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Original Article

Association of Foot Arch Morphology with Balance Performance in Young Adults: A Comparative Observational Study

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ABSTRACT

Background: The medial longitudinal arch contributes to load distribution, shock absorption, and sensorimotor regulation during upright posture and locomotion. Alterations in foot arch morphology can influence postural control, yet comparative evidence in healthy young adults remains limited.
Objectives: To assess the association of foot arch morphology with static and dynamic balance performance in young adults and to compare balance outcomes across normal arch, low arch, and high arch groups.
Methods: This comparative observational study was conducted among 100 healthy young adults aged 18–25 years. Foot arch morphology was categorized as normal arch, low arch, or high arch after clinical assessment of medial longitudinal arch characteristics. Balance performance was assessed using the single-leg stance test, functional reach test, Y-balance test, and Timed Up and Go test. Data were analyzed using descriptive statistics, one-way analysis of variance, and chi-square test, with $p < 0.05$ considered statistically significant.
Results: Of the 100 participants, 52.0% were males and the mean age was 21.3 ± 1.8 years. Normal arch was observed in 52.0% of participants, low arch in 28.0%, and high arch in 20.0%. Baseline characteristics were comparable across groups. Participants with normal arch showed the best balance performance, with higher mean single-leg stance time, functional reach distance, and Y-balance composite score, along with lower Timed Up and Go duration. The low arch group demonstrated the poorest performance across most measures. The association between foot arch morphology and overall balance category was statistically significant.
Conclusion: Abnormal foot arch morphology, particularly low arch pattern, was associated with inferior static and dynamic balance performance in young adults. Assessment of foot arch structure can provide useful clinical information while evaluating postural stability in this age group.

Keywords: *foot arch morphology, balance performance, postural stability, pes planus, pes cavus, young adults.*

INTRODUCTION

Human postural stability depends on the coordinated integration of visual, vestibular, and somatosensory inputs, together with an intact musculoskeletal system that can generate timely corrective responses. Among the peripheral structures involved in this process, the foot plays a central role because it is the primary interface between the body and the supporting surface. The plantar surface provides continuous sensory feedback, while the osseoligamentous and muscular architecture of the foot contributes to load transfer, shock absorption, and maintenance of alignment during standing and movement [6-10]. Alterations in foot posture can therefore influence both static stance and dynamic balance performance.

The medial longitudinal arch is one of the most important structural determinants of foot function. A normal arch supports efficient force transmission and contributes to mechanical adaptability during gait and stance. In contrast, a low arch or pes planus is often associated with excessive pronation, altered plantar pressure distribution, and reduced mechanical efficiency, whereas a high arch or pes cavus can be linked to reduced flexibility, altered shock attenuation, and a relatively rigid foot lever [5-8]. These structural variations have been studied in relation to gait mechanics, lower-limb loading, functional ability, and injury susceptibility [5,7,8].

Several investigations have reported an association between foot posture and postural control. Pronated and supinated foot postures have been shown to affect static and dynamic postural stability, and alterations in foot and ankle characteristics have also been linked with impaired balance performance [5,9,10]. More recent studies have demonstrated that low medial longitudinal arch height is associated with poorer postural stability and that individuals with flexible flatfoot may show reduced balance and proprioceptive performance compared with those with neutral foot posture [11-12]. However, findings across studies are not fully uniform, partly because of differences in populations, age groups, assessment methods, and balance outcomes. Evidence from healthy young adults, particularly in the Indian setting, remains relatively sparse.

Young adulthood represents an important period for examining this relationship because individuals in this age group are typically free from overt degenerative disease, allowing clearer observation of the functional relevance of foot morphology itself. Identifying arch-related differences in balance in healthy young adults is clinically meaningful for screening, early rehabilitation, sports participation, and preventive strategies directed at lower-limb dysfunction. It can also provide useful baseline data for physiotherapy, sports medicine, and community-level musculoskeletal assessment.

The objectives of this study were to determine the distribution of foot arch morphology among young adults, to compare static and dynamic balance performance across normal arch, low arch, and high arch groups, and to evaluate the association between foot arch morphology and overall balance category in a healthy young adult population.

METHODOLOGY

Study design and setting

This comparative observational study was carried out in the Department of Physiology and associated academic facilities of Nova Institute of Medical Sciences, Hyderabad, Telangana, India, over a 14-month period from January 2025 to February 2026. The study was designed to compare balance performance across participants with different foot arch morphologies under standardized testing conditions.

Study population

A total of 100 healthy young adults aged 18 to 25 years were included. Participants were recruited by convenience sampling from undergraduate students and other young adult volunteers available within the institution. Individuals who were willing to participate and able to follow test instructions were considered eligible. Participants with a history of lower-limb fracture or surgery, acute musculoskeletal injury, neurological disease, vestibular disorder, clinically significant visual impairment not corrected with lenses, congenital foot deformity other than arch variation, limb-length discrepancy, inflammatory joint disease, or current foot pain severe enough to interfere with testing were excluded. Written informed consent was obtained from all participants before enrolment.

Assessment of foot arch morphology

Foot arch morphology was assessed clinically with the participant in relaxed standing using standard foot posture assessment principles based on the Foot Posture Index framework and medial longitudinal arch observation [1]. To improve practical categorization for analysis, the observed foot posture and arch profile were used to classify participants into three groups: normal arch, low arch [pes planus], and high arch [pes cavus]. Assessment was performed bilaterally, and the predominant arch pattern was considered for grouping. All measurements were carried out by trained investigators using a uniform protocol to minimize observer variation.

Assessment of balance performance

Both static and dynamic balance were evaluated. Static balance was assessed using the single-leg stance test and the functional reach test. The single-leg stance time was recorded in seconds as the participant maintained balance on one limb with the opposite limb flexed comfortably, and the best performance from standardized trials was documented. Functional reach distance was measured in centimeters using the standard forward reach procedure described by Duncan et al. [2]. Dynamic balance was assessed using the lower-quarter Y-balance test and the Timed Up and Go test. The Y-balance composite score was recorded as a percentage after standardized reach assessment in the designated directions, following accepted reliability procedures [4]. Functional mobility and dynamic balance were additionally measured with the Timed Up and Go test, recorded in seconds according to the conventional method described by Podsiadlo and Richardson [3]. Participants were allowed familiarization before formal testing, and all tests were performed in a quiet, well-lit area with adequate rest between trials.

Data collection and statistical analysis

Baseline demographic and anthropometric data, including age, sex, height, weight, and body mass index, were recorded for all participants. Continuous variables were summarized as mean ± standard deviation, while categorical variables were expressed as frequency and percentage. Comparison of baseline characteristics and balance parameters across the three arch groups was performed using one-way analysis of variance for continuous variables and chi-square test for categorical variables. Overall balance performance was further categorized into good, moderate, and poor balance based on combined test interpretation for comparative analysis. A p value of less than 0.05 was considered statistically significant. Statistical analysis was carried out using standard statistical software. Prior approval was obtained from the Institutional Ethics Committee before commencement of the study, and confidentiality of participant information was maintained throughout the research process.

RESULTS

A total of 100 young adults were included in the study. The age of the participants ranged from 18 to 25 years, with a mean age of 21.3 ± 1.8 years. Among them, 52 [52.0%] were males and 48 [48.0%] were females. The majority of participants belonged to the 21-23 years age group [44.0%], followed by 18-20 years [38.0%] and 24-25 years [18.0%]. The mean height, weight, and body mass index [BMI] of the study population were 167.2 ± 8.4 cm, 62.4 ± 9.6 kg, and 22.3 ± 3.0 kg/m², respectively. The baseline characteristics of the study participants are shown in Table 1.

Table 1. Baseline characteristics of study participants [N = 100]

Variable	Category / Value	n	% / Mean ± SD
Age group [years]	18-20	38	38.0
	21-23	44	44.0
	24-25	18	18.0
Sex	Male	52	52.0
	Female	48	48.0
Age [years]	21.3 ± 1.8		
Height [cm]	167.2 ± 8.4		
Weight [kg]	62.4 ± 9.6		
BMI [kg/m²]	22.3 ± 3.0		

Based on foot arch morphology assessment, normal arch was the most common pattern, observed in 52 participants [52.0%], followed by low arch in 28 [28.0%] and high arch in 20 [20.0%]. The distribution of foot arch morphology is presented in Table 2.

Table 2. Distribution of foot arch morphology among study participants [N = 100]

Foot arch morphology	n	%
Normal arch	52	52.0
Low arch [pes planus]	28	28.0
High arch [pes cavus]	20	20.0

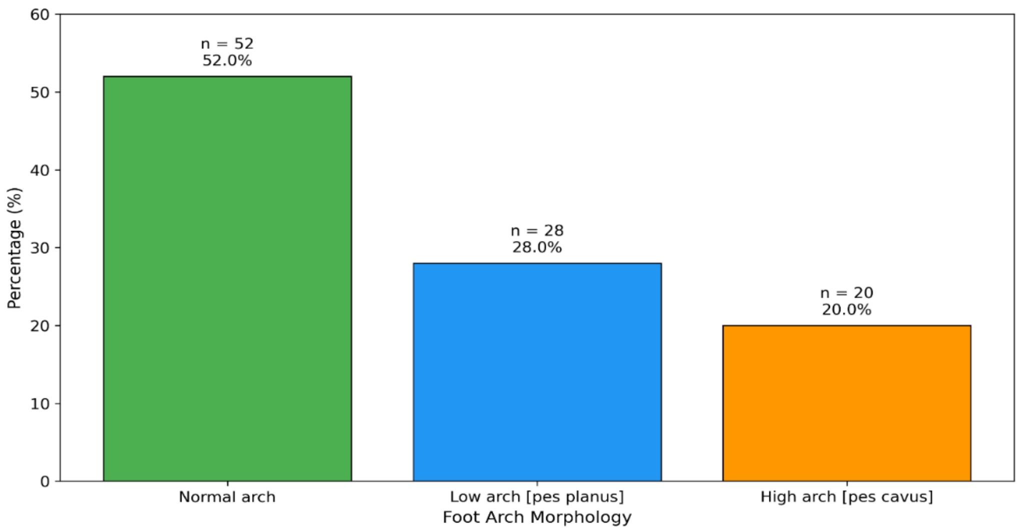

Figure 1: Distribution of foot arch morphology among study participants

The baseline characteristics were comparable across the three foot arch groups. There were no statistically significant differences in age, sex distribution, or BMI between participants with normal arch, low arch, and high arch morphology [p > 0.05], indicating that the groups were broadly similar at baseline. These findings are shown in Table 3.

Table 3. Comparison of baseline characteristics according to foot arch morphology

Variable	Normal arch [n = 52]	Low arch [n = 28]	High arch [n = 20]	p value
Age [years], mean ± SD	21.2 ± 1.7	21.5 ± 1.8	21.3 ± 1.9	0.73
Male, n [%]	27 [51.9]	14 [50.0]	11 [55.0]	0.93
Female, n [%]	25 [48.1]	14 [50.0]	9 [45.0]	0.93
BMI [kg/m²], mean ± SD	22.1 ± 2.9	22.8 ± 3.2	22.4 ± 3.0	0.58

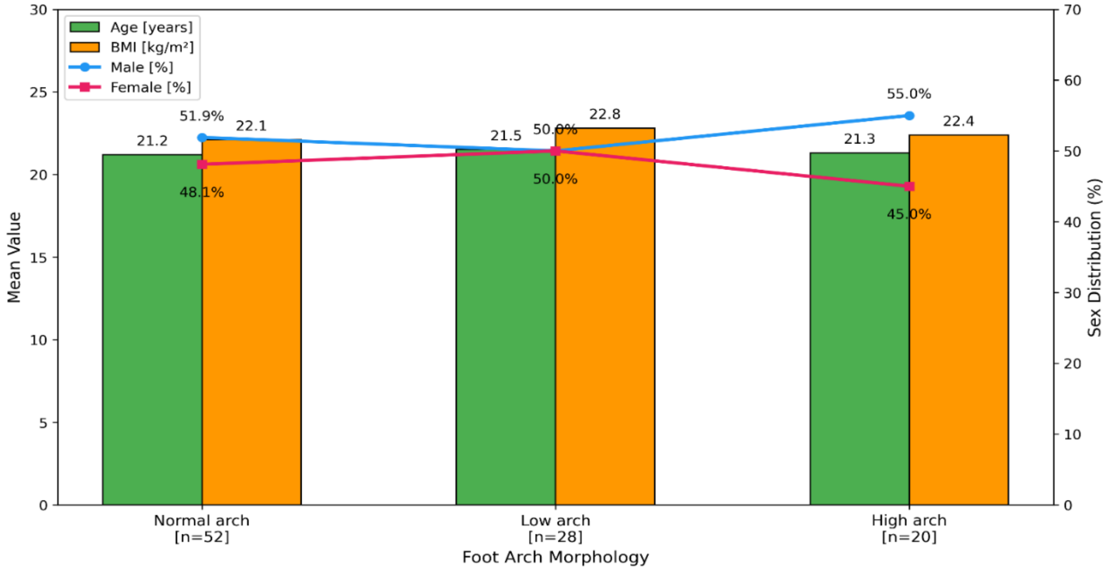

Figure 2: Comparison of baseline characteristics according to foot arch morphology

Comparison of balance performance demonstrated significant differences across foot arch groups. Participants with normal arch morphology showed the best balance performance on both static and dynamic balance measures. The mean single-leg stance time was highest among those with normal arch [37.4 ± 6.5 seconds], followed by the high arch group [32.6 ± 6.9 seconds], and was lowest in the low arch group [31.2 ± 7.3 seconds]. Similarly, the normal arch group had the highest mean functional reach distance [35.1 ± 4.2 cm] and Y-balance composite score [95.8 ± 5.6%]. In contrast, the low arch group demonstrated the poorest performance on these measures. Timed Up and Go test duration was significantly longer in the low arch group [8.0 ± 1.0 seconds], indicating relatively poorer dynamic balance and mobility, compared with the normal arch group [7.0 ± 0.8 seconds]. These differences were statistically significant [$p < 0.05$], as shown in Table 4.

Table 4. Comparison of balance performance according to foot arch morphology

Balance parameter	Normal arch [n = 52]	Low arch [n = 28]	High arch [n = 20]	p value
Single-leg stance time [seconds], mean ± SD	37.4 ± 6.5	31.2 ± 7.3	32.6 ± 6.9	<0.001
Functional reach distance [cm], mean ± SD	35.1 ± 4.2	31.6 ± 4.8	32.4 ± 4.5	0.001
Y-balance composite score [%], mean ± SD	95.8 ± 5.6	89.9 ± 6.4	91.5 ± 6.0	<0.001
Timed Up and Go [seconds], mean ± SD	7.0 ± 0.8	8.0 ± 1.0	7.6 ± 0.9	<0.001

When overall balance performance was categorized, good balance was more frequently observed in participants with normal arch morphology, whereas poor balance was more common among those with low arch and high arch patterns. In the normal arch group, 59.6% had good balance and only 7.7% had poor balance. In contrast, poor balance was observed in 28.6% of the low arch group and 20.0% of the high arch group. This association between foot arch morphology and categorized balance performance was statistically significant [p = 0.003], as shown in Table 5.

Table 5. Association between foot arch morphology and overall balance category

Foot arch morphology	Good balance n [%]	Moderate balance n [%]	Poor balance n [%]	Total	p value
Normal arch [n = 52]	31 [59.6]	17 [32.7]	4 [7.7]	52	
Low arch [n = 28]	7 [25.0]	13 [46.4]	8 [28.6]	28	
High arch [n = 20]	6 [30.0]	10 [50.0]	4 [20.0]	20	
Total [N = 100]	44 [44.0]	40 [40.0]	16 [16.0]	100	0.003

Overall, the findings indicate that abnormal foot arch morphology, particularly low arch pattern, was associated with poorer static and dynamic balance performance among young adults. Participants with normal arch morphology consistently performed better across all balance assessments, suggesting that foot arch structure may play a meaningful role in postural control and functional stability.

DISCUSSION

This study demonstrated a clear association between foot arch morphology and balance performance in young adults. Participants with normal arch morphology showed the best overall results across both static and dynamic balance measures, whereas the low arch group consistently demonstrated poorer performance and the high arch group showed intermediate values. Because age, sex distribution, and BMI were comparable across the three groups, the observed differences are more likely to reflect the functional influence of foot structure rather than major demographic confounding.

The findings are consistent with earlier work showing that deviations from neutral foot posture can adversely affect postural stability. Cote et al. reported that pronated and supinated foot postures altered both static and dynamic balance, suggesting that abnormal foot alignment affects the control of body sway and movement strategies [5]. Hunt and Smith also demonstrated biomechanical differences between flat and normal feet during stance, while Buldt et al. showed that planus and cavus foot types are associated with distinct lower-foot kinematics during gait [6,7]. These biomechanical alterations provide a plausible explanation for the reduced balance efficiency observed in participants with abnormal arch patterns in the present study.

The low arch group in this study had the shortest single-leg stance time, the lowest functional reach distance, the lowest Y-balance composite score, and the highest Timed Up and Go duration. This pattern suggests that reduced medial longitudinal arch height is linked not only to poorer static postural control but also to compromised dynamic balance and functional mobility. Similar observations have been reported by Karataş et al., who found that lower arch height negatively affected postural balance, and by Koshino et al. and Ghorbani et al., who documented impaired balance performance in individuals with flexible flatfoot compared with those with neutral feet [11,13,14]. Gul et al. likewise observed a relationship between medial longitudinal arch characteristics and postural stability in healthy young adults [14].

The relatively poorer performance of the high arch group compared with the normal arch group is also important. Although the deficits were not as marked as those seen with low arches, participants with high arches showed lower reach distances and balance scores than those with normal arches. A high-arched foot is often more rigid and less capable of dissipating ground reaction forces effectively, which can influence proprioceptive adaptation and balance responses [5-7]. This supports the view that both excessive lowering and excessive elevation of the arch can disturb optimal foot-ground interaction.

The present findings also have clinical relevance. Foot posture is easy to examine in outpatient, sports, and screening settings, and early identification of abnormal arch patterns can help target corrective exercises, footwear advice, proprioceptive training, and rehabilitation aimed at improving balance. Previous work has shown that foot and ankle characteristics are associated with balance and functional ability, and systematic evidence indicates that interventions directed at foot function can influence dynamic postural control [8-10]. In young adults, such strategies are particularly relevant for prevention of future musculoskeletal problems and performance-related deficits. Overall, this study strengthens the concept that foot arch morphology is not merely an anatomical variation but an important functional factor in postural stability.

Limitations

This study was conducted in a single institution with a convenience sample of healthy young adults, which limits wider generalizability. Foot arch grouping was based on clinical assessment rather than radiographic evaluation. Muscle strength, plantar pressure mapping, and detailed gait analysis were not included. Because of the cross-sectional design, causality between arch morphology and impaired balance cannot be established from these findings.

CONCLUSION

This comparative observational study showed that foot arch morphology was significantly associated with balance performance in young adults. Participants with normal arch pattern demonstrated superior static and dynamic balance, whereas those with low arch pattern had the least favorable outcomes across single-leg stance, functional reach, Y-balance, and Timed Up and Go measures. High arch morphology also showed reduced performance compared with normal arch, although the deficit was less pronounced than that seen in the low arch group. These findings support the clinical relevance of routine foot arch assessment during musculoskeletal and functional evaluation. Early identification of abnormal arch patterns can help guide targeted balance training, corrective strategies, and preventive rehabilitation in young adults.

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