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Original Article

A comparison of foot pain and dynamic stability among flat and heeled footwear users in undergraduate female medical students

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Abstract

Objective: To compare foot pain and dynamic stability among flat and heeled footwear users in undergraduate medical students, raising awareness about the importance of appropriate footwear for improving health and stability.

Methods: This analytical cross-sectional study targeted 305 undergraduate female medical students to assess foot pain and dynamic stability. Participants were selected using a convenience sampling technique and pre-specified inclusion/exclusion criteria. Foot pain was measured using a 100 mm visual analog scale, with validity (0.76 to 0.84) and reliability (0.66 to 0.77). Dynamic stability was assessed using the four square step test (FSST), which showed excellent test-retest reliability (ICC = 0.92). The sample size was calculated using Yamane's formula, resulting in 305 participants.

Results: The study showed that 68.9% of participants had a normal body mass index, with 33.8% reporting no foot pain, while 56.1% experienced mild pain, and 10.2% severe pain. The ANOVA test revealed a significant increase in stability test times with higher heels (flat: 6.62s, low: 7.39s, high: 8.91s, $F = 68.880$, $p < 0.001$), and the Kruskal-Wallis test (Non normally distributed data) showed increased pain with higher heels ($p = 0.001$). The most common pain areas were the heels (38%) and the arch (27.9%), highlighting the negative impact of heel height on both pain and dynamic stability.

Conclusion: The study indicates that elevated heel heights substantially exacerbate foot discomfort and hinder dynamic balance when compared to flat shoes among female undergraduate medical students.

Level of evidence III; Analytical Cross-sectional Study.

Keywords: Postural Balance; Foot pain, shoes; Pain measurement; Medical students.

Introduction

Footwear has been used by humans for centuries. Soon after its invention, it gained huge popularity because it served a very important function of protecting the foot. Cultural differences also influence the styles. Footwear comes in a variety of sizes, shapes, and heel heights. High heels with pointed toes have been associated with elegance and a symbol of fashion in females, while flat footwear has been associated with comfort. The elegance associated with high-heeled footwear also brings lower back pain, due to increased curvature of the spine, disturbance of bone alignment, and leg pain; as well as increased weight on the foot and instability[1].

Different footwear, specifically different heel heights [0 cm (flat), 4 cm (low), 7 cm (medium), and 10 cm (high)], can have a significant influence on stability as higher heels raise the center of gravity and shift it away from the base of support[2]. In a static position, the condition for stability is that the center of gravity must pass through the base of support. During walking or other movements, 'dynamic

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stability' is required, defined as the ability of an individual to control body position and balance during movement or when shifting from a dynamic position to a static position. Both the center of gravity and the base of support are actively moving in dynamic conditions; for the prevention of falls, it is essential to maintain balance in these conditions[3].

Walking down a curved path or changing directions rapidly requires more balance compared to walking in a straight line. Therefore, for testing dynamic stability, the four square step test (FSST) will be used, as this test combines rapid stepping with changing directions simultaneously[4]. While wearing proper footwear can protect from a wide range of injuries, wearing improper footwear, on the other hand, is the leading cause of various health problems and has been strongly associated with foot pain[5]. Approximately 24% to 30% of the adult population suffers from foot pathologies and pain[6].

Women tend to be at a higher risk of foot pain compared to men, due to the use of high heels[5]. The Visual Analogue Scale (VAS) will be used to assess foot pain, as this scale has been used to measure pain, quality of life, and anxiety since the 1920s[6]. The test typically consists of a 100 mm horizontal line with endpoints ranging from "no pain" to the "worst pain possible"[7]. For participants who report foot pain, the specific location of the foot pain will also be assessed[8].

A correlational study was conducted by Rajalaxmi et al.[9] in 2017, involving 100 male and female students, to investigate the correlation of habitual footwear with balance and foot pain among physiotherapy students. The study consisted of two groups: Group A, which included 50 males (A1, shoes with heels; A2, shoes without heels), and Group B, which included 50 females (B, flat slippers; B2, high-heeled slippers). The participants were assessed using the star excursion balance test and the foot function index. The results showed a significant difference in scores between the two groups. Group B2 had more pain, and Group A2 had better balance. These results conclude that wearing heeled footwear affected balance and caused more foot pain. A comparative study performed by Kaur and Chitkara in 2020 evaluated the impact of high heels on dynamic stability in young females by comparing habitual and non-habitual heel users. The dynamic stability of the 60 participants was assessed using the FSST. The results showed that non-habitual heel users had more dynamic stability and a lower chance of developing foot abnormalities compared to habitual heel users[10].

A study conducted by Fatima et al.[11] in 2022 evaluated the association between foot pain and high-heeled shoes in working women. The study consisted of 285 office workers and school teachers. The data were collected using the foot health status questionnaire (a 0-100 point scoring scale). The results showed a very high prevalence of foot pain (94.6%) among high-heeled shoe users. Previous studies have explored the link between foot pain and balance in high-heeled and flat footwear users, but without specifying heel height, and primarily among physical therapy students. No research has been conducted on this topic in Pakistan. This study aims to compare foot pain and dynamic stability among flat and heeled footwear users in undergraduate medical students, raising awareness about the importance of appropriate footwear for improving health and stability.

Methods

This study was approved by the Institutional Review Board, and written informed consent was obtained from all participants before their inclusion in the study. The study was conducted according to STROBE guidelines.

This analytical cross-sectional study was conducted at C.M.H Lahore Medical College and IOD, Lahore, focusing on undergraduate female medical students. Participants were recruited through a convenience sampling method, with eligibility criteria including being over 18 years old, maintaining good health, and habitually wearing either heeled footwear (for at least 2-3 hours, 2-3 days per week) or flat footwear. Exclusion parameters encompassed individuals with congenital or acquired musculoskeletal anomalies, foot injuries, trauma, obesity (Body mass index (BMI $\geq$ 30)), pregnancy, or reliance on assistive devices. The sample size was calculated using Yamane's formula, resulting in 305 participants from a population of 900, with a 0.05 marginal error[12,13].

Data acquisition involved measuring foot pain using a 100 mm VAS, where participants indicated their pain intensity along a continuum from no discomfort (rightmost point) to excruciating pain (leftmost point). The VAS exhibited robust validity (0.76-0.84) and moderate-to-good reliability (0.66-0.77)[7,14]. Additionally, individuals experiencing foot pain were able to pinpoint the precise location of discomfort using a foot diagram. Dynamic stability was evaluated through the FSST, which required participants to navigate a cross-patterned arrangement of squares swiftly and accurately, avoiding balance disturbances, missteps, or falls. Each participant completed the test twice, with the superior performance time recorded for analysis. The FSST demonstrated outstanding test-retest reliability (ICC = 0.92)[15]. Data were analyzed using SPSS version 26. Descriptive statistics were reported as frequencies and percentages for categorical variables, and means ± standard deviation for continuous variables. Normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Between-group differences in test performance time were analyzed using one-way ANOVA followed by Tukey's post-hoc test. VAS scores across heel height categories were compared using the Kruskal–Wallis test followed by Bonferroni-adjusted pairwise comparisons. The significance level was set at $p < 0.05$.

Results

The study, conducted in 305 participants, revealed significant findings regarding heel height, foot pain, and dynamic stability. The sample consisted of two age groups: 18–21 years (59%) and 22–25 years (41%). Most participants were classified within the normal BMI range (68.9%), followed by 17.4% who were underweight and 13.8% who were overweight (Table 1).

Regarding footwear preferences, 47.21% preferred flat heels, 41.97% opted for medium heels, and 10.82% wore high heels. The VAS showed that 33.8% of participants reported no pain, while 56.1% experienced mild pain, 89.8% moderate pain, and 10.2% severe pain. One participant reported the worst imaginable pain. Pain location indicated that the heels (38%) and the arch (27.9%) were the most affected areas, followed by the ball of the foot (21.6%) and the toes (11.8%). While 66.6% of participants did not avoid wearing heels due to concerns about pain, 33.4% indicated that pain influenced their decision to wear heels.

Dynamic stability was assessed using a stability-related test, and the results showed a significant impact on heel height ($F = 68.880$, $p < 0.001$). Flat-heel users had the shortest test times (6.62 seconds), followed by low-heel users (7.39 seconds) and high-heel users (8.91 seconds) (Table 2). Tukey's post-hoc comparisons confirmed that the differences in stability test times between all heel height groups were statistically significant ($p < 0.001$), indicating that increased heel height compromised dynamic stability (Table 3). The normality of the data was assessed using the Shapiro-Wilk test, which indicated that VAS pain scores were not normally distributed across heel height groups ($p < 0.05$). Consequently, the Kruskal-Wallis test, a non-parametric alternative to ANOVA, was used to analyze pain levels across heel heights (Table 4). This test revealed significant differences in VAS scores by heel height ($p = 0.001$) (Figure 1). Pairwise comparisons with Bonferroni correction further confirmed that higher heels were associated with significantly greater pain than flats and low heels.

Overall, the findings demonstrate a clear inverse relationship between heel height and comfort and dynamic stability. High heels were associated with increased foot pain, particularly in

Table 1. Demographics characteristics of participants (n = 305)

Variable	Categories	N (%)
Age group (Years)	18-21	180 (59.00)
	22-25	125 (41.00)
BMI (Kg/m²)	Underweight (< 18.5)	53 (17.40)
	Normal (18.5-24.5)	210 (68.90)
	Overweight (25-29.5)	42 (13.80)
Heel height (cm)	Flat	144 (47.21)
	Low	128 (41.97)
	High	33 (10.82)
Pain distribution (VAS)	No pain	103 (33.4%)
	Mild pain	68 (22.3%0
	Moderate pain	103 (33.8%)
	Severe pain	30 (9.8%)
	Worst pain imaginable	1 (0.30%)
FSST (Sec)	Balanced (< 6.4)	104 (34.1%)
	Unbalanced (6.4 and Above)	201 (65.9%)

BMI: Body mass index; FSST: Four square step test; Heel height classification: Flat (0 cm), Medium (2-5 cm), High (>5 cm); Percentages are calculated based on the total sample size (N = 305); Cumulative percent represents the progressive sum of participants experiencing each pain category; The FSST showed 34.1% balanced and 65.9% unbalanced among 305 participants.

Table 2. Pairwise comparison of heel heights (cm)

Sample 1- Sample 2	Test statistic	Std. error	Std. test statistic	p-value	Adj. Sig.
Flat (< 0.8) - Low (0.8-4)	-19.937	10.499	-1.899	0.058	0.173
Flat (< 0.8) - High (> 4)	-62.458	16.681	-3.744	0.000	0.001
Low (0.8-4) - High (> 4)	-42.521	16.874	-2.520	0.012	0.035

$p < 0.05$ is considered statistically significant; Adj. Sig: Adjusted significance, values account for multiple comparisons to reduce the risk of Type I error; Negative test statistics indicate a higher mean difference in the second group compared to the first.

Table 3. Post-hoc tests showing multiple comparisons

	(I) Heel height (cm)	(J) Heel height (cm)	Mean Difference	p-value
Tukey HSD	Flat (< 0.8)	Low (0.8-4)	-.77898*	< 0.001*
		High (> 4)	-2.29580*	0.001*
	Low (0.8-4)	High (> 4)	-1.51681*	0.001*

$p < 0.05$ is considered statistically significant; Tukey HSD: Honestly Significant Difference tests was performed for post-hoc multiple comparisons of heel height groups; Negative mean differences indicate higher test performance time in the second group compared to the first.

Table 4. Analysis of variance (ANOVA) for test performance time among different footwear groups

	Test performing time (Second)				
	Sum of squares	df	Mean square	F	p- value
Among the groups	150.654	2	75.327	68.880	< 0.001*
Within groups	330.265	302	1.094		
Total	480.919	304			

df: Degrees of freedom; A statistically significant difference (*$p < 0.001$) was observed in test performance time across different footwear groups; The four square step test was used to measure dynamic stability; Higher F-values indicate significant variance between groups.

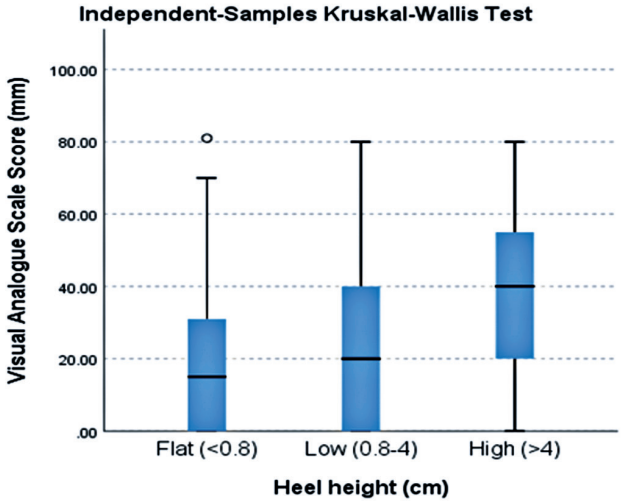

Figure 1. Pain scores across various heel heights.

the heel and arch regions, and impaired stability, as evidenced by longer test times. In contrast, flat shoes provided better outcomes for pain and dynamic stability, making them a more ergonomic choice for extended wear.

Discussion

The discussion on high-heeled versus flat footwear highlights differences in aesthetics, comfort, and practicality. High heels are often chosen for their elegance and formal appeal, but are associated with significant physical strain, including impaired balance, foot pain, and altered posture. In contrast, flat footwear offers better comfort and dynamic stability, making it more suitable for extended wear.

This study evaluated the effects of high heels on dynamic stability using the FSST. The results showed that flat footwear users (0.8 cm) had better dynamic stability than high-heel users (> 5 cm), similar to the findings of Kaur and Chitkara[10], who reported greater stability in non-habitual heel users compared to habitual users. Likewise, Rajalaxmi et al.[9] observed that wearing heels adversely affected balance and increased foot pain, findings consistent with this study.

Kahile M et al.[16] demonstrated a significant correlation between heel height and pain, where higher heels were associated with an increased prevalence of heel pain. This corroborates the results of our study, which identified heel pain as the most significant complaint among high-heeled users. Similarly, Joshi et al.[17] observed that heel height negatively impacted dynamic balance, lumbar lordosis, and core muscle strength using the Y-balance test, aligning with the current findings. Randal et al.[18] further supported this, noting significant static and dynamic balance impairments with increasing heel heights.

Additionally, Fatima et al.[11] found a 96% prevalence of foot pain among women wearing high heels, with the majority experiencing mild to moderate pain, which aligns with our study's observation of increased foot discomfort in high-heeled users. Kumar et al.[19] reported that wearing high heels, compared to flat footwear, significantly impaired balance and stability dynamics, as evidenced by altered kinetic parameters. These results align with the current study's findings, which demonstrated a decline in dynamic stability with increasing heel height.

In summary, high-heeled footwear significantly impairs dynamic stability, balance, and foot comfort, with higher heel heights exacerbating these effects. Flat footwear provides better stability and comfort, making it a more practical option for prolonged wear. These findings emphasize the importance of carefully considering biomechanical and ergonomic factors when selecting footwear to promote optimal function and musculoskeletal health.

Study limitations

- Employing convenience sampling from a single academic setting restricts the broader applicability of the findings;
- The cross-sectional nature of the study reflects relationships at a single time point and does not permit conclusions regarding causality;
- Foot discomfort ratings obtained through the VAS may be subject to recall inaccuracies and personal differences in pain interpretation;
- It was not feasible to fully regulate all potential confounding variables, such as variations in daily physical activity, prior injuries, and differences in footwear use.

Practical implications

- Educating undergraduate students, particularly females, on the adverse effects of high heels can promote healthier footwear choices;
- Integrating foot health education into medical curricula can equip future healthcare professionals to counsel patients on footwear-related risks;
- Encouraging the use of flat or low-heeled shoes for prolonged standing or walking can help minimize foot pain and enhance stability;
- Universities and workplaces can implement guidelines or campaigns to promote ergonomic footwear and reduce balance-related injuries.

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