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Original Research Article

Gender wise Differences of Body Dimensions to Foot Type in Healthy Young Adults

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ABSTRACT

Background: Body Dimensions vary in both males and females. Foot being the only part of the body to transmit the body weight during propulsion might be adapting to preferred foot postures with different body dimensions in both the genders.
Material and Methods: 79 Healthy males and 160 female healthy individuals within the age group of years (19-25) years were recruited by random sampling technique. All subject's anthropometric characteristics were recorded as per ISAK and foot type as per the Normalized Truncated Navicular Height Ratio (NTNH).
Results: The gender specific difference between the means was observed by unpaired t- test. A p-value ≤ 0.05 was considered statistically significant at 95% CI. Female subjects of flat foot type were found to have significantly higher values of HT (p=0.034); LBH (p=0.004); and BA (p=0.029) whereas UBH: LBH ratio (p=0.029) was significantly lower than that of females with neutral foot type. The male subjects with flat foot type were found to have significantly lower values of WC (p=0.034) and WC: HC ratio (p=0.005) than the males of neutral foot group
Conclusion: In the study population flat foot type, was found to be associated with linear body dimensions in females and with circumferential body dimensions in males.

Keywords: Young Adults, Anthropometry, Flat foot

INTRODUCTION

Standing is a continuous process of aligning the center of gravity on the base of support that changes between pronation and supination as per flexibility of foot. [1] Foot being the most distal and the only part of extremity in contact with the ground influences the lower limb gait kinematics, [2] muscle activity [3] and functional ability. [4]

Flat foot is among the commonest pathological foot postures to initiate the altered kinematics and kinetics as the body mainly functions in close-kinetic chain. [4] Few foot anthropometric features have shown to have relation with foot type. Static Navicular Drop is seen to be associated with wider heel width [5] whereas Dynamic Navicular Drop is influenced by foot length and gender. [6] Arch Height Index (AHI) sitting was negatively related to stride length, implying that individuals with a lower arch height have longer stride lengths. [7]

Various studies on Body Dimensions have on the other hand shown a relation between metabolic cost and stability. Females had wider bi- trochanteric breadth have shown increased muscular contractions of hip abductors and extensors increased lateral stability (decreased excursion) itself has been shown to reduce energetic expenditure. [8]

The individuals' functional foot attitude and body dimensions might be considered the important predictors of functional stability, altered kinematic and kinetics values and energy expenditure in day-to-day activities.

During the static stance, acquired stability of an individual relies on relative and opposite shifts of center of pressure of foot and center of mass. [9] Further, it was hypothesized that as an individual's body dimensions determine COM location, the adapting stability strategy of foot in response to body characteristics might influence the foot type attitude of an individual. The intended observational study was an effort to explore the association of a biomechanical measure of foot structure (arch height) to gender specific anthropometrics characteristics of body in asymptomatic healthy individuals.

MATERIAL AND METHODS

The researchers Murley GS et al [3] 2009 and Derya Atamtürk [10] 2009; have obtained the incidence of deformities i.e. flat foot, high arch and others to be between 1.2% to 34.1% in their respective samples. Considering the mid values of their percentages i.e. 17.65% as the reference and allowing a margin of error of 5%, the minimum required sample size for our study with 5% level of significance is found out to be two hundred and twenty-four subjects. The respondent for this cross-sectional observational study were selected using random sampling technique. The five hundred (500) under graduate collegiate students were assigned a serial number in lieu of their roll no. A computer program was run on MS Excel software to generate a random number between serial number one and three hundred. The selected serial number was traced back to the corresponding roll number and that specific student was selected as study sample. Total two hundred and sixty (260) students were screened. Healthy male and female individuals with age group nineteen to twenty-five (19-25) years were recruited with approval of institutional ethical committee to participate in this study. Subjects having anatomical limb length discrepancies; other associated pathologies of the lower limbs or injuries; any neurological deficit (history of cerebral concussions or visual, sensory or vestibular disorders) or any previous surgeries in foot and ankle area were excluded from the study. Participants with high-arched feet were not included for this study. Since high-arched feet are susceptive to injury and warrant greater research, [11] this foot type is far less common than normal- and flat-arched feet, [1] thus we chose to focus on two participant groups that would have greater generalizability to the wider population. Final sample size of two hundred and thirty-nine (239) subjects was comprised of one hundred and sixty (160) females and seventy-nine (79) males after excluding twenty-one (21) subjects. Participants were asked to sign the informed consent.

All subjects were screened for anthropometric characteristics viz. weight (kg), total height (cm), upper body and lower body heights (cm), waist and hip circumference (cm), bi-acromial and bi-iliac widths (cm), and Normalized Truncated Navicular Height ratio. Measurements were taken by two individuals to avoid any error. One of them acted as recorder to record, enter and assist the measurer. Two measurements were taken, and mean value was used for data analysis.

Anthropometric characteristics: The following anthropometric measurements were taken in accordance with ISAK (International Standards for Anthropometric Assessment) standards. [12] Weight (WT) kg, Height (HT) cm, Upper Body Height (UBH) cm, Lower Body Height (LBH) cm, Waist Circumference (WC) cm, Hip Circumference (HC) cm, Bi-Acromial width (BA) cm, Bi-iliac Width (BI) cm and Normalized Truncated Navicular Height (NTNH) ratio. The Indices of BMI (Kg/m^2), Waist Circumference: Hip Circumference ratio (WC: HC), Bi- acromial: Bi-iliac ratio (BA: BI), Upper Body: Lower Body Height ratio (UB: LB) were calculated.

Normalized Truncated Navicular Height (NTNH): The normalized navicular height has displayed strongest association with the radiographic angles classifying feet type. [13]

Hence, foot types of the subjects were classified according to normalized truncated navicular height. Single rater conducted this test to optimize its reliability on the dominant foot. While bearing the equal weight on their feet the subjects were asked to stand on a wooden platform. The navicular tuberosity and head of first metatarsal of the foot were palpated and marked with a small point using a fine tipped blue pen to avoid any potential inaccuracies. The bony landmarks were identified using surface anatomy guidelines using gray's anatomy. The navicular height of the dominant lower extremity was measured with an index card using George S Murley's method. [13] The distance was measured from most medial prominence of navicular tuberosity to the supporting surface. The truncated foot length (FL) was measured using anthropometer. This was the perpendicular distance from first Metatarsophalangeal (MTP) joint to the most posterior aspect of heel.

Normative value for NTNH measurements taken from Scott et al [14] based on 50 young adults. The participants reported on by Scott and colleagues were of similar age to the target participants for our study. Navicular height to truncated foot length ratio was taken to classify foot type. Subject having ratio ≤0.21 were classified as having flat foot, whereas ratio range from 0.22 to 0.31 was classified as normal foot.

The quantitative variables were expressed as mean (SD) and the difference between the two means was observed by unpaired t- test whereas Chi-square/Fisher's Exact test was applied to observe the difference between the proportions. A p-value <0.05 was considered statistically significant at 95% CI. Statistical Package for Social Sciences (SPSS) version 15.0 was used for analysis of data.

Total two hundred and thirty-nine (239) subject; seventy-nine (79) males and one hundred and sixty (160) females with mean age 21.03 (1.75) and 21.10 (1.53) respectively were enrolled in this study. Neutral foot type was detected in one hundred and sixty-eight (168) subjects (70.3%) comprised of one hundred and seven (107) females (66.9%) and sixty-one (61) males (77.2%) whereas flat foot type was detected in seventy-one (71) subjects (29.7%) comprised of fifty-three (53) females (33.1%) and eighteen (18) male subjects (22.8%). There was no association between the sex and foot type. The chi-square statistic is 2.70 and the p-value is .09. The result is not significant at p >.05. Both types of foot were equally observed between both the genders (Table-1).

Table-1: Distribution and Association of Foot Type and Sex

Foot Type as per NTNH	Female		Male		p-value
	n	%	n	%	
Neutral Foot (168) 70.3%	107	66.9%	61	77.2%	
Flat Foot (71) 29.7%	53	33.1%	18	22.8%	0.09
TOTAL	160	100%	79	100%	

*The Chi-Square Statistic is 2.70. The P-value is .09. The result is not significant at P >.05

RESULTS

Table-2: Comparison of Mean and Standard Deviation of Anthropometric Characteristics Vs Foot Type in the Whole Group

Anthropometric characteristics	Whole group (mean ± SD) both sex, n=239		
	Neutral foot (n=168)	Flat foot (n=71)	P value
Weight (Kg)	56.98±12.44	55.07±11.65	0.27
Height (cm)	160.05±14.22	161.33±7.89	0.47
BMI (Kg/m^2)	21.86±3.81	21.09±3.89	0.15
UBH (cm)	84.89±4.11	84.40±3.83	0.38
LBH (cm)	76.04±5.82	76.93±4.98	0.27
UBH: LBH ratio	1.11±0.75	1.09±0.05*	0.04*
WC (cm)	72.24±9.50	69.56±8.37*	0.04*
HC (cm)	91.54±7.63	91.11±7.75	0.69
WC: HC ratio	0.78±0.06	0.75±0.05*	0.006*
BA (cm)	34.60±3.16	34.51±2.55	0.83
BI (cm)	25.21±1.84	25.10±1.74	0.66
BA: BI ratio	1.36±0.11	1.37±0.09	0.82
NTNH ratio	0.24±0.02	0.19±0.01*	0.000

*P≤0.05- Student T Test for Comparison of Mean and Standard Deviation.

In between group analysis (neutral vs. flat foot type) to Anthropometric Characteristics showed that the overall mean of anthropometric characteristics like (WC) (value=0.04); (UBH: LBH) (p value=0.04), (WC: HC) (p value=0.006) were significantly lower in subjects with flat foot than the subjects with neutral foot (Table-2).

The gender specific analysis revealed that the female subjects of flat foot type were found to have significantly higher values of HT (p=0.034); LBH (p=0.004); and BA (p=0.029) whereas UBH: LBH (p=0.029) was significantly lower than that of females with neutral foot type. The male subjects with flat foot type were found to have significantly lower values of WC (p=0.034) and WC: HC (p=0.005) than the males of neutral foot group (Table-3).

Table-3: Gender Wise Comparison of Mean and Standard Deviation of Anthropometric Characteristics to Foot Type

Anthropometric characteristics	Female group (mean ± SD), n=160			Male group (mean ± SD), n=79		
	Neutral foot (n=107)	Flat foot (n=53)	P value	Neutral foot (n=61)	Flat foot (n=18)	P value
Weight (Kg)	51.87±10.23	52.55±10.50	0.69	65.94±8.5	62.48±11.98	0.24
Height (cm)	155.99±6.06	158.03±4.75	0.03*	167.18±20.41	171.06±7.27	0.43
BMI (Kg/m^2)	21.30±3.96	21.05±4.21	0.71	22.84±3.35	21.21±2.85	0.06
UBH (cm)	82.82±3.10	83.03±2.82	0.67	88.54±2.97	88.43±3.63	0.89
LBH (cm)	73.12±3.93	74.99±3.44	0.004*	81.20±4.98	82.63±4.46	0.27
UBH: LBH ratio	1.13±0.07	1.10±0.05	0.02*	1.08±0.06	1.06±0.04	0.23
WC (cm)	68.48±8.43	67.88±8.11	0.67	78.83±7.50	74.51±7.23	0.03*
HC (cm)	91.16±8.20	91.42±8.05	0.84	92.21±6.51	90.19±6.91	0.25
WC: HC ratio	0.74±0.04	0.73±0.04	0.33	0.85±0.03	0.82±0.03	0.005*
BA (cm)	32.81±2.07	33.56±1.94	0.02*	37.75±2.10	37.31±2.06	0.43
BI (cm)	24.97±1.85	25.11±1.72	0.64	25.64±1.75	25.08±1.87	0.24
BA: BI ratio	1.31±0.08	1.33±0.08	0.10	1.46±0.08	1.48±0.05	0.43
NTNH ratio	0.24±0.02	0.19±0.01	0.000*	0.25±0.02	0.19±0.14	0.000*

*P≤0.05- Student T Test for Comparison of Mean and Standard Deviation

DISCUSSION

The study aimed at finding the association between biomechanical measure of foot structure (arch height) and gender specific anthropometrics characteristics of body in asymptomatic healthy individuals. The result of the study revealed that there was no association between the gender and foot type. The overall mean of anthropometric characteristics like WC; UBH: LBH ratio and WC: HC ratios were significantly lower in subjects with flat foot than the subjects with neutral foot. Gender specific analysis revealed that the female subjects of flat foot type were found to have significantly higher values of HT; LBH; and BA whereas UBH: LBH ratio was significantly lower than that of females with neutral foot type whereas the male subjects with flat foot type were found to have significantly lower values of WC and WC: HC ratio than the males of neutral foot group.

Female characteristics:

The female subjects with flat foot were found to have statistical significant lower values of upper body height -lower body height ratio (UBH: LBH ratio), which was mainly contributed by higher values of lower body height (LBH). The female subjects with flat foot type also had significant higher values of bi-acromial width (BA).

Flat Foot and Longer Lower Limb Length

Comparison of our results with data provided by other authors is difficult since no published data measuring or describing the relationship of lower extremity length to foot type has been found in the literature. However, literature does support the anatomical difference in the make of bones with respect to the length of the bones of the two sexes. Extremities have shown to have a positive correlation to height where the distal segment (tibia) always contributes more than proximal segment. [15] Tibia has shown to have different anthropometric and mechanical characteristics in both the sexes. The body mass, muscle area and the tibial length are the most relevant factor for the development of bone stiffness and strength in terms of torsion and bending. [16] Yuki

Yoshioka [17] documented a mean of tibial torsion lateral, 21 degrees for males and 27 degrees for females (p>.025) whereas foot lateral mean rotation, internal - 5 degree for males, and external 11 degrees for females (p>.005). He also quoted that,' the greater lateral tibial torsion combined with external foot rotation in females represents a remarkable 'kneeing-in" when the foot is positioned straight ahead in stance' Tibia is shown to be a key component in lower extremity to induce postural changes due to hyper pronation. This has been simulated by Sam Khamis [18] where an anterior pelvic tilt occurred simultaneously with induced calcaneal eversion, through a mediating effect of the shank. All the above studies relate to length of lower extremity to tibial length and contribution of tibial torsion, foot rotation, anterior pelvic tilt & kneeing in posture.

Further studies should be undertaken to examine the relationship of tibial and femoral length individually, femoral and tibial torsion, Strength and ROM of rotations at hip joint and knee joint in flexion in individuals with longer lower limb. This would classically enable us to differentiate between the anatomical and functional contribution to flat foot. It will also strengthen designing of exercise protocol in flat feet.

Flat Foot and Broader Bi-acromial Width

The female subjects with flat foot type in this study who had significant higher values of bi-acromial width, also had longer lower limb height. The role of longer tibia [15] with external torsion and lateral foot rotation in females [16] has already stated the importance of rotational torques to produce flat foot as above. The result of Bi-acromial width having a significant relation with flat feet was interesting to be read along with studies as quoted by Richard C. Schafer. [19] It was reported that there exists a close relation between stride length and the degree of thigh /leg rotation in transverse plane which is in phase with pelvic rotation and balanced by a reverse angular momentum of the upper body aided by arm swing resulting from shoulder rotation. Studies have shown that the upper thoracic vertebrae rotate to a degree about equal to that of the shoulder girdle and the lower lumbar vertebrae rotate to a degree about equal with the pelvis. These transverse rotations of the thigh and leg are in phase with pelvic rotations and increase progressively in degree of displacement from below upward.

With this understood fact, it might open another area of research for a further study of exploring the relationship between ROM of spine and arm swing in individuals with flat foot.

Male characteristics:

The male subjects with flat foot type were found to have significantly lower values of WC and WC: HC ratio than the males of neutral foot group.

Flat Foot and Small Waist Circumference

The male subjects with flat foot type were found to have significantly lower values of WC: HC ratio, which was mainly contributed by lower values of WC.

In this study, the male subjects in flat foot group had lower values of BMI, HC, BA and BI concluding that they were lean built. Previous studies of weight class effects on gait have determined that stance width increase with higher weight class, [20] hence it can be stated that individuals with small waist circumference have small base of support and the line of gravity tends to lie closer to medial arch of foot creating a moment more towards flat foot.'

There are not many studies where waist circumference has shown any relation to flat foot. However, few studies have proved a relation of lower arch height and longer stride length. During walking with longer strides a negative relation of stride length to AHI sitting is observed where individuals with a lower arch height have longer stride lengths. [6] Previous studies of truncal mechanics while walking at higher speed highlight its relation to lumbar spine kinematics and muscular control. It is reported that that the global lumbar spine Range of Motion (ROM) in transverse plane and frontal & transverse plane velocity significantly increase with increasing walking velocity. [21] Christoph Anders [22] study states that except Rectus Abdominis Muscle (RA), all other trunk muscles develop mixed phasic patterns reflecting both, global mobilizing and stabilizing characteristics at high speed. Erector Spinae Muscle (ES) eccentric activation matches characteristics related to global stabilizing muscles. With the knowledge of before mentioned facts, further studies can be undertaken to find relation of flat feet to base of support, stride length and spinal mobility and strength.

Though, there are studies contradicting to our results with respect to BMI and its negative correlation with arch index / navicular drop. [23-25] To be very specific those studies had comparatively examined these outcomes for athlete population. In this study, the male subjects in flat foot group were lean built. This might explain why this study result shows flat foot association with low waist circumference in males.

Clinical relevance:

Finding a relation between such body dimensions, which influence foot type, would provide focus of assessment and designing exercise protocol in individuals with flat foot and normal foot.

The study intended to link foot behavior to changing body dimensions. Considering the influence of body dimension on foot type can be a preventive strategy for possible flat foot, so that the negative impact of excessive flat foot can be avoided in near future.

CONCLUSION

The body's anthropometric features viz-linear dimensions in females and the circumferential dimensions in male are related to occurrence of flat feet in young healthy population in the study.

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