

# Sexual Dimorphism In Foot Dimensions Among Adult Nigerians

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## Abstract

This study is aim at quantitatively analysing physical difference that exist in foot dimensions in males and in females and within both sexes thus providing normal value for foot length and foot breadth for the design and construction of a comfortable foot support in our population. Sexual dimorphism in foot dimension exists within and across both sexes. These gender differences in foot dimension may not be known until they are quantified, as they appear symmetrical at first sight. The foot length and breadth of 477 (249 males and 28 females) individuals were measured directly using the sliding calliper. Their age ranged between 18yrs and above. The mean values for the right foot length of males and females were  $26.92 \pm 1.02$  and  $25.00 \pm 1.33$  respectively. The mean value for the right foot breadth of males and females were  $9.87 \pm 0.53$  and  $9.14 \pm 0.58$  respectively. The mean values for the left foot length of males and females were  $26.92 \pm 0.13$  and  $24.75 \pm 0.17$  respectively. The mean value for the right foot breadth of males and females were  $9.75 \pm 0.07$  and  $8.92 \pm 0.08$  respectively. Males had significantly higher values of foot length and foot breadth than females,  $p < 0.001$ . Males have longer and broader feet than females for a given age. Female feet are not simply scaled – down versions of male feet. Males and females feet in our population had higher mean foot length than that of Caucasians, which is an adaptation to tropical climate. These findings are useful to shoe design and selection of shoe sizes and to forensic anthropometry.

## INTRODUCTION

Qualitative analysis of sexual dimorphism of foot dimensions is important to the study of ergonomics, forensic science and anthropometry hence, the relevance of this work to the development of these fields of study in Nigeria.

Anthropometry is a series of systematized measuring techniques that express quantitatively the dimensions of the human body and skeleton. Anthropometry is often viewed as a traditional and perhaps the basic tool of biological anthropology, but it has a long tradition of use in forensic sciences and it is finding increased use in medical sciences especially in the discipline of forensic medicine. It is highly objective and reliable in the hands of trained anthropometrists. The significance and importance of somatometry, cephalometry, craniometry and osteometry in the identification of human remains have been described and a new term of 'forensic anthropometry' is coined<sup>[1]</sup>.

The human foot, the foundation of bipedal locomotion, is a highly complex multibone structure with 26 bones and numerous articulation<sup>[2,3]</sup>. It is required to be stable for supporting body weight in standing, resilient for walking and

accommodating to variations of surface on which it is placed. The normal human foot shows great individual variation in length, breadth and general in males and females<sup>[4,5]</sup>.

Literature on sexual dimorphism in shape differences among human feet have focused on osteological difference between men and women. Linear measurement in size and shape differences between males and females foot bones showed that male bones were larger than female bones. Also measurement of articular surface suggested that females bones have the potential for more movement to occur in the direction of adduction, possibly resulting in the female first metatarsal being more adducted than it the male skeleton. Such differences may underline the predisposition of the female foot to develop hallus valgus deformity<sup>[6]</sup>.

A few studies have also compared population who habitually use different types of foot wear, but these studies have been limited in the variables examined and rarely considered ethnic differences unrelated to footwear<sup>[7]</sup>. They documented that among Urban Japanese, proportionate to stature, women have smaller feet than men.

Appreciation to the sexual dimorphism of foot shape is essential to proper design of shoe shape as correct shoes is commonly recognised to be attained by matching shoe shape to foot shape. Hence, understanding the morphological and functional response to variation in foot pattern among ethnically different population necessitates a basic understanding of racial variation among population using similar foot wear. Information in gender and racial differences in foot pattern becomes very useful[8].

Wunderlich and Cavanagh analyzed gender differences in foot shape in large samples of young individuals using data from the U.S. army foot and leg anthropometric data. In their study they found out that men have long and broader feet than women for a given stature after normalization of the measurements by foot length, males and females were found to differ significantly in four foot shape variables. Classification by gender using absolute value was correct at least 93% of the time. Using the variables standardized to foot length gender, was correct classified 85% of time from this, they demonstrated that female feet and legs are not simply scaled down versions of male feet but rather differ in number of shape characteristics, particularly at the arch, the lateral side of the foot, the first toe and ball of the foot. These differences should be taken into account in the design and manufacture of women's shoes for better fit and more comfort[8].

Didia et al in their study, the use of foot print contact index II for classification of flat feet in the Nigeria population, observed that contact indices values were lower in females than in males, a proof that the arches are better developed in males. Also, they mentioned that other factors such as type of foot wear, physical activities and weight bearing habits may also played a role[9].

Obikili and Didia found that the mean values of the right foot length of young adult Nigeria males and females population were  $27.1 \pm 1.3\text{cm}$  and  $25.1 \pm 1.1\text{cm}$ , respectively. The values for the right foot were  $9.9 \pm 0.6\text{cm}$  and  $9.2 \pm 0.5\text{cm}$  respectively. Males had significantly higher values of foot length and breadth than females,  $p < 0.001$  comparing with other populations. They concluded that males and females in our populations had higher mean foot length than the Caucasian which probably is an adaptation to tropical climate[10].

Although, several studies have been conducted on foot and footprints for stature estimation having bearing on personal identification, prediction and forensic medicine/science, and

foot biomechanics[11,12,13,14,15,16,17]; others have used foot and shoeprint[18], foot and boot dimensions[19] in determining stature. Recent study has correlated foot length and body weight[20].

This present study is aimed at providing anthropometric values for foot length and width and comparing them to existing data needed for the establishment of reference standard for the Nigerian population on the basis of which populations can be compared with one another, and sexual differences established.

It is also aimed at providing standard needed for objective clinical assessment of individuals as well as body modelling. Also, to provide baseline data for design and manufacture of shoes for correct shoe fit.

## **MATERIALS AND METHOD**

### **MATERIALS**

The subject studies were four hundred and seventy-seven (477) adult Nigerians (249 males and 228 females) resident in Port Harcourt. Their ages ranged from 18 yrs and above. The foot dimensions were measured with a sliding calliper

### **METHOD**

For this study direct measurement techniques was employed. The foot dimensions were measured with sliding calliper, with foot placed on a horizontally flat surface, while the subject was standing. The maximum foot length was measured from acropodian (It is the most forwardly projecting point on the head of the 1st or 2nd toe whichever is larger when the subject stands erect) to pternion (It is the most backwardly projecting point on the heel when the subject is standing upright with equal pressure on both the feet). The foot breadth was measured as the distance between the medial margin of the head of the first metatarsal and the lateral margin of the head of the fifth metatarsal.

The foot index was calculated as shown in the formula below.

**Figure 1**

$$\text{Foot index} = \frac{\text{Foot breadth}}{\text{Foot length}} \times 100$$

To ensure accurate result all measurements were done by one person while sitting on low chair to avoid errors that could be caused by discomfort or individual differences. All subject who did not know their age and those who had

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recognized foot deformities were exempted or excluded from this study. The measurements were repeated to avoid errors.

## RESULTS

A total of four hundred and seventy-seven (477) subjects 18yrs and above were used for the study. The parameters measured from each right and left foot are the foot length and foot breadth. This was measured directly from each foot with the subject placing the foot on a horizontally placed flat surface.

The age group and number of individuals in each group for both male and female are represented in table 1.

**Figure 2**

Table 1: Sample Size

Age groups	Number of individuals	
	Males	Females
18-20	60	51
21-23	66	60
24-26	48	51
27-29	30	30
30-above	45	45
<b>Total</b>	<b>249</b>	<b>228</b>

Table 2 shows the range of the foot length and foot breadth for males and females in centimetres.

**Figure 3**

Table 2: Range of Foot Dimension for Males and Females

	Right Foot		Left Foot	
	Foot Length	Foot Breadth	Foot Length	Foot Breadth
Males (cm)	24.01-29.50	8.80-11.35	23.92-29.40	8.27-11.20
Females (cm)	20.61-27.71	7.71-11.24	20.11-27.54	7.59-11.03

Table 3 and 4 show the mean foot length of males and females by age while table 5 and 6 shows the mean foot breadth of males and females by age. Also, tables 9 and 10 show the mean foot length and mean foot breadth of males and females population respectively and their coefficient of variation and confidence interval at 95% accuracy. Males had significantly higher foot length than females, and significantly broader foot breadth then females,  $p < 0.001$ .

Table 7 and 8 shows the foot indices of males and females with the right foot index larger than that of the left, in both sexes. Table 11 is a comparative data in foot length.

**Figure 4**

Table 3: Foot Length of Males by Age in CM

Age (Yrs)	No	Right Foot		Left Foot	
		Mean (CM)	SD	Mean (CM)	SD
18-20	60	27.08	0.99	26.83	1.04
21-23	66	27.17	0.92	26.98	0.92
24-26	48	27.05	1.28	26.82	1.36
27-29	30	26.69	0.59	26.51	0.31
30-above	45	26.62	1.32	26.43	1.31
All	249	26.92	1.02	26.71	0.99

**Figure 5**

Table 4: Foot Length of Females by Age in CM

Age (Yrs)	No	Right Foot		Left Foot	
		Mean (CM)	SD	Mean (CM)	SD
18-20	51	24.93	1.69	24.83	1.75
21-23	60	25.04	1.19	24.80	1.23
24-26	51	27.05	1.59	24.84	1.50
27-29	30	25.17	0.77	24.93	0.97
30-above	36	24.08	1.43	24.43	1.22
All	228	25.00	1.33	24.75	1.33

**Figure 6**

Table 5: Foot Breadth of Males by Age in CM

Age (Yrs)	No	Right Foot		Left Foot	
		Mean (CM)	SD	Mean (CM)	SD
18-20	60	9.79	0.50	9.69	0.52
21-23	66	10.01	0.61	9.88	0.65
24-26	48	10.14	0.84	9.94	0.90
27-29	30	9.74	0.29	9.65	0.31
30-above	45	9.66	0.40	9.59	0.35
All	249	9.87	0.53	9.75	0.55

**Figure 7**

Table 6: Foot Breadth of Females by Age in CM

Age (Yrs)	No	Right Foot		Left Foot	
		Mean (CM)	SD	Mean (CM)	SD
18-20	51	9.10	0.76	8.86	0.71
21-23	60	9.36	0.68	9.16	0.68
24-26	51	9.04	0.43	8.77	0.48
27-29	30	9.36	0.59	9.15	0.59
30-above	36	8.83	0.43	8.64	0.47
All	228	9.14	0.58	8.92	0.59

**Figure 8**

Table 7: Foot Index of Males by Age

Age (Yrs)	No	Right Foot		Left Foot	
		Mean (CM)	SD	Mean (CM)	SD
18-20	60	36.24	1.91	36.13	1.94
21-23	66	36.76	2.41	36.64	2.26
24-26	48	37.45	2.11	37.01	2.24
27-29	30	36.51	1.52	36.43	1.47
30-above	45	36.37	1.82	36.33	1.96
All	249	36.67	1.95	36.51	1.97

**Figure 9**

Table 8: Foot Index of Females by Age

Age (Yrs)	No	Right Foot		Left Foot	
		Mean (CM)	SD	Mean (CM)	SD
18-20	51	36.61	3.63	36.04	3.54
21-23	60	37.39	2.09	36.90	2.15
24-26	51	35.88	1.66	35.38	1.73
27-29	30	37.18	1.58	36.70	1.57
30-above	36	35.68	2.31	35.42	2.34
All	228	36.55	2.25	36.09	2.27

**Figure 10**

Table 9: Mean Foot Length and Breadth of Male Sample Population

		Mean (CM)	SD	CV (%)	CI
Right Foot	Foot Length	26.92	1.02	3.83	26.92 ± 0.13
	Foot Breadth	9.87	0.53	5.37	9.87 ± 0.07
Left Foot	Foot Length	26.71	0.99	3.71	26.71 ± 0.12
	Foot Breadth	9.75	0.55	5.64	9.75 ± 0.07

**Figure 11**

Table 10: Mean Foot Length and Breadth of Females Sample Population

		Mean (CM)	SD	CV (%)	CI
Right Foot	Foot Length	25.00	1.33	5.32	25.00 ± 0.17
	Foot Breadth	9.14	0.58	6.35	9.14 ± 0.08
Left Foot	Foot Length	24.75	1.33	5.37	24.75 ± 0.17
	Foot Breadth	8.92	0.59	6.61	8.92 ± 0.08

**Figure 12**

Table 11: Comparative Data of Foot Length of Males and Females

Country	Authors	Years	Age	Males	Females
Poland	Wolanski <sup>21</sup>	1962	18	26.2	23.7
Bulgaria	Stranisev et al <sup>22</sup>	1970	18	26.3	24.2
Ireland	Dupertius et al <sup>23</sup>	1972	28	-	23.8
Nigeria	Saxena <sup>24</sup>	1982	20-30	25.4	-
Nigeria	Obikili and Didia <sup>19</sup>	2004	2-28	27.1	25.1
Nigeria	Present Study	2009	18-above	26.9	25.0

**DISCUSSION**

This study was carried out to determine the sexual dimorphism in the foot dimension among adult Nigerians and also provide anthropometrics data for foot length and foot breadth of adult Nigerians to add to existing data.

The small value for the standard deviation of foot dimensions for both sexes implies that the foot length and foot breadth are clustered around the mean values for both right and left foot in both sexes. The small percentages of coefficient of variation also observed in males and females in the right and left foot length and breadth, implies that small variation occurs between the mean values of foot length and foot breadth for sample population and mean values of foot length and foot breadth by age.

From this observation, we found that the males had

significantly higher foot breadth than females  $p < 0.001$  for the foot length, the right foot length was found to be higher than left foot length by 0.21cm and 0.25 for males and females respectively. This value is greater than the finding of Bonnie et al, on Caucasian<sup>[25]</sup>.

The foot dimension in males and females in this study is comparatively larger than Caucasian values. This finding is in accord with theoretical expectation that populations living in warm climates would have longer arms and legs than populations living in cold environments<sup>[26]</sup>. Schreider reported that tropical climate dwellers have longer limbs than temperate climate dwellers. Large foot dimensions are adaptation to tropical environment as they increase the surface area available for heat loss<sup>[26]</sup>.

Ashizawa et al and Wunderlich and Cavanagh reported in their respective study showed that males have longer and broader feet than females for a given stature<sup>[78]</sup>. The larger foot dimension of males in this study in comparison with females is in agreement with this postulation. Besides, Saxena, and Obikili and Didia in their various study on the Nigeria population also found that males, have broader and longer foot dimensions than females<sup>[2410]</sup>.

On the clinical application of foot dimension, Gorman et al in their study on the relationship between shoe size in women and mode of delivery noted that a woman with a small shoe size did not have a higher chance of being delivered by Caesarean section<sup>[27]</sup>. Schultz et al reported that many girls with Rett Syndrome had small feet for height<sup>[28]</sup>. Besides, Rodier et al noted that children with autism had smaller feet compared with the control group<sup>[29]</sup>. This study like that of Obikili and Didia<sup>[10]</sup> provides added reference standard of foot dimension for the Nigerian population and form a basis for further studies on clinical application of foot dimension.

**CONCLUSION AND RECOMMENDATION**

This study is able to establish that the mean value of right foot length in males and females were  $26.92 \pm 1.02$  and  $25.00 \pm 1.33$  and the mean values for right foot breadth for males and females were  $9.87 \pm 0.53$  and  $9.14 \pm 0.58$ . The males have longer and broader foot dimensions than females ( $p < 0.001$ ). Besides, the right foot is longer and broader than the left foot. Females foot are not scaled-down versions of males as they differ in length and breadth.

This finding may be useful for both shoe design and selection of shoe size. As the right foot was significantly

wider than the left foot, we suggest that the shape of the left and right shoes might not need to be symmetrical during design. The width of the shoe could be 2 to 3mm wider on the right foot for a better fit. This study suggests that one try the shoe on the right foot first and consider how it will fit. Besides, this study can be successfully utilized in forensic examination of the foot for personal identification. Because the subjects measured for this study were mostly right hand dominant, the question of whether side dominance has significant effects on the tested results needs further study.

### CORRESPONDENCE

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