



Exploring the Impact of BMI on Foot Anthropometric Dimensions: A Pilot Study

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DOI: <https://doi.org/10.54392/ijpefs2617>

Received: 04-12-2025; Revised: 04-02-2026; Accepted: 09-02-2026; Published: 17-02-2026



Abstract: Age, gender, and Body Mass Index (BMI) significantly influence foot dimensions. However, research on BMI's impact is limited, focusing primarily on implications for shoe design. This study aimed to collect foot anthropometric data from Indian adults and examine the impact of BMI on foot dimensions. A total of 270 volunteers participated, divided into Normal (n=135) and Overweight (n=135) groups based on BMI. The average age, height, and weight of the normal and overweight participants were 21.96 ± 4.174 years, 162.58 ± 8.925 cm, and 58.24 ± 8.593 kg, and 24.17 ± 7.476 years, 165.87 ± 9.205 cm, and 74.65 ± 9.662 kg, respectively. Foot anthropometric data were recorded using a 3D foot scanner and analyzed with SPSS v26. Spearman correlation indicated a significant positive relationship between BMI and foot dimensions, excluding arch height ($p < 0.01$). The Mann-Whitney U test showed significant differences ($p < 0.05$) between normal and overweight groups in all measured parameters, except for foot arch height. The findings of this study reveal that BMI significantly influences foot morphology in overweight participants, who exhibit broader and longer feet than those of normal-weight individuals. These variations highlight the need for BMI-specific footwear design to improve fit, comfort, and stability. However, further research with a larger sample size, considering age, sex, and ethnicity, is necessary to establish a comprehensive database.

Keywords: BMI, Foot Dimension, Overweight, Footwear Sizing System, Dimensional Variation

1. Introduction

Anthropometry is an anthropological method for measurement and analysis of human body. Foot anthropometry involves specifically measuring the size and dimensions of the foot (Maity *et al.*, 2024). The initial phase of measurements was conducted in the England prior to the hundred year's war (1337-1453). In Romania, mass anthropometry was initiated in 1968 and replicated in 1981-82 and 1994-95, but with much reduced sample sizes (Manganaro *et al.*, 2023). Now foot anthropometry can be applied not just to determination of health status or to identifying an individual, also it is very crucial in epidemiology, evolutionary studies, and ergonomics. Previous studies examined anthropometric differences within various populations focused on how Gender, Age, BMI and ethnicity affect foot dimensions (Kim *et al.*, 2018; Puszczalowska-Lizis *et al.*, 2023). Body Mass Index is an

informal measurement of a person based on their body weight and height. It is a common diagnostic tool to detect whether one is normal, underweight, overweight or obese. Some suggestions are stated that Body Mass Index (BMI) can successfully impact the foot measurements like foot length, foot breadth and arch height under various weight bearing conditions (Keys *et al.*, 1972). Previous study stated that higher BMI individuals had larger foot width and plantar contact area, indicating adaptive adjustments for bearing extra body weight (Rein *et al.*, 2010). Wearing *et al.* (2006) noted that, changes in medial longitudinal arch (MLA) height in obese patients that could influence in to foot pathologies such as plantar fasciitis and over pronation. Impact of BMI on foot anthropometry has fundamental implications for several different fields of study, among them podiatry, orthotics, and footwear design (Menz and Morris, 2005). By using of foot dimension data in

footwear design can enhance the comfort and fit of shoes while minimizing risk of injury (McWhorter *et al.*, 2003). The standard approach to measuring the fitment of shoes should matching with foot length, width, heel width, ball circumference, instep circumference, heel circumference, and instep height with the footwear product (Wang, 2010; Xu *et al.*, 2019). The Effect of BMI was found in the studies on static foot width. Particularly children's foot morphology and functionality of longitudinal arch are affected by BMI (Xiong *et al.*, 2009). However, Standardized shoe sizing systems don't accommodate the morphological changes that come with higher BMI so you may experience discomfort and foot injuries such as sprains, strains, corn, bunion, blister and other stress fractures (Wunderlich and Cavanagh, 2001). Current existing Footwear affects muscles, bones and joints that over time get stretched and changed the feet's morphological and structural attributes. This can be pain, discomfort or disfigurement like hallux valgus, hallux rigidus, flat foot, hollow foot, hammer toes etc. Ill-fitting or poorly made footwear can cause the mentioned foot problems that can change over time (Paiva de Castro *et al.*, 2010; Jana *et al.*, 2024). Notably, Rao *et al.* (2012) stated that BMI related changes in foot dimensions can affect gait mechanics, potentially exacerbating musculoskeletal strain and predisposing individuals to conditions such as osteoarthritis and stress fractures. Although, there are limited study available on Effects of BMI on foot anthropometric dimensions. Therefore, in order to address this research gap present Study Aims to collect foot anthropometric data from Indian young adults, analyze the data and examine the impact of BMI on foot dimensions. This will contribute to evidence-based clinical assessment, footwear, and related product development and results in greater comfort, injury reduction and foot health.

2. Materials & Methods

2.1. Selection of Participants

A total of Two Hundred Seventy (N=270) volunteers (Male = 152 and Female =118) were participated in this study. Categorized them into Normal (n=135, Average age, height, weight and BMI of the participants were 21.96 ± 4.174 years, 162.58 ± 8.925 cm, 58.24 ± 8.593 kg and 21.93 ± 1.744 kg/m²) and Overweight individuals based on Body Mass Index (n=135, Average age, height, weight and BMI of the participants were 24.17 ± 7.476 years, 165.87 ± 9.205 cm, 74.65 ± 9.662 kg and 27.03 ± 1.463 kg/m²). All

Participants were physically fit and they have no foot deformities or musculoskeletal abnormalities in the lower limbs and no history of musculoskeletal disorders or fractures on the lower extremity and vestibular system.

2.2. Experimental Design of the Study

Before beginning the study, the participants were informed about all the necessary information and the study protocol, like - how this study will be conduct and what the purposes are, and also completed an informed consent form by participants. The subjects had the right to withdraw their participation at any stage during the experiment. Then told them to remove their shoes and socks for height and weight measurement, by using an Anthropometric rod (R.S. Scientific Works, India) and a standard weighing machine. Following this, participants underwent a foot scanning process, ensuring equal distribution of body weight on both feet (right and left). The scanning process took 5-10 seconds to capture both feet. Upon successful completion of the scan, measurements of both feet were displayed to the participants and recorded in a 3D foot scanner instrument.

While this study categorized participants into Normal and Overweight groups based on BMI, the influence of physical activity (PA) levels remains a significant confounding variable in foot anthropometry. All participants in the current study were screened to be physically fit; however, the degree of weight-bearing activity they engage in daily was not recorded.

2.3. Instrumentation

In this study, all foot anthropometric parameters were captured by LSF-350-A (Shenzhen 3DOE Technology Co., Ltd., China) 3D foot scanner, designed with a compact, portable and closed-loop optical system with 8-angle full-field scanning as shown in figure 1. The intelligent touch screen allows for one-click operation, ensuring ease of use. Utilizing non-contact laser scanning, it guarantees safety for both human bodies and eyes. The scanner has fast scanning speed of less than 10 seconds per foot and high accuracy (within 0.5mm), this system efficiently extracts 65+ parameters of the foot. The laboratory environment was maintained at an optimal temperature and humidity of 25°C - 27°C and 50% - 55%, respectively.

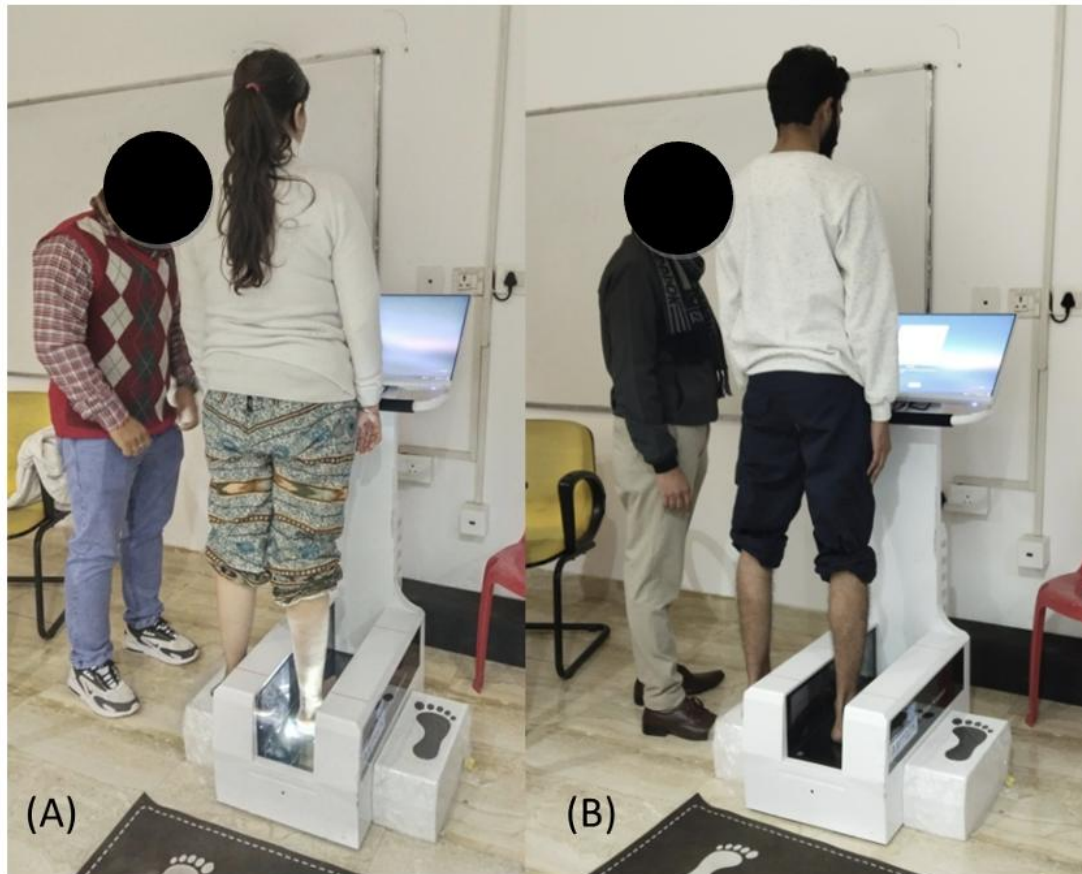


Figure 1. (A and B) Collection of Foot anthropometric data by 3D Foot scanner.

2.4. Studied Anthropometric Parameters

Foot length, Feet width, Toe width, Heel girth, Waist girth, Instep girth, Ball girth, Foot arch height, Thumb height, Heel heart width, Heelpiece total length, Heelpiece pump height- (mm).

2.5. Ethical Clearance

The present research protocol of human utilization as a test subject and the entire principles of the experiment as per the Declaration of Helsinki Protocol, 1964, and approved by ethical clearance No HMC/IEC/BU/09, dated 14.08.25.

2.6. Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) statistics software package (IBM SPSS statistics for windows, Version 26.0, IBM corp., Armonk, NY, USA). Normal distribution of data showed that parameters were not normally distributed, which was assessed by the Shapiro-Wilk normality test, along with visual histograms and Q-Q plots. All the data were summarized as mean \pm SD. Spearman rank Correlation (2-tailed) was performed to determine the positive and negative correlation between BMI and Foot anthropometric

dimensions. The Mann-Whitney U test was done to evaluate the statistical significant difference between Normal and Overweight individual across studied foot anthropometric parameters. The significance level was set at 0.05 levels.

3. Results

Present study focused on the implication of Body Mass Index on Foot dimensions among normal and overweight individuals. For representation of the demographic data of sample; percentage analysis was used, while mean and SD were used to represent the measurement of foot anthropometric data. Since the data was non-parametric, so Spearman correlation coefficient was applied to determine the relationship between BMI and foot dimensions. However, the Mann-Whitney U test was performed to compare BMI categories across all foot dimensions.

Present study also illustrates the statistically significant effect of BMI on studied parameters, which include; Foot length, Feet width, Toe width, Ball girth, Heel girth, waist girth, Instep girth, Foot arch height, Thumb height, Heel heart width, Heelpiece total length, Heelpiece pump height - (mm). The detailed statistical results are described in following section.

Table 1. Spearman-Correlation analysis between BMI and foot anthropometric dimensions.

	BMI	FL	FW	BG	HG	WG	IG	FAH	TH	TW	HHW	HTL	HPH
BMI	1	.235** (0.00)	.321** (0.00)	.447** (0.00)	.396** (0.00)	.443** (0.00)	.447** (0.00)	0.019 (0.66)	.370** (0.00)	.286** (0.00)	.241** (0.00)	.176** (0.00)	.314** (0.00)
FL	.235** (0.00)	1	.792** (0.00)	.803** (0.00)	.893** (0.00)	.774** (0.00)	.815** (0.00)	0.082 (0.05)	.618** (0.00)	.629** (0.00)	.641** (0.00)	.185** (0.00)	.421** (0.00)
FW	.321** (0.00)	.792** (0.00)	1	.868** (0.00)	.845** (0.00)	.827** (0.00)	.858** (0.00)	0.061 (0.15)	.627** (0.00)	.781** (0.00)	.666** (0.00)	.205** (0.00)	.309** (0.00)
BG	.447** (0.00)	.803** (0.00)	.868** (0.00)	1	.862** (0.00)	.927** (0.00)	.933** (0.00)	.182** (0.00)	.774** (0.00)	.790** (0.00)	.567** (0.00)	.250** (0.00)	.555** (0.00)
HG	.396** (0.00)	.893** (0.00)	.845** (0.00)	.862** (0.00)	1	.837** (0.00)	.895** (0.00)	.170** (0.00)	.675** (0.00)	.707** (0.00)	.731** (0.00)	.206** (0.00)	.373** (0.00)
WG	.443** (0.00)	.774** (0.00)	.827** (0.00)	.927** (0.00)	.837** (0.00)	1	.944** (0.00)	.122** (0.00)	.736** (0.00)	.699** (0.00)	.568** (0.00)	.261** (0.00)	.524** (0.00)
IG	.447** (0.00)	.815** (0.00)	.858** (0.00)	.933** (0.00)	.895** (0.00)	.944** (0.00)	1	.116** (0.00)	.733** (0.00)	.708** (0.00)	.617** (0.00)	.240** (0.00)	.489** (0.00)
FAH	0.019 (0.66)	0.082 (0.05)	0.061 (0.15)	.182** (0.00)	.170** (0.00)	.122** (0.00)	.116** (0.00)	1	.165** (0.00)	.177** (0.00)	-0.017 (0.69)	-0.012 (0.77)	.162** (0.00)
TH	.370** (0.00)	.618** (0.00)	.627** (0.00)	.774** (0.00)	.675** (0.00)	.736** (0.00)	.733** (0.00)	.165** (0.00)	1	.591** (0.00)	.451** (0.00)	.264** (0.00)	.527** (0.00)
TW	.286** (0.00)	.629** (0.00)	.781** (0.00)	.790** (0.00)	.707** (0.00)	.699** (0.00)	.708** (0.00)	.177** (0.00)	.591** (0.00)	1	.483** (0.00)	.180** (0.00)	.359** (0.00)
HHW	.241** (0.00)	.641** (0.00)	.666** (0.00)	.567** (0.00)	.731** (0.00)	.568** (0.00)	.617** (0.00)	-0.017 (0.69)	.451** (0.00)	.483** (0.00)	1	.322** (0.00)	.140** (0.00)
HTL	.176** (0.00)	.185** (0.00)	.205** (0.00)	.250** (0.00)	.206** (0.00)	.261** (0.00)	.240** (0.00)	-0.012 (0.77)	.264** (0.00)	.180** (0.00)	.322** (0.00)	1	.453** (0.00)
HPH	.314** (0.00)	.421** (0.00)	.309** (0.00)	.555** (0.00)	.373** (0.00)	.524** (0.00)	.489** (0.00)	.162** (0.00)	.527** (0.00)	.359** (0.00)	.140** (0.00)	.453** (0.00)	1

BMI = Body Mass Index, FL=Foot length, FW=Feet width, BG=Ball girth, HG=Heel girth, WG=waist girth, IG=Instep girth, FAH=Foot arch height, TH=Thumb height, TW=Toe width, HHW=Heel heart width, HTL=Heelpiece total length, HPH=Heelpiece pump height. Correlation is significant** at the 0.01 level (2-tailed).

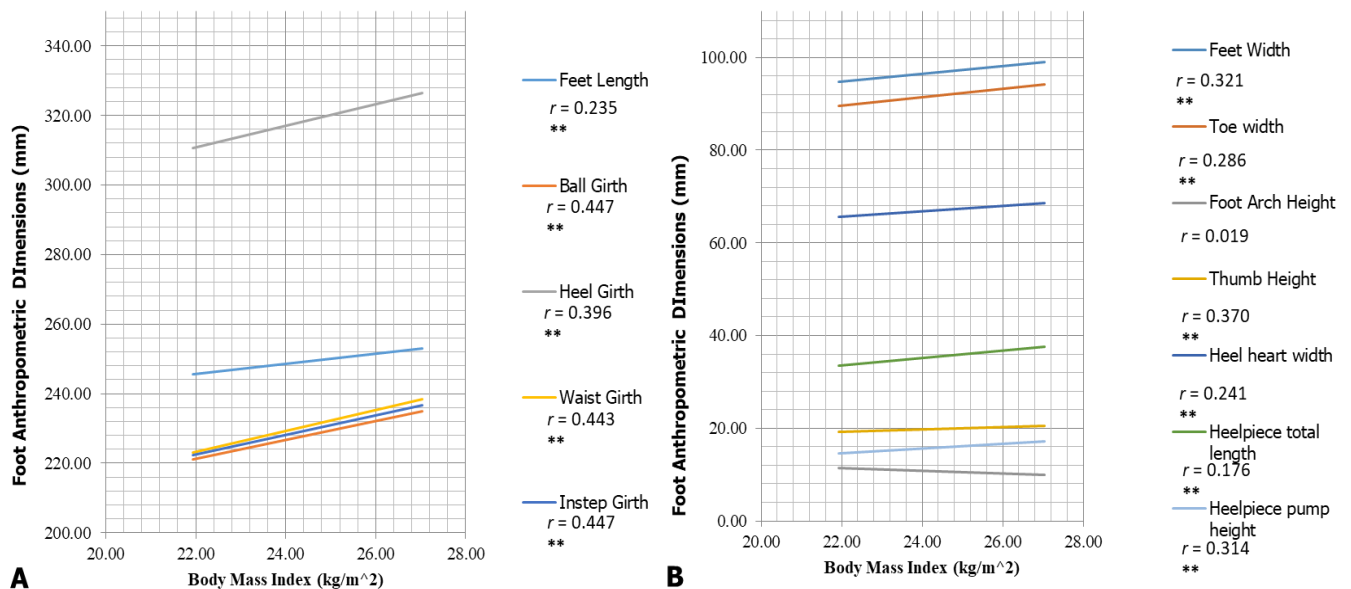


Figure 2. (A and B) Scatterplot of Spearman rank correlations illustrate the relationship between BMI and foot dimensions. The upward trend lines indicate a positive significant correlation; suggested a higher BMI was associated with increased foot dimensions. Whereas, the downward trend line shows non-significant correlation at $p < 0.01$ level. Average BMI of Normal and Overweight was 21.93 ± 1.744 and 27.03 ± 1.463 kg/m^2

Table 2. Mean \pm SD of studied Foot Anthropometric parameters and Mann Whitney u test between Normal and Overweight participants.

Parameters (mm)	Total (N= 270)		Percentage (%) difference b/w Overweight and Normal weight	Mann-Whitney U Test	Asymp. Sig. (2-tailed)
	Normal (n= 135)	Overweight (n = 135)			
	Mean \pm S.D	Mean \pm S.D			
Feet Length	245.58 \pm 15.726	252.91 \pm 17.206	2.9% \uparrow	27495.00	0.00 (P<0.05)
Feet Width	94.72 \pm 7.146	99.08 \pm 6.985	4.4% \uparrow	24272.50	0.00 (P<0.05)
Toe width	89.47 \pm 9.336	94.21 \pm 8.138	5.1% \uparrow	25501.00	0.00 (P<0.05)
Ball Girth	221.08 \pm 17.855	234.92 \pm 16.399	6.0% \uparrow	20738.00	0.00 (P<0.05)
heel Girth	310.67 \pm 21.714	326.36 \pm 22.672	4.9% \uparrow	22698.50	0.00 (P<0.05)
waist Girth	223.03 \pm 18.541	238.35 \pm 19.083	6.6% \uparrow	20675.50	0.00 (P<0.05)
instep Girth	222.29 \pm 17.654	236.80 \pm 17.557	6.3% \uparrow	20703.00	0.00 (P<0.05)
Foot Arch Height	11.39 \pm 8.085	9.97 \pm 4.439	13.2% \downarrow	34149.00	0.20 (P>0.05)
Thumb Height	19.23 \pm 2.424	20.58 \pm 2.461	6.7% \uparrow	24801.50	0.00 (P<0.05)
Heel heart width	65.52 \pm 6.727	68.60 \pm 7.186	4.5% \uparrow	27542.00	0.00 (P<0.05)
Heelpiece total length	33.45 \pm 15.774	37.51 \pm 15.156	11.4% \uparrow	30246.00	0.00 (P<0.05)
Heelpiece pump height	14.63 \pm 5.929	17.18 \pm 5.967	16.0% \uparrow	26230.00	0.00 (P<0.05)

mm= Millimeter, S.D= Standard Deviation

A Spearman rank correlation analysis test was performed to examine the relationship between BMI and foot dimensions.

The result showed a fine significant positive correlation between BMI and Foot length ($r=0.235$, 95 % CI [0.15, 0.31] $p<0.01$), Foot width ($r=0.321$, 95 % CI [0.23, 0.39] $p<0.01$), Ball girth ($r=0.447$, 95 % CI [0.38, 0.51] $p<0.01$), Heel girth ($r=0.396$, 95 % CI [0.31, 0.48] $p<0.01$), Waist girth ($r=0.443$, 95 % CI [0.37, 0.51] $p<0.01$), Instep girth ($r=0.447$, 95 % CI [0.37, 0.51] $p<0.01$), Toe height ($r=0.370$, 95 % CI [0.30, 0.44] $p<0.01$), Toe Width ($r=0.286$, 95 % CI [0.20, 0.35] $p<0.01$), Heel heart width ($r=0.241$, 95 % CI [0.15, 0.31] $p<0.01$), Heelpiece total length

($r=0.176$, 95 % CI [0.09, 0.25] $p<0.01$) and Heelpiece pump height ($r=0.314$, 95 % CI [0.23, 0.40] $p<0.01$). Notably no significant correlation was found between BMI and Foot arch height ($r=0.019$, 95 % CI [-0.06, 0.11] at $p > 0.66$ level).

The Mann-Whitney U test statistic was performed to assess the variation between Normal and Overweight categories across studied foot anthropometric parameters. In case of overweight group anthropometric values of Foot length, Feet width, Toe width, Ball girth, Heel girth, waist girth, Instep girth, Thumb height, Heel heart width, Heelpiece total length, Heelpiece pump height-(mm) were larger \uparrow 2.94 %, 4.49 %, 5.17 %, 6.07 %, 4.92 %, 6.64 %, 6.32 %, 6.75

%, 4.59 %, 11.46 % and 16.05 % respectively, than Normal BMI group; except arch height (mm)13.28 % ↓.

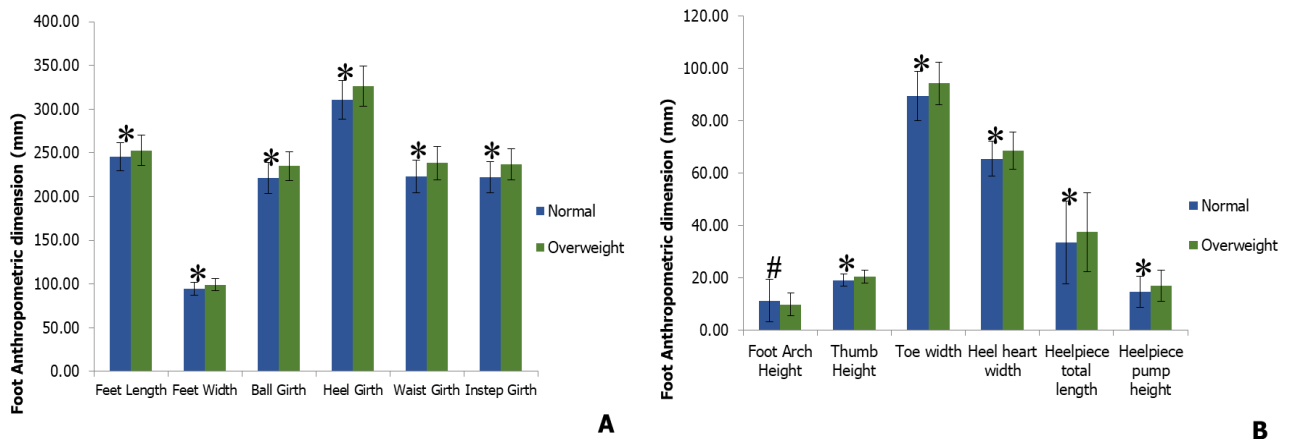


Figure 3. (A and B) Comparison of foot anthropometric parameters between Normal and Overweight group. The “*” sign indicate statistical significant difference and “#” sign indicate No significant difference between Normal and Overweight category among studied anthropometric dimensions at 0.05 level.

In this study statistically significant difference was found between Normal and Overweight categories across most studied Foot anthropometric dimensions except foot arch height, at $P=0.05$ level.

4. Discussions

Present study examined the influence of Body Mass Index (BMI) on foot anthropometric dimensions among Two Hundred Seventy ($N=270$) volunteers (Male = 152 and Female =118), which comprised Normal ($n=135$) and Overweight ($n=135$) groups based on BMI Chart (Average age, height, and weight of the Normal and overweight participants were 21.96 ± 4.174 years, 162.58 ± 8.925 cm, 58.24 ± 8.593 kg and 24.17 ± 7.476 years, 165.87 ± 9.205 cm, 74.65 ± 9.662 kg) demonstrating significant variations in foot morphology associated with increased body weight across all studied parameters. The calculation of BMI, defined as how healthy a person based on height and weight. To determine Overweight and normal weight; a BMI measure of 25.0-29.9 consider as overweight, score between 18-24.9 are considered normal weight (Flegal *et al.*, 2010).

In this study spearman rank correlation coefficient(r) test was applied to determine the relationship between BMI and studied foot anthropometric parameters. The result (Table 1) and scatterplot (Figure 2A and 1B) illustrate the correlation analysis between them. In Figure 2A; Ball girth ($r=0.447$), Heel girth ($r=0.396$), Waist girth ($r=0.443$),

Instep girth ($r=0.447$), have strong linear correlation with BMI at $p<0.01$ statistically significant level. Based on these results current study stated that overall girth of the foot increase with increase BMI, possibly as the soft tissue enlarges and the structures have decompensated against more weight. On the other hand, foot length ($r=0.235$) showed a weak correlation; represent foot length is less influenced by BMI than foot girth and width. Menz *et al.* (2013) stated that, BMI has very minimal effect on foot length, this finding supported the result of current study as we found (Menz and Morris, 2005). Analysis in Figure 2B reveals additional significant correlations between BMI and foot width Foot width ($r=0.321$) Toe height ($r=0.370$), Toe Width ($r=0.286$), Heel heart width ($r=0.241$), Heelpiece total length ($r=0.176$) and Heelpiece pump height ($r=0.314$). Notably, there was a non-significant and weak correlation between BMI and foot arch height ($r = 0.019$) at $p<0.01$ level. Findings of this correlation coefficient suggest that a higher BMI influence a broader and more massive foot form in terms of width and girth of foot, but not to vertical construction of arch. Previous literature stated that values of size-related foot parameters, heel girth, foot length, heel width, instep girth, and instep height, were significantly higher in subjects with higher BMI (Zhao *et al.*, 2017). However, Atamturk (2009) reported no relationship between existence of flat feet or high arch and body weight or BMI in Turkish individuals (17.6–82.5 years). Wearing *et al.* (2006) also reported that BMI is an important predictor of arch height, which reflects structural foot

adaptation to increased weight. Another study has demonstrated the causal relationships of the BMI, foot length and foot width. The findings had indicated that BMI had a positive effect towards the foot length and width. Unadjusted pair wise Pearson correlations revealed that; the following measurement was significantly correlated with BMI: foot length ($r = .295$, $df = 97$, $p = .003$), ball radius ($r = .357$, $df = 97$, $p = .000$), foot breadth ($r = .474$, $df = 97$, $p = .000$), heel breadth ($r = .602$, $df = 97$, $p = .000$). Mean age of attendees was 21.22 years ($SD = 2.184$). The average height and weight for this population was 166.53 cm and 64.77 kg. Data variables obtained using a 3D foot scanner (Park, 2013).

In this study Mann -Whitney U test was applied (Table 2) to assess the variation between Normal and Overweight categories across studied Foot anthropometric parameters. Results of current study showed all studied foot dimensions were significantly larger in overweight category than normal weight except arch height. Present study also stated statistically significant differences were found across all anthropometric parameters but no significant differences was found in arch height at $p < 0.05$ level. Findings of this study suggest that person with higher BMI have wider and girthy feet and tendency to develop flat arch. This finding supported a previous study; Hills *et al.* (2001) noted that plantar pressures are higher and foot widths are wider in obese children compared to non-obese children.

Studied by Butterworth *et al.* (2012) and Riddiford-Harland *et al.* (2011), stated that the foot morphology, soft tissue properties and functional capabilities are altered among overweight individuals, with reduced longitudinal arch heights. Bar charts in Figure 3A and B represents the visual clarification of Mean, SD of Normal and overweight category along with foot dimensions. Foot length, girth and width measurements are more sensitive to BMI changes, compared to foot arch height. This constancy of the foot arch height implies that as the foot enlarges laterally with increasing weight, its vertical structure undergoes little change. Tsung, Zhang, Fan, and Boone (2003) studied the effect of weight bearing on foot shape. They found that load 5 significantly increased contact area, foot length, foot width and rear foot width, and decreased average arch height, and arch angle. The changes in foot length would be $2.7\% \pm 1.2\%$, whilst that in foot width would be $2.9\% \pm 2.4\%$. Full weight bearing resulted in foot length increases of $3.4\% \pm 3.1\%$ and foot width $6.0\% \pm 2.1\%$. These studies using

foot digitizing and impression casting, which eliminates errors of skin displacement and tissue distortion (Tsung *et al.*, 2003). According to Frey *et al.* (1993), "Women are less likely to wear shoes that fit perfectly than men". It has been shown in women who have continuously used smaller-sized shoes than their own feet; as a result, shoes were found to be the main reason for female foot disorders. Medical reports let us know that bad fitting shoes might cause discomfort along with foot conditions including blisters, calluses, dark or even blue toes, bunions, pain, achy feet and so on (Stebbins *et al.*, 2006).

The lack of a physical activity profile in the current sample restricts the generalizability of findings to athletic or highly active groups. Nonetheless, the BMI-related foot anthropometric abnormalities found in this study have important implications for groups that participate in frequent sports or physically demanding activities. Physically active people frequently exhibit sport-specific structural adaptations of the foot, such as enhanced arch stiffness, optimized shock-attenuation capacity, and better load transfer mechanisms, which contribute to performance efficiency during dynamic movements. These adaptations are closely linked to total body composition, indicating that higher BMI may affect functional foot behaviours differently in active populations than in sedentary persons.

The practical implications of these findings are considerable for both clinical practice and product design. By understanding the effect of BMI on foot dimensions, footwear can be developed based on BMI categories, ensuring greater comfort and reducing risk factors for foot-related pathologies. Furthermore, this data can be employed by healthcare providers and footwear designers as references to design and estimate interventions for reducing foot discomfort and preventing disorders among overweight and obese individuals. The present study offers novel insights by providing a detailed analysis of foot anthropometric variations across normal and overweight BMI groups and by identifying significant differences in foot dimensions that have been limited in previous studies.

In addition to offering static anthropometric insights, the current study lays the groundwork for comprehending how morphological variances associated with BMI may affect human mobility, balancing techniques, and lower-limb biomechanics. Changes in load distribution patterns that may impact kinematic and kinetic behaviours during locomotion, running, and athletic tasks are suggested by increased foot breadth, girth, and changed plantar dimensions

seen in overweight persons. A wider, more "girthy" foot functions as an adaptation mechanism to transfer increased plantar pressures in the context of biomechanics. The foot's capacity to function as a stiff lever during the "toe-off" phase of the gait cycle may be jeopardized by this adaptation, which frequently leads to a comparatively lower arch height.

According to previous literature, overweight people's wider feet and higher soft-tissue deformation result in altered plantar pressure profiles, which may change stride length, medial-lateral stability, and total proprioceptive input during dynamic movement. These biomechanical compensations have been linked to a higher risk of overuse injuries, decreased force transfer efficiency, and worse stability-variables directly related to the fields of movement science and sports performance (Chow *et al.*, 2022).

Therefore, by showing how BMI-driven morphological alterations may predispose athletes and active people to altered gait mechanics, lower running economy, and heightened musculoskeletal stress, the current findings help connect anthropometric data with functional consequences. This correlates with observations indicating foot shape greatly affects shock absorption capacity, postural control, and performance in sports involving quick directional changes, leaping, or extended weight-bearing. From an applied standpoint, the existing information can aid in the creation of BMI-specific, performance-optimized shoe designs that aim to lower injury risks, increase energy return, and improve midfoot stability. In sports science, where footwear must account for both size and morphological variation resulting from variations in body composition, these design concepts are becoming more crucial.

BMI-related differences in foot breadth, girth, and length have substantial biomechanical consequences for posture, gait mechanics, and musculoskeletal stress. Overweight people have larger transverse and circumferential foot measurements, which may indicate increased soft-tissue deformation and changed plantar surface contact while carrying weight. The distribution of plantar pressures, centre-of-pressure trajectories, and foot stability during both static and dynamic tasks can all be impacted by these morphological alterations (Sole *et al.*, 2017). A wider contact area during stance is usually produced by wider feet with greater girth, which may first seem beneficial for load distribution. But the corresponding decrease in medial longitudinal arch height, which is frequently observed in people with high BMI, may weaken the arch's ability to absorb strain. Excessive pronation,

changed foot alignment, and compensatory internal rotation of the tibia and femur might result from this, which can ultimately impact the kinematics of the knee and hip joints during locomotion (Jacob, 2001).

Additionally, larger or longer feet might alter stride patterns and step width. In order to maintain equilibrium with increasing body mass, overweight people frequently adopt wider step widths and shorter strides as compensatory strategies. These modifications may result in increased energy expenditure when walking, decreased gait efficiency, and increased mediolateral sway. Moreover, the plantar fascia, intrinsic foot muscles, and Achilles tendon may experience higher mechanical strain due to increased plantar loading under the midfoot and hindfoot (Cavanagh and Kram, 1989). These changes may put people at risk for overuse problems such as metatarsal overload, Achilles tendinopathy, medial tibial stress, and plantar fasciitis. The biomechanical effects of larger feet become more noticeable during dynamic motions like running or jumping. Elastic energy return may be hampered by decreased arch height and greater soft-tissue compliance, which would reduce propulsion efficiency. Furthermore, altered loading patterns may cause musculoskeletal strain by transmitting increased ground-reaction forces to the lumbar spine and knee (D'Hondt *et al.*, 2024). Furthermore, the present study is limited by a small sample size and by differences between gender, age group, and ethnicity with respect to BMI-related foot changes, which were not addressed in this study. To support such conclusions, longitudinal research is needed to follow the time development of foot structural changes due to BMI changes. Moreover, the present study used static anthropometric measurements that cannot reflect the dynamic functional changes occurring during the gait process. By including dynamic measures, a broader picture of the impact of increased BMI on foot dimensions would be revealed.

5. Conclusion

The present study examined the influence of Body Mass Index (BMI) on the studied foot anthropometric dimensions, revealing several important findings. Correlation analysis between BMI and foot dimensions demonstrates a significant positive correlation ($p < 0.01$) across Length, width and Girths dimensions of the studied parameters, except foot arch height. Comparison between the normal and overweight group demonstrated that the overweight category has significantly ($p < 0.05$) greater foot measurements

(2.94% -16.05%) in most parameters except foot arch height. These results ensured that Increased BMI is associated with broader and larger foot dimensions, particularly in foot width and girth, while vertical foot arch height was relatively decreased, which may have negative implications for the medial longitudinal arch, the bones that support it, and overall foot health. The study evaluated static anthropometric dimensions only, without incorporating dynamic gait metrics, plantar pressure distribution, or longitudinal foot adaptation. As such, any potential relevance for footwear design, clinical screening, or injury-prevention strategies should be considered preliminary. While the observed morphological trends may suggest avenues for future development of BMI-sensitive footwear or biomechanical assessments, definitive recommendations cannot be made without complementary functional or long-term data. The significant differences in foot dimensions among both BMI-specific groups suggest that the same type or standard size of footwear may not be adequate for both groups. Findings of the present study suggest that footwear should be designed for individualized BMI specific that could prevent musculoskeletal strain and preserve the normal function of the foot. However, it is important for podiatrists, medical professionals and shoe designers to design person-specific footwear as per the BMI profile. Future research should integrate dynamic analyses, such as gait kinematics, pressure mapping, and biomechanical modeling, to better understand how BMI-related foot morphology interacts with movement patterns and injury risk. Longitudinal studies would also help determine whether these structural differences contribute to progressive changes in foot function over time. Incorporating diverse age groups, activity levels, and ethnic backgrounds would further strengthen the applicability of the findings.

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Author's contribution & Statement

Ayan Maity: Data collection, processing, Analysis, Statistical analysis and interpretation, Manuscript preparation, Writing and Editing. Chandan Ram: Involved data collection, processing, and Review of literature. Sugata Das Kumar: Data interpretation, Review and Editing. Tushank Jain: Conceptualisation, Experimental design and finalisation of study protocol, Overall supervision of study, Editing of final manuscript. All authors read and approved the final manuscript.

Ethics Approval Statement

The present research protocol of human utilization as a test subject and the entire principles of the experiment as per the Declaration of Helsinki Protocol, 1964, and approved by the Department of Physiology, City College, ethical clearance No HMC/IEC/BU/09, dated 14.08.25.

Additional Materials

All Research data and materials are not publicly archived and are available on request from the corresponding author.

Funding Source

The study was financially supported by SneakTech Solutions Pvt. Ltd, A-9, Maharana Pratap Enclave, Pitampura, New Delhi, Delhi, 110034.

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