 patients spanning a wide age range (20–75 years), with a mean of 43.54 ± 14.46 years. Adults in their third decade were the single largest subgroup (20–29 years; 24.7%), followed by those in the fifth (40–49 years; 22.4%) and seventh decades or beyond (≥ 60 years; 20.0%); full age distribution data are presented in Table 1. Male patients predominated, accounting for 62.4% (n = 53) of the cohort. Comorbid diabetes mellitus and thyroid dysfunction were each documented in 17.6% (n = 15) of participants, while active smoking was reported by 35.3% (n = 30). The characteristic symptom of morning start-up pain was reported by 62.4% (n = 53). Mean pain chronicity was 189.18 ± 106.05 days, indicating that the majority presented in a subacute-to-chronic phase. Pain intensity was severe (VAS 7–10) in 40.0% of patients, moderate (4–6) in 37.6%, and mild (1–3) in 22.4%, with an overall mean VAS of 5.79 ± 2.9 [Table 1].

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Table 1: Demographic, Comorbidity, and Pain Profile of Study Participants (n = 85)

Parameter	Subgroup / Statistic	Frequency (n) or Mean ± SD	Percentage (%)
Age (years)	20–29	21	24.7
	30–39	13	15.3
	40–49	19	22.4
	50–59	15	17.6
	≥ 60	17	20.0
	Mean ± SD	43.54 ± 14.46 years	—
Sex	Male	53	62.4
	Female	32	37.6
Diabetes mellitus	Present	15	17.6
	Absent	70	82.4
Thyroid dysfunction	Present	15	17.6
	Absent	70	82.4
Smoking status	Current smoker	30	35.3
	Non-smoker	55	64.7
Morning first-step pain	Present	53	62.4
	Absent	32	37.6
Pain duration (days)	Mean ± SD	189.18 ± 106.05	—
VAS pain category	Mild (score 1–3)	19	22.4
	Moderate (score 4–6)	32	37.6
	Severe (score 7–10)	34	40.0
VAS score (overall)	Mean ± SD	5.79 ± 2.9	—

VAS = Visual Analog Scale. Data represent absolute counts (n) and column percentages unless stated otherwise. Mean ± SD is reported for continuous variables.

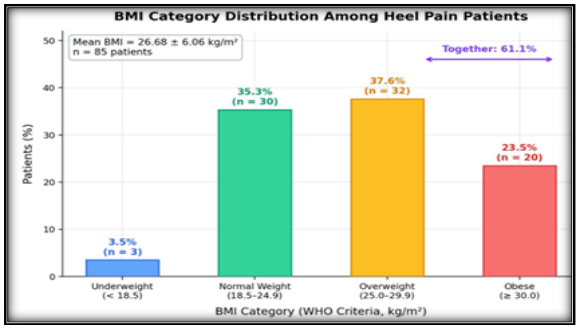

Figure 1: BMI category distribution among heel pain patients (n = 85). Overweight (37.6%) and obese (23.5%) patients together comprised more than 61% of the cohort.

Anthropometric and Sonographic Parameters

Mean participant height was 169.46 ± 12.21 cm and mean body weight was 75.69 ± 14.40 kg. The resulting mean BMI of 26.68 ± 6.06 kg/m² placed the average study subject within the overweight category. Categorically, 37.6% of participants were overweight and 23.5% were obese, together exceeding 60% of the cohort [Figure 1]. Ultrasonographic interrogation of the affected heel recorded a mean PFT of 5.00 ± 0.34 mm—a value exceeding the established sonographic cut-off for plantar fasciitis—alongside a mean HPT of 20.96 ± 3.82 mm [Table 2].

Table 2: Anthropometric and Ultrasonographic Summary Statistics (n = 85)

Variable	Mean	Standard Deviation (SD)	Range (Min–Max)
Height (cm)	169.46	12.21	145 – 198
Body weight (kg)	75.69	14.40	45 – 110
Body mass index – BMI (kg/m²)	26.68	6.06	18.2 – 41.4
Plantar fascia thickness – PFT (mm)	5.00	0.34	4.3 – 5.8
Heel fat pad thickness – HPT (mm)	20.96	3.82	14.0 – 30.9
BMI Category Distribution (n = 85)			
BMI Category	**WHO Range (kg/m²)**	**Frequency (n)**	**Percentage (%)**
Underweight	< 18.5	5	5.9
Normal weight	18.5 – 24.9	28	32.9
Overweight	25.0 – 29.9	32	37.6
Obese	≥ 30.0	20	23.5
Total	—	85	100.0

All ultrasonographic measurements were obtained by a single trained radiologist. PFT was measured at the calcaneal enthesis; HPT was measured perpendicularly from skin surface to calcaneal periosteum. Values represent the mean of three successive readings per participant.

Correlation between BMI and Ultrasonographic Parameters: Pearson's correlation analysis revealed a strong positive linear relationship between BMI and PFT ($r = 0.839$, $p < 0.001$) [Figure 2] and an even more pronounced association between BMI and HPT ($r = 0.961$, $p < 0.001$) [Figure 3]. Both correlations achieved the highest tier of statistical significance with p-values far below the predefined threshold [Table 3]. These data indicate that rising BMI is accompanied by progressive, measurable enlargement of both plantar fascial and heel fat pad dimensions.

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Table 3: Pearson Correlation Coefficients between BMI and Ultrasonographic Parameters (n = 85)

Ultrasonographic Parameter	Pearson r	p-value	Strength of Correlation
Plantar Fascia Thickness (PFT)	0.839	< 0.001	Strong positive correlation
Heel Fat Pad Thickness (HPT)	0.961	< 0.001	Very strong positive correlation

Cross-Study Comparison: BMI Correlation with PFT and HPT

Study (Year)	n	BMI vs PFT (r)	BMI vs HPT (r)	Statistical Significance
Present Study	85	0.839	0.961	Both p < 0.001
Taş et al. (2017)	80	0.536	0.500	Both p < 0.001
Khan et al. (2021)	60	0.381	N/S	PFT: p = 0.003
Suhas Aradhya (2023)	30	N/S	0.404	HPT: p = 0.027
Narindra et al. (2019)	226	Sig (p < 0.05)	—	PFT significant
Jha et al. (2023)	148	Sig (p < 0.001)	—	PFT significant
Belhan et al. (2019)	100	N/S	N/S	Not significant
Maemichi et al. (2020)	1126	N/S	N/S	Not significant

N/S = Not statistically significant. Pearson r ≥ 0.7 is considered a strong correlation; r ≥ 0.9 is considered a very strong correlation. All p-values are two-tailed.

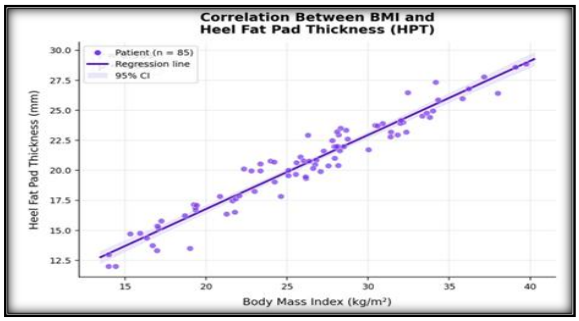

Figure 2. Scatter plot with regression line demonstrating the very strong positive correlation between BMI and heel fat pad thickness (HPT) (r = 0.961, p < 0.001). This is the strongest correlation observed in the study.

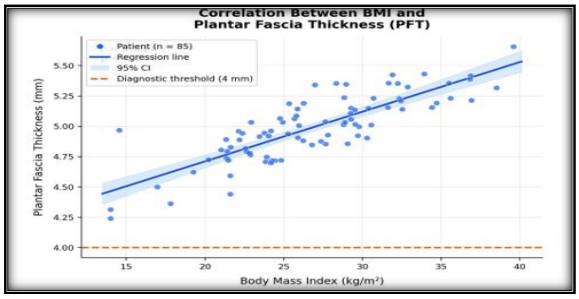

Figure 3. Scatter plot with regression line illustrating the strong positive correlation between BMI and plantar fascia thickness (PFT) (r = 0.839, p < 0.001). The dashed orange line marks the 4 mm ultrasonographic diagnostic threshold for plantar fasciitis. D

Ultrasonographic findings of study

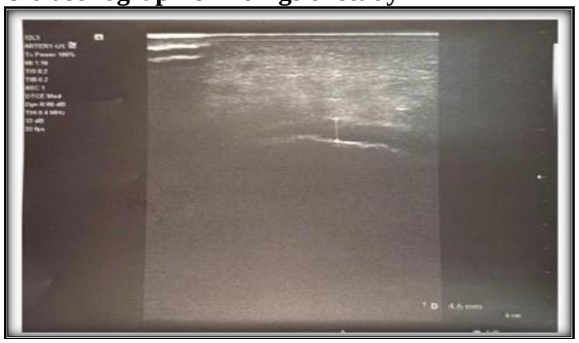

Figure 4: Ultrasonographic picture showing the thickened and hypoechoic plantar fascia (4.6mm)

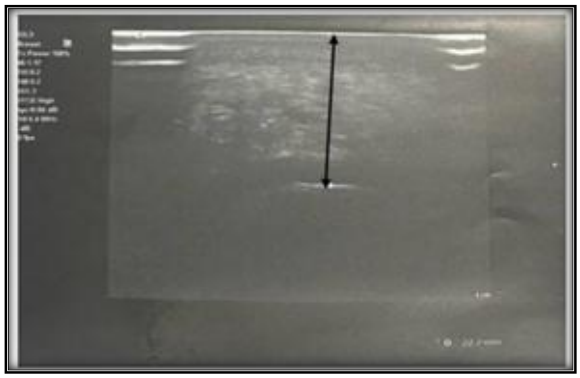

Figure 5: Ultrasonographic picture showing the thickened and hypoechoic heel fat pad (22.7mm)

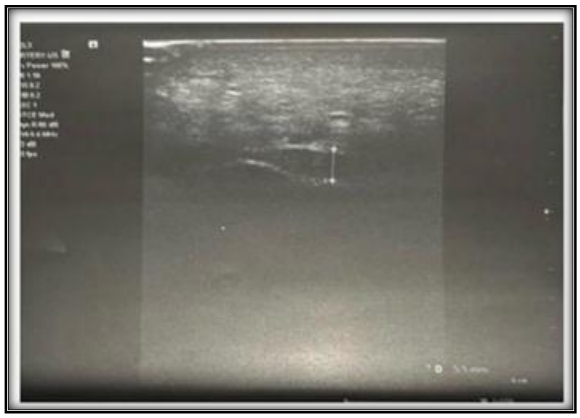

Figure 6: Ultrasonographic picture showing the thickened and hypoechoic plantar fascia (5.5mm)

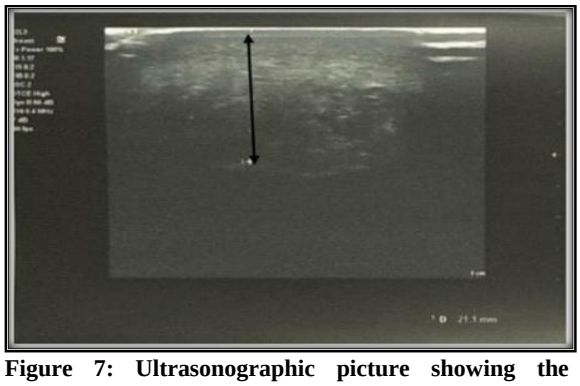

Figure 7: Ultrasonographic picture showing the thickened and hypoechoic heel fat pad (21.1mm)

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DISCUSSION

The central finding of this investigation is a highly significant, bidirectional association between increasing BMI and greater ultrasonographic dimensions of both plantar fascial and heel adipose tissue. The correlation magnitudes observed—particularly r = 0.961 for HPT—are among the highest documented in the published literature, and the simultaneous assessment of both structural endpoints in a single symptomatic cohort represents a meaningful contribution to the field.

The cohort profile warrants contextual discussion. A mean age of 43.54 years is consistent with the recognised peak incidence of plantar heel pain in middle-aged, economically active individuals,1 and the 189-day mean symptom duration confirms that most patients had progressed beyond the acute phase. Morning first-step pain—reported by nearly two-thirds of participants—is a clinically validated hallmark reflecting overnight fascia contracture followed by initial loading stress.[5] The moderate-to-severe average pain score (VAS 5.79) underlines the functional impact of the condition. Male predominance in our series (62.4%) contrasts with the female preponderance reported by several studies,[10,11] and may reflect occupational exposure patterns such as manual labour prevalent in the male workforce of our catchment area.

The mean BMI of 26.68 kg/m² positions our cohort within the overweight stratum. This mirrors data from comparable investigations: Ozdemir et al. noted a mean BMI of 28 kg/m² in sonographically confirmed plantar fasciitis cases, significantly exceeding their control figure of 25 kg/m²,8 and the meta-analytic evidence of van Leeuwen et al. identified BMI > 27 as the dominant clinical risk factor for plantar fasciopathy with an odds ratio of 3.7.7 The mean PFT of 5.00 mm in our cohort surpasses the widely adopted 4 mm diagnostic threshold.[8,9]

The BMI–PFT correlation of r = 0.839 is stronger than most comparable estimates. Taş et al. obtained r = 0.536 in asymptomatic volunteers,[6] Khan et al. reported r = 0.381 in a symptomatic outpatient series,[11] and Narindra et al. also documented significant associations of PFT with weight (r = 0.35) and height (r = 0.37) in addition to BMI.[12] Jha et al. found a significant BMI–PFT relationship even in healthy controls without heel complaints, suggesting subclinical load-driven remodelling preceding symptomatic presentation.[10] Nafees et al. demonstrated via ANCOVA that both BMI and weight-bearing status independently influenced PFT.[16]

The very strong BMI–HPT correlation (r = 0.961) may reflect the directly proportional response of adipose tissue to cumulative load: unlike fibrous fascial collagen, which thickens through degenerative fibroplasia, heel fat expands via adipocyte hypertrophy and septal remodelling. Taş et al. reported a moderate BMI–HPT correlation of r = 0.500,6 Suhas Aradhya et al. recorded r = 0.404 with a diagnostically useful HPT cut-off of 17.45 mm at 90% sensitivity,[13] and Maemichi et al. demonstrated age- and sex-linked heel fat pad growth trajectories closely tied to body mass.4 Early radiographic evidence by Jackson found that 65% of individuals exceeding 91 kg had heel pad dimensions above 21 mm.[14]

The pathomechanical underpinning is well established. Excess body mass amplifies ground reaction forces through the heel during stance and gait, imposing repetitive supraphysiological strain on both the calcaneal enthesis of the plantar fascia and the fibroseptal network of the heel pad. In the fascia, this precipitates a cycle of microtear formation, failed collagen remodelling, and fibrovascular proliferation—the degenerative phenotype termed plantar fasciopathy (plantar fasciosis).5 In the fat pad, sustained pressure promotes adipocyte enlargement and progressive structural thickening that may paradoxically reduce shock-absorbing efficiency.

Discordant findings were reported by Belhan et al., who found no significant BMI–HPT or BMI–PFT correlations, with age as the dominant morphological determinant,[15] and by Maemichi et al. in a younger cohort where no significant BMI-linked fascial change was detected.[4] These divergences underscore that BMI does not operate in isolation; activity level, footwear, foot posture, and disease chronicity inevitably modulate the BMI–tissue morphology relationship.

The high correlation coefficients in our series likely reflect several methodological strengths: a symptomatic cohort with confirmed pathology (mean PFT > 4 mm), a broad BMI distribution (18–41 kg/m²), a single-operator ultrasonographic protocol, and simultaneous capture of both structural endpoints. Limitations include the cross-sectional design precluding causal inference, single-centre setting, and absence of a BMI-matched asymptomatic control group. Prospective studies with structured weight-loss interventions and repeat sonographic assessments are strongly warranted.

CONCLUSION

In patients presenting with heel pain, BMI exhibits a strong-to-very-strong positive linear correlation with both sonographic PFT (r = 0.839) and HPT (r = 0.961), underscoring body mass as the primary modifiable biomechanical driver of heel soft tissue enlargement. Routine BMI documentation should be embedded in the initial clinical assessment of every patient with plantar heel pain, and weight reduction counselling should be integrated into first-line conservative management protocols. Musculoskeletal ultrasonography offers clinicians a reproducible, radiation-free method to objectively track structural changes during treatment. Prospective studies examining whether targeted

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weight reduction translates into sonographically measurable tissue regression and sustained symptom relief represent an important research priority.

Clinical Significance

- BMI correlates strongly (r = 0.839) with PFT and very strongly (r = 0.961) with HPT in symptomatic heel pain patients, establishing BMI as a key structural determinant.
- A mean PFT of 5.00 mm—exceeding the 4 mm diagnostic threshold—in a predominantly overweight cohort reinforces the role of elevated BMI in fascial pathology.
- Musculoskeletal ultrasonography provides objective, quantitative evidence of BMI-related structural changes that can guide diagnosis and monitoring of treatment response.
- The very strong BMI–HPT correlation (r = 0.961) suggests heel fat pad thickness may serve as a sensitive biomarker of metabolic loading in plantar pain disorders.
- Weight management—dietary modification, structured low-impact exercise, and behavioural counselling—should form an integral component of first-line conservative treatment in overweight and obese patients with heel pain.

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