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Relationship Between Body Mass Index and Medial Longitudinal Arch Morphology Among Female MBBS Students - A Cross-Sectional Study

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Abstract

Background: The medial longitudinal arch (MLA) is an important structural component of the foot that contributes to weight distribution, shock absorption, balance, and efficient locomotion. Body mass index (BMI) has been proposed as an important factor influencing foot morphology; however, evidence regarding its relationship with MLA remains inconsistent. The present study was undertaken to evaluate the relationship between BMI and the medial longitudinal arch among female MBBS students.

Materials and Methods: A cross-sectional observational study was conducted in the Department of Anatomy, Government Medical College, Srinagar, among 100 female MBBS students aged 18–25 years. Height and weight were measured to calculate BMI according to World Health Organization criteria. The medial longitudinal arch was assessed using Clarke's angle obtained from static footprints and classified as

flat arch, normal arch, or high arch. The association between BMI categories and arch type was evaluated using the Chi-square test, while Pearson's correlation coefficient was used to assess the relationship between BMI and Clarke's angle.

Results: Normal BMI was observed in 52% of participants, while 22% were overweight, 18% were underweight, and 8% were obese. Normal arch morphology was the most common finding (54%), followed by flat arch (28%) and high arch (18%). Mean Clarke's angle progressively decreased from 46.8 ± 5.2° in underweight participants to 32.9 ± 4.7° in obese participants ($p < 0.001$). A statistically significant association was observed between BMI category and arch type ($\chi^2 = 24.73$, $p = 0.001$). Pearson correlation analysis demonstrated a moderate negative correlation between BMI and Clarke's angle ($r = -0.472$, $p < 0.001$), indicating a reduction in arch height with increasing BMI.

Conclusion: Increasing BMI was significantly associated with lowering of the medial longitudinal arch among female MBBS students. Higher BMI categories demonstrated a greater prevalence of flat arch morphology, suggesting that body weight may play an important role in foot biomechanics and arch characteristics.

Keywords: Body Mass Index, Medial Longitudinal Arch, Clarke's Angle, Foot Arch, Female MBBS Students, Foot Biomechanics.

Introduction

The medial longitudinal arch (MLA) is an important structural component of the foot that contributes to weight distribution, shock absorption, balance, and efficient locomotion. Alterations in MLA morphology may predispose individuals to foot pain, gait abnormalities, and lower limb musculoskeletal disorders. Previous studies have demonstrated that MLA characteristics are influenced by factors such as age, sex, foot dimensions, and body mass index (BMI).[1]Body mass index is an important indicator of body composition and may influence foot structure through increased mechanical loading. However, the relationship between BMI and MLA remains controversial.[1] reported significant correlations between BMI and footprint-based arch indices, particularly among women, whereas Soni JD and Shah D[2] observed a higher prevalence of low arches among overweight individuals but found no statistically significant association between BMI and medial arch height.

Sex-related differences in foot morphology have also been reported. Women generally exhibit greater ligamentous laxity, altered lower limb biomechanics, and lower arch characteristics compared to men, which may influence the relationship between BMI and MLA. Furthermore, WozniackaR et al. (2013)[3] demonstrated that the association between body weight and medial longitudinal arch morphology was stronger in females than in males.

Female MBBS students represent a relatively homogeneous population with similar age and educational backgrounds. Prolonged standing during practical sessions and clinical postings, combined with sedentary study habits and changing lifestyle patterns, may influence both BMI and foot biomechanics.[4-7] Despite this, limited data are available regarding the relationship between BMI and MLA among female medical students, particularly in the Indian population. Therefore, the present study was undertaken to evaluate the relationship between body mass index and the medial longitudinal arch of the foot in female MBBS students.

Materials and Methods

This cross-sectional observational study was conducted in the Department of Anatomy, Government Medical College (GMC), Srinagar, Jammu and Kashmir, India, over a period of six months following approval from the Institutional Ethics Committee. The study aimed to evaluate the relationship between body mass index (BMI) and the medial longitudinal arch (MLA) of the foot among female MBBS students.

A total of 100 female MBBS students aged between 18 and 25 years were recruited using convenience sampling after obtaining written informed consent. Participants with a history of congenital foot deformities, previous foot or ankle surgery, recent lower limb trauma, neuromuscular disorders affecting gait, inflammatory joint diseases, connective tissue disorders, or pregnancy were excluded from the study.

Demographic details including age, academic year, height, and weight were recorded for all participants. Height was measured in centimeters using a wall-mounted stadiometer with participants standing barefoot in the anatomical position. Body weight was measured in kilograms using a calibrated digital weighing scale. Body mass index was calculated using the formula: weight (kg)/height² (m²). Based on World Health Organization (WHO) criteria, participants were categorized as underweight (BMI <18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30 kg/m²).

Assessment of the medial longitudinal arch was performed using Clarke's angle obtained from static footprints. Footprints were recorded using the ink footprint method. Participants were instructed to stand comfortably in a relaxed bipedal position with equal weight distribution on both feet. The footprint obtained was analyzed, and Clarke's angle was measured using a standard goniometric technique. Based on the measured angle, the medial longitudinal arch was classified as flat foot (<31°), normal arch (31°–45°), or high arch (>45°).

All measurements were performed by the same investigator to minimize inter-observer variability. The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Quantitative variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The association between BMI categories and foot arch type was assessed using the Chi-square test. Differences in mean Clarke's angle among BMI categories were evaluated using one-way analysis of variance (ANOVA). Pearson's correlation coefficient was used to determine the relationship between BMI and Clarke's angle. A p-value of less than 0.05 was considered statistically significant.

Results

Table 1: Demographic Characteristics and BMI Distribution of Study Participants (N=100).

Variable	Frequency	Percentage (%)
Age Group (years)		
18–19	28	28.0
20–21	47	47.0
22–23	20	20.0
≥24	5	5.0
BMI Category		
Underweight	18	18.0
Normal Weight	52	52.0
Overweight	22	22.0
Obese	8	8.0

As shown in Table 1, the majority of female MBBS students belonged to the 20–21 years age group (47%),

followed by 18–19 years (28%). Regarding nutritional status, more than half of the participants (52%) had normal BMI, while 22% were overweight, 18% were underweight, and 8% were obese.

Table 2: Distribution of Medial Longitudinal Arch Types Among Study Participants (N=100)

Arch Type	Frequency	Percentage (%)
Flat Arch	28	28.0
Normal Arch	54	54.0
High Arch	18	18.0
Total	100	100.0

As presented in Table 2, a normal medial longitudinal arch was the most common finding and was observed in 54% of participants. Flat arch morphology was present in 28% of students, whereas 18% demonstrated a high arch.

Table 3: Mean Clarke's Angle According to BMI Categories

BMI Category	Mean Clarke's Angle (°) ± SD
Underweight	46.8 ± 5.2
Normal Weight	41.9 ± 6.1
Overweight	36.7 ± 5.8
Obese	32.9 ± 4.7

ANOVA F = 12.86, p <0.001

As shown in Table 3, the mean Clarke's angle progressively decreased with increasing BMI. Underweight participants exhibited the highest mean Clarke's angle (46.8 ± 5.2°), followed by normal-weight (41.9 ± 6.1°), overweight (36.7 ± 5.8°), and obese students (32.9 ± 4.7°).

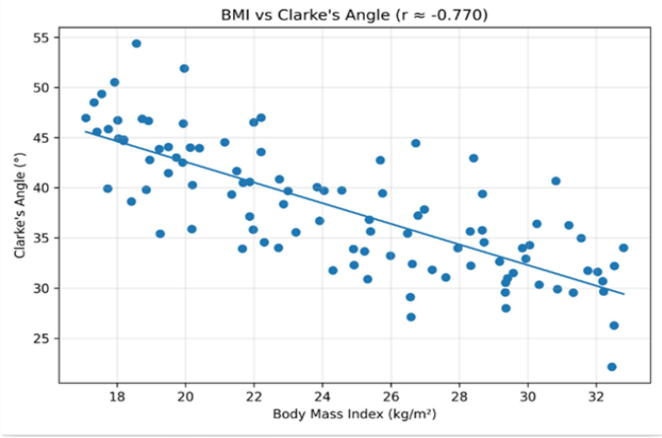
The difference in mean Clarke's angle across BMI categories was statistically significant (p <0.001), indicating a reduction in medial longitudinal arch height with increasing body mass.

Table 4: Association Between BMI Category and Medial Longitudinal Arch Type

BMI Category	Flat Arch n (%)	Normal Arch n (%)	High Arch n (%)	Total
Underweight	2 (11.1)	7 (38.9)	9 (50.0)	18
Normal Weight	10 (19.2)	34 (65.4)	8 (15.4)	52
Overweight	12 (54.5)	10 (45.5)	0 (0.0)	22
Obese	4 (50.0)	3 (37.5)	1 (12.5)	8
Total	28	54	18	100

As demonstrated in Table 4**,** high arch morphology was predominantly observed among underweight participants, with 50.0% exhibiting a high medial longitudinal arch. In contrast, flat arch prevalence was considerably higher among overweight (54.5%) and obese (50.0%) students. Normal arch morphology was most frequently observed in participants with normal BMI (65.4%). The association between BMI category and medial longitudinal arch type was statistically significant ($\chi^2 = 24.73$, $p = 0.001$), indicating that increasing BMI was associated with a tendency toward flattening of the medial longitudinal arch.

Figure 1: Correlation Between Body Mass Index and Clarke's Angle.



Pearson correlation analysis demonstrated a statistically significant moderate negative correlation between BMI and Clarke's angle **(**r = −0.472, p <0.001**)** (Figure 1). This finding indicates that increasing BMI was associated with decreasing Clarke's angle values, reflecting a reduction in medial longitudinal arch height. The scatter plot further illustrates the inverse relationship between body mass index and foot arch morphology among female MBBS students.

Discussion

The present study investigated the relationship between body mass index (BMI) and the medial longitudinal arch (MLA) of the foot among female MBBS students using Clarke's angle. The findings demonstrated a significant inverse relationship between BMI and MLA morphology.

In the present study, normal arch morphology was the most common finding, accounting for 54% of the study population, while flat arch and high arch were observed in 28% and 18% of participants, respectively. Similar observations were reported other researchers, who found that normal arch morphology predominated in the study population. Their analysis further demonstrated significant differences in MLA morphology according to sex and BMI, emphasizing the importance of evaluating female populations separately.[1, 7-10]

A major finding of the present study was the significant reduction in Clarke's angle with increasing BMI. Biomechanically, increased body weight imposes greater stress on the plantar fascia, spring ligament, and intrinsic foot musculature, leading to increased mid foot loading and gradual flattening of the arch. Similar findings were reported by Rosende-Bautista et al., who observed significant positive correlations between BMI and footprint-based arch index measurements. Among women,[1] BMI demonstrated moderate positive correlations with arch index values for both feet (left foot r = 0.463, right foot r = 0.441; p <0.001), indicating greater footprint flattening with increasing body mass.[1] Additionally, normalized navicular height measurements showed weak but significant negative correlations with BMI among women (r = −0.160 to −0.168; p <0.01), supporting the concept that increasing BMI may be associated with reduced arch height.

The significant association observed between BMI category and arch type in the present study ($\chi^2 = 24.73$, p = 0.001) is also supported by the findings of WoźniackaR et al., who examined 1,115 children and reported a statistically significant relationship between adiposity and MLA morphology. Their study demonstrated that high-arched feet were more common among underweight individuals, whereas increasing adiposity was associated with alterations in arch morphology. Importantly, the authors noted that the correlation between body weight and MLA was stronger among girls than boys.[3] Similarly, in the present study, high arches were predominantly observed among underweight participants (50.0%) whereas flat arches were considerably more common among overweight and obese students.[11-13]

The findings of the present study also show agreement with observations reported by Soni and Shah, who evaluated 360 healthy adults aged 18–45 years using the normalized truncated navicular height (NTNH) method.[2] Although their study did not demonstrate a statistically significant association between BMI and arch type (left foot p = 0.097; right foot p = 0.136), they reported that high arches were more prevalent among underweight individuals, whereas low arches were more frequently observed in overweight and obese participants. This

trend is consistent with the present findings despite differences in statistical significance.

However, the significant correlation observed in the present study differs from the conclusions of Soni and Shah, who reported no significant relationship between BMI and medial longitudinal arch height. Several factors may explain this discrepancy. First, the present study included only female MBBS students, whereas Soni and Shah included both sexes.[1] Previous studies have shown that females exhibit greater ligamentous laxity, increased joint mobility, and different lower limb biomechanics, all of which may influence arch morphology. Second, the present study used Clarke's angle derived from footprints, whereas Soni JD and Shah D employed navicular-height–based anthropometric measurements.[1] Variations in measurement techniques may therefore contribute to differences in observed associations.[14]

Another explanation for the observed findings relates to the influence of body composition on footprint morphology. Rosende-Bautista C et al. emphasized that increased plantar adipose tissue in overweight and obese individuals may enlarge the mid foot contact area and increase arch index values without necessarily producing equivalent changes in the osseous structure of the arch. They concluded that footprint-based measurements may be influenced by BMI and should therefore be interpreted cautiously when evaluating medial longitudinal arch morphology. Nevertheless, even if part of the observed change is attributable to soft tissue expansion, increased mid foot loading remains clinically relevant because it may contribute to altered gait mechanics, reduced shock absorption, and future musculoskeletal complaints.[1]

The present study specifically focused on female MBBS students, a population that experiences prolonged standing during practical classes and clinical postings while simultaneously engaging in prolonged periods of sedentary academic work. Such lifestyle characteristics may contribute to both increasing BMI and altered foot biomechanics. Therefore, the observed relationship between BMI and MLA morphology may have important implications for the musculoskeletal health of medical students.[15]

A major strength of the present study is its focus on a relatively homogeneous population of female MBBS students, minimizing the influence of age- and sex-related confounding variables. The study employed Clarke's angle, a simple, non-invasive, and widely accepted method for assessing the medial longitudinal arch, and demonstrated a statistically significant moderate negative correlation between BMI and arch height ($r = -0.472$, $p < 0.001$). In addition, both categorical and correlational analyses were performed, providing a comprehensive evaluation of the relationship between BMI and MLA morphology.

However, certain limitations should be acknowledged. The cross-sectional study design does not permit establishment of a causal relationship between BMI and arch changes. The study was conducted at a single institution and included only 100 participants, which may limit generalizability. Furthermore, footprint-based assessments such as Clarke's angle may be influenced by plantar soft tissue thickness, particularly in overweight and obese individuals. Similar concerns were highlighted by Rosende-Bautista et al., who demonstrated significant BMI-related changes in footprint-derived arch indices despite only weak correlations with normalized navicular height measurements.[1] Other potentially important factors such as physical activity level, footwear habits, plantar

pressure distribution, ligamentous laxity, and lower limb alignment were not evaluated. Future multi centric studies incorporating larger sample sizes, radiographic or anthropometric arch measurements, and dynamic biomechanical assessments are recommended to further clarify the relationship between BMI and medial longitudinal arch morphology.

Conclusion

The present study demonstrated a significant relationship between body mass index and medial longitudinal arch morphology among female MBBS students. A progressive decline in Clarke's angle was observed with increasing BMI, indicating a reduction in medial longitudinal arch height. Flat arch morphology was more prevalent among overweight and obese participants, whereas high arches were predominantly observed among underweight students. A statistically significant association between BMI category and arch type, along with a moderate negative correlation between BMI and Clarke's angle , suggests that increasing body mass may contribute to lowering of the medial longitudinal arch. These findings highlight the importance of maintaining a healthy body weight for preserving normal foot biomechanics and may facilitate early identification of individuals at risk of developing foot-related musculoskeletal problems.

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