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AN OBSERVATIONAL STUDY TO ASSESS THE ROLE OF FOREFOOT AND HINDFOOT WEIGHT DISTRIBUTION PATTERN USING SENSOR PLATE EVALUATION IN PATIENTS WITH UNSPECIFIED HEEL PAIN

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KEYWORDS

Heel pain, unspecified heel pain, forefoot load, hindfoot load, plantar pressure, sensor plate, weight distribution, COP shift.

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Abstract

Background: Heel pain is commonly seen in physiotherapy and orthopaedic practice. In many patients, routine examination does not reveal one clear cause. The way body weight is shared between the front and back of the foot may place repeated stress on the heel. Sensor plate assessment provides an objective record of this loading pattern and may help identify abnormal weight-bearing in patients with unspecified heel pain.

Aim: To examine forefoot and hindfoot weight distribution using sensor plate assessment in patients with unspecified heel pain.

Methodology: This observational study included 50 participants aged 20 to 70 years with unspecified heel pain. Participants were selected according to the study criteria. Age, sex, body measurements, duration and side of pain, and pain intensity on the Visual Analogue Scale were recorded. Sensor plate assessment measured forefoot and hindfoot load, the difference between these regions, the hindfoot-to-forefoot ratio, plantar pressure, posterior centre-of-pressure shift and the overall loading impression. Data were analysed using descriptive and inferential statistics, with significance set at $p < 0.05$.

Results: The participants had a mean age of 39.28 ± 11.19 years; 28 were male and 22 were female. Mean BMI was 27.28 ± 3.63 kg/m2 and mean VAS pain was 3.90 ± 1.13. Mean forefoot load was 39.67 ± 7.08%, compared with 60.33 ± 7.08% over the hindfoot. Hindfoot load was significantly greater than forefoot load, with a mean difference of 20.66% ($t = 10.32$, $p < 0.001$), and was also above the neutral reference value of 50% ($p < 0.001$). Higher hindfoot load was strongly related to greater heel pain ($r = 0.746$, $p < 0.001$). Posterior centre-of-pressure shift also showed a significant positive relationship with pain intensity ($r = 0.645$, $p < 0.001$).

Conclusion: Participants with unspecified heel pain commonly placed more weight through the hindfoot. Greater hindfoot loading and a more posterior centre of pressure were associated with higher pain levels. Sensor plate assessment may therefore be useful for identifying altered plantar loading and for planning more focused physiotherapy management.

INTRODUCTION

Heel pain is a frequent complaint in clinical practice. It can make standing, walking, working and everyday activity uncomfortable. Conditions such as plantar fasciitis, calcaneal spur, heel-pad irritation, nerve sensitivity and soft-tissue overload are often considered, yet some patients continue to have pain without a clearly defined diagnosis. These cases are commonly described as unspecified heel pain.

In such patients, the problem may not be explained by a local structural change alone. Foot mechanics, long periods of standing, increased body weight, footwear, reduced shock absorption and the way weight is transferred through the foot may all contribute. Because the foot forms the base of support, an uneven balance between forefoot and hindfoot loading can repeatedly stress one area.

The heel receives body weight during initial contact and also supports the body in standing. When too much weight remains over the back of the foot, the calcaneus, heel pad, plantar fascia attachment and nearby tissues may be exposed to repeated pressure. This makes hindfoot-dominant loading a possible mechanical contributor when no single pathology fully explains the symptoms.

A sensor plate allows this loading pattern to be measured rather than estimated. It records how much weight is placed over the forefoot and hindfoot, regional pressure and movement of the centre of pressure. These findings can complement the pain history and may help guide footwear changes, cushioning, load redistribution, gait training and exercise selection.

This study was therefore designed to examine forefoot and hindfoot weight distribution in patients with unspecified heel pain and to determine whether greater hindfoot loading and posterior centre-of-pressure shift were related to pain intensity.

Heel pain is best understood as more than a problem at one small point under the calcaneus. The plantar fascia supports the arch and tightens during the windlass mechanism as the great toe extends during push-off. If ankle dorsiflexion is limited, the foot remains on the heel for longer, pronation is poorly controlled, great-toe extension is restricted or push-off is weak, strain at the plantar fascial attachment may increase. At the same time, a backward position of the centre of pressure can increase compression under the heel. The painful heel may therefore be the final site where a wider loading problem becomes noticeable [31].

The heel also acts as a meeting point between the Achilles tendon and plantar fascia. These tissues are closely connected around the calcaneus. Tightness in the calf or reduced movement of the Achilles tendon can limit forward movement of the shin over the foot and keep pressure toward the back of the foot. This may increase both plantar fascial tension and heel compression during standing and walking [32,33].

The same idea can be viewed through the posterior myofascial chain. The plantar fascia is linked through connective tissues with the Achilles tendon, calf, hamstrings and tissues around the pelvis and lower back. Anatomical research supports continuity along parts of these chains, although the exact amount of force transmitted over long distances is still being studied. Clinically, this means that calf or hamstring stiffness, pelvic control and trunk posture may be worth examining when heel pain persists [34].

Possible global contributors include reduced ankle dorsiflexion, tight calf or hamstring muscles, weak hip abductors or extensors, altered femoral rotation, poor pelvic or trunk control, prolonged standing, increased body weight and compensatory walking patterns. These factors may change rearfoot position, foot progression, centre-of-pressure movement and the length of time spent on the heel. They should be considered as possible influences rather than assumed to be the cause in every patient.

For this reason, sensor plate findings should be combined with an examination of the whole movement chain. The plate shows where pressure is concentrated; the clinical examination helps explain why. Useful areas to assess include ankle dorsiflexion, calf flexibility, great-toe and first-ray mobility, foot posture, hip strength, pelvic control, trunk alignment, footwear, occupation and gait.

NEED OF THE STUDY

Heel pain is common, but its cause is not always clear. Clinical assessment often concentrates on the painful area and possible structural changes, while the way the patient loads the foot may receive less attention. If body weight remains concentrated over the hindfoot, the heel may be repeatedly stressed during standing and walking. This study was therefore needed to determine whether sensor plate measurements of forefoot and hindfoot loading are related to pain in patients with unspecified heel pain.

AIM OF THE STUDY

To assess the role of forefoot and hindfoot weight distribution pattern using sensor plate evaluation in patients with unspecified heel pain.

OBJECTIVES OF THE STUDY

1. To observe forefoot and hindfoot weight distribution pattern in patients with unspecified heel pain.
2. To assess hindfoot loading and posterior center of pressure shift using sensor plate evaluation.
3. To correlate hindfoot loading with heel pain intensity measured by Visual Analogue Scale.
4. To evaluate whether sensor plate impression is associated with pain severity in patients with unspecified heel pain.

HYPOTHESIS

Null hypothesis: There will be no significant relation between unspecified heel pain and forefoot-hindfoot weight distribution pattern.

Alternative hypothesis: There will be a significant relation between unspecified heel pain and forefoot-hindfoot weight distribution pattern.

MATERIALS AND METHODOLOGY

Study design: Observational study.

Source of data: Pacific Medical College and Hospital, Bedla, Udaipur, Rajasthan.

Sample size: 50 participants.

Sampling method: Purposive sampling method.

Study population: Male and female participants aged 20 to 70 years with unspecified heel pain who fulfilled the study criteria.

Outcome measures: Visual Analogue Scale for heel pain intensity and sensor plate evaluation for forefoot load, hindfoot load, pressure values, forefoot-hindfoot load difference, hindfoot/forefoot ratio and posterior center of pressure shift.

INCLUSION CRITERIA

5. Patients with unspecified heel pain.
6. Age between 20 and 70 years.
7. Participants willing to participate in the study.
8. Informed consent obtained.

EXCLUSION CRITERIA

9. Cancer.
10. Spinal trauma or amputation.
11. Systemic inflammatory disorders or progressive neurological conditions.
12. Pregnancy or open wound.
13. Use of selected medications such as NSAIDs, anticoagulants or steroids.
14. Fracture, calcaneal spur or visible foot deformity.

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PROCEDURE

Participants were screened according to the inclusion and exclusion criteria. Written informed consent was obtained before data collection. Demographic details, anthropometric measurements, occupation, duration of heel pain and affected side were recorded. Pain intensity was assessed using the Visual Analogue Scale. Each participant was then assessed on the sensor plate. Forefoot and hindfoot load distribution, pressure values, load difference, hindfoot/forefoot ratio and posterior COP shift were recorded. The collected data were entered for statistical analysis.

STATISTICAL ANALYSIS

Continuous data were summarised using mean and standard deviation, while categorical data were presented as frequency and percentage. Normality was checked with the Shapiro-Wilk test. Forefoot and hindfoot loads were compared using a paired t-test, and hindfoot load was also compared with the neutral value of 50% using a one-sample t-test. Pearson correlation was used to examine the relationship of hindfoot load and posterior centre-of-pressure shift with VAS pain. One-way ANOVA compared pain scores across loading categories, and the chi-square test examined the association between loading impression and pain category. Statistical significance was set at $p < 0.05$.

RESULTS

Fifty participants with unspecified heel pain completed the assessment. Their mean age was 39.28 ± 11.19 years, and the largest age group was 31-40 years. There were 28 males and 22 females. Mean BMI was 27.28 ± 3.63 kg/m2, showing an overall overweight tendency. Symptoms had been present for a mean of 10.84 ± 5.46 weeks, and the mean VAS pain score was 3.90 ± 1.13.

Table 1: Demographic and clinical profile of participants

Variable	Mean ± SD / Frequency (%)
Age (years)	39.28 ± 11.19
Male	28 (56.00%)
Female	22 (44.00%)
BMI (kg/m2)	27.28 ± 3.63
Duration of heel pain (weeks)	10.84 ± 5.46
VAS heel pain score (/10)	3.90 ± 1.13

Sensor plate findings showed that participants placed more weight through the hindfoot than the forefoot. Mean forefoot load was 39.67 ± 7.08%, while mean hindfoot load was 60.33 ± 7.08%. The average absolute difference between the two regions was 21.80 ± 12.31%, and the mean hindfoot-to-forefoot ratio was 1.60 ± 0.47.

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Table 2: Forefoot and hindfoot load distribution

Variable	Mean	SD	Minimum	Maximum
Forefoot load (%)	39.67	7.08	27.10	55.00
Hindfoot load (%)	60.33	7.08	45.00	72.90
Absolute F-H load difference (%)	21.80	12.31	0.20	45.90
Hindfoot/Forefoot ratio	1.60	0.47	0.82	2.70

Ten participants showed mild hindfoot loading, 27 showed moderate loading and 13 showed high loading. In total, 80% of the sample fell into the moderate or high hindfoot-loading categories. Both peak and mean pressure were also greater at the hindfoot.

Table 3: Sensor plate impression

Sensor plate impression	Frequency	Percentage
Mild hindfoot loading	10	20.00
Moderate hindfoot loading	27	54.00
High hindfoot loading	13	26.00
Total	50	100.00

Table 4: Sensor plate pressure values

Variable	Mean	SD	Minimum	Maximum
Peak forefoot pressure (kPa)	330.15	39.34	260.00	427.00
Peak hindfoot pressure (kPa)	453.35	42.28	382.90	565.60

Mean forefoot pressure (kPa)	136.06	14.41	115.00	165.00
Mean hindfoot pressure (kPa)	176.17	19.54	135.90	220.40

The paired t-test confirmed that hindfoot load was significantly greater than forefoot load. The mean difference was 20.66% ($t = 10.32$, $p < 0.001$). Hindfoot load was also significantly higher than the neutral reference value of 50% ($t = 10.32$, $p < 0.001$).

Table 5: Inferential analysis of load distribution

Test	Variable / Comparison	Value	p value	Interpretation
Paired t-test	Hindfoot load vs Forefoot load	t = 10.32	<0.001	Significant
One-sample t-test	Hindfoot load against 50% neutral value	t = 10.32	<0.001	Significant

Higher hindfoot load was associated with higher VAS pain ($r = 0.746$, $p < 0.001$). A posterior shift of the centre of pressure was also related to greater pain ($r = 0.645$, $p < 0.001$). In practical terms, participants who kept more weight toward the back of the foot tended to report more intense heel pain.

Table 6: Correlation analysis

Variables	Pearson r	p value	Interpretation

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Hindfoot load (%) vs VAS heel pain	0.746	<0.001	Significant positive correlation
COP posterior shift (mm) vs VAS heel pain	0.645	<0.001	Significant positive correlation

Pain differed significantly across the three hindfoot-loading categories ($F = 36.98$, $p < 0.001$). Participants in the high-loading group reported the greatest pain. The chi-square test also showed a significant association between loading category and pain category (chi-square = 16.18, df = 4, $p = 0.0028$).

Table 7: VAS score according to hindfoot loading category

Sensor plate impression	N	Mean VAS	SD
Mild hindfoot loading	10	2.86	0.87
Moderate hindfoot loading	27	3.61	0.71
High hindfoot loading	13	5.29	0.60

DISCUSSION

This study examined how weight was shared between the forefoot and hindfoot in people with unspecified heel pain. The clearest finding was a hindfoot-dominant pattern. On average, participants placed considerably more weight through the heel than through the forefoot, and this difference was statistically significant.

Heel pain was present across adulthood, with most participants in the young and middle-aged groups. This shows that it is not only a problem of older age. Work demands, footwear, body weight, long periods of standing and altered movement patterns may also contribute. The average BMI was in the overweight range, which may have added to the load placed on the plantar surface.

The average hindfoot load was 60.33%, compared with 39.67% at the forefoot. This represents a backward-shifted loading pattern. When a person repeatedly keeps more weight over the heel, the calcaneus, heel pad and plantar fascia attachment may receive greater stress. In patients without a clear structural diagnosis, this pattern offers a reasonable mechanical explanation for at least part of the pain.

Pressure measurements supported the same finding. Both peak and mean pressure were higher under the hindfoot. The heel was therefore exposed not only to a larger share of body weight but also to greater pressure. This is clinically important because repeated pressure can irritate sensitive soft tissues even when no major structural lesion is identified.

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The relationship between hindfoot load and VAS pain adds strength to this interpretation. Participants who loaded the heel more heavily tended to report more pain. A more posterior centre of pressure showed a similar relationship. These objective measurements therefore provided useful information that could not be obtained from a pain score alone.

Pain also increased in a stepwise manner from mild to moderate and high hindfoot loading. The high-loading group had the greatest average VAS score. This suggests that classifying the loading pattern may help identify patients who need more attention to heel offloading and forward weight transfer.

The findings agree with previous work showing that plantar pressure, body weight, occupation and gait can influence heel pain. Research has also supported the use of pressure measurement to identify areas that are repeatedly overloaded. The present study adds to this evidence by showing a clear relationship between forefoot-hindfoot balance and pain in patients whose heel pain was not linked to one specific diagnosis.

Clinically, heel pain should not be assessed only by locating tenderness. It is equally important to observe how the patient stands and walks. Sensor plate assessment can show whether the heel is carrying an unusually high share of the load. Treatment can then be directed toward the individual pattern and may include cushioning, footwear advice, calf and plantar fascia exercises, foot intrinsic strengthening, gait retraining, gradual load redistribution and weight-management support where appropriate.

The findings supported the alternative hypothesis. Hindfoot load was significantly greater than forefoot load, and both hindfoot load and posterior centre-of-pressure shift were related to pain intensity. However, because this was an observational study, these relationships should not be interpreted as proof that posterior loading alone caused the pain.

The results also support a whole-chain assessment. Management may combine local reduction of heel stress with work on ankle dorsiflexion, calf capacity, great-toe mobility, foot strength, hip and trunk control, gait, footwear and gradual return to standing or walking. A sensor plate cannot diagnose a fascial restriction, but it can show the final loading pattern created by several interacting local and global factors.

Control higher up the limb may influence how the heel is loaded. Reduced hip abductor or extensor control can allow pelvic drop, inward rotation of the thigh and changes in leg alignment during stance. Trunk position can also move the body's centre of mass and alter the path of pressure under the foot. Persistent heel pain may therefore involve both local tissue sensitivity and compensations at the ankle, knee, hip, pelvis or trunk.

A myofascial-chain view offers another possible explanation. Connective tissues link the plantar fascia with the Achilles tendon, calf, hamstrings and thoracolumbar region. Reduced movement or increased tension in one part of this posterior pathway may influence how strain is shared during standing and walking. Although anatomical continuity is supported, distant fascial restrictions should be tested clinically rather than assumed in every patient [34].

The windlass mechanism is also relevant. As the great toe extends during late stance, the plantar fascia tightens, raises the arch and helps the foot become a firm lever for push-off. If great-toe movement, forefoot loading or forward movement of the centre of pressure is limited, the person may stay on the heel for longer. This may increase local pressure and help explain why posterior loading was associated with greater pain.

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The Achilles-calcaneus-plantar fascia connection further explains the pattern. A stiff calf or Achilles tendon can reduce forward movement of the shin and maintain pressure toward the back of the foot. Because the Achilles tendon and plantar fascia are linked around the calcaneus, this may create both compression under the heel and tension through the plantar fascia [32,33].

CONCLUSION

Patients with unspecified heel pain showed a clear tendency to load the hindfoot more than the forefoot. Hindfoot load was significantly above 50%, and greater hindfoot loading and posterior centre-of-pressure shift were associated with higher pain. Participants with high hindfoot loading also reported the greatest pain. Sensor plate assessment may therefore be a useful addition to clinical examination for identifying altered loading and guiding individual physiotherapy management. These findings show association and should not be taken as proof of a single cause.

LIMITATIONS

1. The study was conducted on a limited sample size of 50 participants.
2. Purposive sampling was used, so selection bias cannot be completely ruled out.
3. The observational design can show association but cannot prove cause and effect.
4. A healthy control group was not included for comparison.
5. Advanced imaging such as MRI or ultrasound was not used to classify exact pathology.
6. Other biomechanical factors such as ankle range of motion, calf flexibility, foot posture index and lower limb alignment were not deeply analysed.
7. Pain was assessed using VAS, which is subjective and may vary between individuals.
8. Long-term follow-up was not performed.

RECOMMENDATIONS

1. Future studies should be conducted with a larger sample size.
2. A comparative study with a healthy control group should be carried out.
3. Future research should include detailed biomechanical assessment such as foot posture index, ankle dorsiflexion range, calf flexibility and gait analysis.
4. Advanced diagnostic investigations may be used to classify different causes of heel pain.
5. Longitudinal studies should assess whether reducing hindfoot loading improves heel pain.
6. Interventional studies can compare the effect of orthoses, heel cups, footwear modification, stretching and strengthening on sensor plate findings.
7. Occupational factors such as standing hours, walking duration, work surface and footwear type should be studied in more detail.
8. Sensor plate evaluation may be included as part of routine assessment in patients with unexplained heel pain.

CLINICAL IMPLICATIONS

Sensor plate assessment can add practical information to the evaluation of unspecified heel pain. It helps show whether body weight is concentrated over the heel or whether the centre of pressure remains too far back. When this pattern is present, treatment may include heel cushioning, footwear modification, calf and plantar fascia rehabilitation, gait retraining, forward load-transfer exercises and gradual activity progression. Findings should always be interpreted together with the patient's symptoms and full kinetic-chain examination.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SOURCE OF FUNDING

Nil.

ETHICAL CONSIDERATION

All participants gave informed consent before assessment. Their information was kept confidential and used only for academic and research purposes.

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