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Original Article

Effect of Weight Bearing on Medial Longitudinal Arch of Foot in Healthy Adults

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ABSTRACT

Background: The medial longitudinal arch (MLA) of the foot plays a pivotal role in biomechanical stability and mobility. Understanding its behavior under different loading conditions is crucial for both clinical and sports-related applications. Previous studies have offered insights into the arch's adaptability, yet the impact of gender on this dynamic has remained underexplored.

Objective: This study aimed to investigate the differences in medial longitudinal arch height between genders in non-weight bearing (NWB) and full weight bearing (FWB) positions, to ascertain if gender influences arch behavior under various loading conditions.

Methods: Conducted at the Biomechanics and Kinesiology Laboratory of Shifa Tameer e Millat University, this cross-sectional study enrolled volunteers aged 18 to 40 years with normal foot arches. Exclusion criteria included history of foot pain, foot anomalies, pregnancy, or menstruation at the time of data collection. Navicular height was measured using Kinovea software (Version 0.9.5), with participants in both NWB and FWB positions. The study received approval from the Institutional Review Board and Ethics Committee of Shifa International Hospital (IRB # 0213-23). Statistical analysis was performed using independent and paired sample t-tests.

Results: The study involved equal numbers of male and female participants, with no significant gender-based differences observed in navicular height in NWB (Males: Left Foot 5.17 ± 0.865, Right Foot 5.19 ± 0.675; Females: Left Foot 5.24 ± 0.89, Right Foot 5.39 ± 0.867) and FWB positions (Males: Left Foot 4.73 ± 0.834, Right Foot 4.88 ± 0.846; Females: Left Foot 4.83 ± 0.898, Right Foot 4.80 ± 0.837). Significant reductions in navicular height from NWB to FWB were noted across both genders ($p < 0.01$).

Conclusion: The medial longitudinal arch height significantly changes under weight bearing, displaying a similar pattern of adaptability across genders. This indicates that gender does not significantly influence the biomechanical behavior of the MLA under the tested conditions.

Keywords: Medial Longitudinal Arch, Non-Weight Bearing, Full Weight Bearing, Gender Differences, Foot Biomechanics.

INTRODUCTION

The human foot, a marvel of biomechanical engineering, is comprised of an intricate assembly of bones, muscles, tendons, and ligaments working in concert to support the body's weight and enable mobility. Within this complex structure, the medial longitudinal arch (MLA) stands out for its pivotal role in maintaining stability and comfort across daily and athletic activities. Stretching from the calcaneus to the metatarsals along the foot's inner side, the MLA acts both as a stabilizer and a shock absorber, crucial to the foot's mechanical efficiency. It adeptly distributes the pressures associated with standing, walking, running, and jumping, thereby minimizing injury risk and discomfort. The MLA's composition includes the calcaneus, talus, navicular, cuneiforms, and metatarsals, bound by a network of ligaments and tendons, illustrating the elegance of evolutionary design. Structurally resembling a bow, with the plantar fascia as the bowstring, the MLA dynamically adjusts to terrain and load variations, acting as a shock absorber and spring, essential for effective movement (1,2,3).

Emerging literature highlights the impact of footwear on foot biomechanics, advocating for regular barefoot walking to optimize foot health (4). Beyond anatomical factors, biomechanical studies reveal significant gender-based differences in arch shape and behavior, influenced by genetic, hormonal, and menstrual cycle factors. These discrepancies have profound implications for foot

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biomechanics, emphasizing the importance of gender-specific assessments in understanding the MLA's response to weight-bearing stresses (5,6,7).

This study aims to explore the variations in MLA height between non-weight-bearing and full-weight-bearing positions among healthy adults, building upon the extensive body of research in podiatry, orthopedics, and biomechanics. Despite a wealth of studies on the MLA's biomechanical and anatomical characteristics under weight-bearing conditions, a comprehensive understanding of its dynamics, particularly in relation to gender-specific variations, remains elusive. Recent findings highlight musculoskeletal asymmetries in healthy adults and the MLA's critical role in force dispersion, shock absorption, and balance during locomotion (8,9,10). Techniques such as dynamic imaging, pressure mapping, and kinematic analysis have enhanced our knowledge of the arch's behavior under various loading conditions, contributing to injury prevention and management strategies. The navicular bone marking, an indirect measurement method, is widely used to assess MLA height, supported by literature. The arch index, correlating with navicular drop, serves as another measurement approach, showcasing the diverse methods for evaluating MLA dynamics (11,12,13,14).

However, the literature's current scope has minimally addressed gender-specific variations in arch dynamics within healthy adult populations. Studies indicate that females typically have higher arches than males, a factor that may influence the MLA's response to weight-bearing scenarios (15,16). The use of Kinovea software for motion analysis, noted for its validity and reliability, marks significant technological advancements in this field (17-20).

Bridging this knowledge gap is imperative for advancing the discipline and refining clinical evaluation and management strategies for the MLA. Given the significant anatomical and biomechanical differences between genders identified by recent research, our study seeks to compare MLA height in non-weight-bearing and full-weight-bearing positions across genders. Additionally, it aims to examine how these differences influence the arch's behavior under various mechanical stresses. This investigation is crucial for gaining a deeper understanding of gender-specific variations in MLA dynamics, with significant implications for clinical practice and therapeutic interventions.

MATERIAL AND METHODS

The study was conducted in the Biomechanics and Kinesiology Laboratory at the Department of Rehabilitation Sciences, Shifa Tameer e Millat University, Park Road Campus, Islamabad, following approval by the Institutional Review Board and Ethics Committee of Shifa International Hospital (IRB # 0213-23). Designed as a cross-sectional investigation, data collection spanned from 10th June 2023 to 10th October 2023. The participant pool consisted of volunteers from both genders, aged 18 to 40 years, who exhibited normal foot arches. Eligibility criteria mandated no history of foot pain in the preceding six months, absence of known foot anomalies, and exclusion of individuals with a history of foot pain, flat feet, high arches, or other foot anomalies. Pregnant individuals and females who were menstruating at the time of data collection were also excluded. Written consent was obtained from all participants prior to their inclusion in the study.

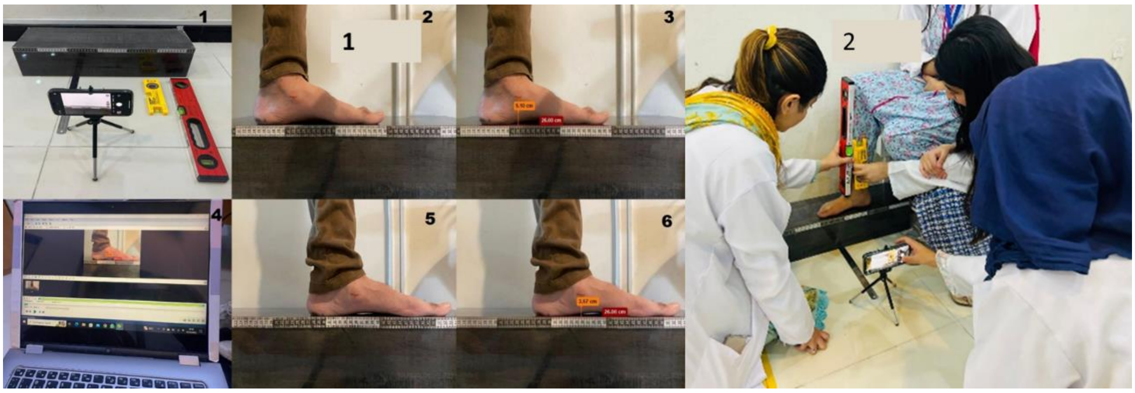

Figure 1 Figure 1 Process of measuring arch height: 1) Setup for image capture, 2) Marking Navicular in NWB, 3) Navicular measurement in NWB with Kinovea, 4) Kinovea software interface, 5) Marking Navicular in FWB, 6) Navicular measurement in FWB with Kinovea; Figure 2 Alignment of tibia using Water Level.

The methodology employed for measuring foot arches involved the use of the navicular bone height. The process, as depicted in Figure 1, included capturing images of the feet, marking the navicular height in a non-weight-bearing (NWB) position, and then measuring the navicular height in both NWB and full-weight-bearing (FWB) positions using the Kinovea software (Version 0.9.5). Calibration of Kinovea was achieved using a measurement tape affixed to a wooden platform, facilitating accurate measurement of the navicular tuberosity height from the platform. These measurements were subsequently recorded in an Excel spreadsheet for analysis. For the NWB position, participants were seated with their feet resting naturally on the platform, while FWB measurements were taken with participants

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standing in a single-leg stance on the platform, ensuring tibial alignment in both the frontal and sagittal planes with the aid of two water levels as illustrated in Figure 2.

Data analysis was performed using SPSS version 25. The primary aim was to compare the navicular height measurements between NWB and FWB positions to identify any significant differences in mean values. The use of Kinovea for image analysis was predicated on its proven reliability for such measurements when markers are employed (18). This comprehensive approach to data collection, measurement, and analysis ensured a rigorous examination of the medial longitudinal arch height variations under different weight-bearing conditions, adhering to the highest standards of ethical and methodological rigor in medical research.

RESULTS

In the analysis conducted to evaluate the differences in navicular height across genders in both non-weight bearing (NWB) and full weight bearing (FWB) positions, the independent t-test revealed no statistically significant differences between males and females. Specifically, the mean navicular height in the left foot in NWB for males was 5.17 ± 0.865 compared to 5.24 ± 0.89 for females, resulting in a p-value of 0.721. Similarly, for the right foot in NWB, males exhibited a mean of 5.19 ± 0.675, while females had a slightly higher mean of 5.39 ± 0.867, with a p-value of 0.124, indicating no significant gender-based differences (Table 1). Furthermore, in FWB conditions, the left foot navicular height mean for males was 4.73 ± 0.834 and for females was 4.83 ± 0.898, yielding a p-value of 0.846. The right foot showed a mean of 4.88 ± 0.846 for males and 4.80 ± 0.837 for females, with a p-value of 0.920, further underscoring the lack of significant gender disparity in navicular height under weight bearing (Table 1).

Table 1 Gender-Based Comparison of Navicular Height in Non-Weight Bearing (NWB) and Full Weight Bearing (FWB) Positions Using Independent t-test

Variables	Male Mean ± SD	Female Mean ± SD	p-values
Left Foot Navicular Height in NWB	5.17 ± 0.865	5.24 ± 0.89	0.721
Right Foot Navicular Height in NWB	5.19 ± 0.675	5.39 ± 0.867	0.124
Left Foot Navicular Height in FWB	4.73 ± 0.834	4.83 ± 0.898	0.846
Right Foot Navicular Height in FWB	4.88 ± 0.846	4.80 ± 0.837	0.920

Table 2 Paired Sample T-test for Comparison of NWB and FWB Positions in Both Feet

Groups	Variables	Non-Weight Bearing Mean ± SD	Full Weight Bearing Mean ± SD	p-value
Male	Left Foot Navicular	5.17 ± 0.86	4.73 ± 0.83	0.002
	Right Foot Navicular	5.19 ± 0.67	4.88 ± 0.84	0.009
Female	Left Foot Navicular	5.24 ± 0.89	4.83 ± 0.89	<0.001
	Right Foot Navicular	5.39 ± 0.86	4.80 ± 0.83	0.001

The paired sample t-test comparison between NWB and FWB positions for each foot and gender demonstrated statistically significant changes within individuals. For males, the navicular height in the left foot decreased from a mean of 5.17 ± 0.86 in NWB to 4.73 ± 0.83 in FWB, with a p-value of 0.002. The right foot also showed a decrease from 5.19 ± 0.67 in NWB to 4.88 ± 0.84 in FWB, with a p-value of 0.009. Females exhibited a similar pattern, where the left foot's navicular height decreased from 5.24 ± 0.89 in NWB to 4.83 ± 0.89 in FWB ($p < 0.001$), and the right foot decreased from 5.39 ± 0.86 in NWB to 4.80 ± 0.83 in FWB ($p = 0.001$) (Table 2). These findings highlight a significant reduction in navicular height when transitioning from a non-weight bearing to a full weight bearing position, indicating the dynamic nature of the medial longitudinal arch in response to loading across both genders.

This comprehensive analysis, supported by detailed statistical data (Tables 1 and 2), underscores the inherent adaptability of the medial longitudinal arch in adjusting to different loading conditions, without significant differences between genders. The significant reductions observed in navicular height from NWB to FWB across both males and females reflect the functional and biomechanical responses of the foot's arch to weight bearing, illustrating its critical role in accommodating and distributing mechanical loads during standing and movement.

DISCUSSION

The results of the present study reveal an absence of gender-specific variations in navicular height between males and females under both non-weight bearing (NWB) and full weight-bearing (FWB) conditions for the variables analyzed. This observation is consistent with the findings of Xuanzhen Cen et al. (2020), who investigated the impact of additional body weight on the arch index and dynamic plantar pressure distribution during walking and gait termination. Their research found no significant alterations in arch height with

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a 10% body weight increase, indicating negligible changes under slight weight variations (p = 0.068 > 0.05). It was only with a weight increase of 20% and 30% body weight that significant differences emerged, pointing to a decrease in arch height, thereby underscoring the resilience of the arch to moderate increases in load (21,22,23). Similarly, the work by Chaichanyut M (2022), focusing on the plantar pressure in individuals with flat feet, lends further support to our findings by highlighting the significant difference in navicular height between NWB and FWB conditions, aligning with our observations on the dynamic nature of the medial longitudinal arch under varied loading conditions (24). Furthermore, research conducted by Naseer S et al. in the radiology department of Deccan College of Medical Sciences, Hyderabad, reinforces the conclusion that medial longitudinal arch height undergoes significant changes upon weight bearing, a phenomenon observed across both genders (25).

Our investigation, supported by these previous studies, underscores the adaptability of the medial longitudinal arch to different weight-bearing scenarios, demonstrating significant height alterations upon load bearing, irrespective of gender. This suggests that the arch behaves similarly in both males and females under stress, indicating that gender may not be a critical factor in determining arch behavior for the examined parameters. Such findings contribute valuable insights into the biomechanical understanding of foot arch dynamics, emphasizing the universality of arch response across genders.

This study, while offering important contributions to the field of biomechanics and podiatry, is not without its limitations. The sample size, though adequate to detect differences, may not fully capture the variability within the broader population. Future research could benefit from larger, more diverse cohorts to generalize findings more effectively. Additionally, the study's cross-sectional design limits the ability to infer causality or changes over time. Longitudinal studies could provide deeper insights into the temporal dynamics of arch behavior under varying weight-bearing conditions.

Acknowledging these limitations opens avenues for further research. Investigations exploring the influence of more significant weight variations, as suggested by the findings of Xuanzhen Cen et al., could elucidate the threshold at which arch behavior significantly changes. Moreover, examining other factors that may influence arch dynamics, such as age, activity level, and foot morphology, could offer a more comprehensive understanding of foot biomechanics.

CONCLUSION

In conclusion, the medial longitudinal arch demonstrates significant height changes under weight bearing, behaving similarly across genders. This study contributes to the biomechanical literature by affirming the arch's adaptability to loading, with gender playing a minimal role in this aspect of foot biomechanics.

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