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Anthropometric Evaluation of Foot Shape Dimensions and Patterns for Ancestral Determination of South-East Nigerians

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ABSTRACT

Sex, age, stature, and ancestry are considered the pillars of identity and primary characteristics determined to establish the biological profile of an individual. Forensic podiatry, a novel research area of anthropometry involving identification of human subjects and artifacts such as foot through measurement of the morphological shapes and dimensions of the foot is of great application during calamity and disasters involving large number of human casualties as well as our day to day life. The application of podiatry for identity of individuals peculiar to a unique population when collating census data occasioned in times of controversies gives it a demographic relevance due to the individuality and infinite morphological variation of the human foot. The aim of the study is to anthropologically evaluate the foot shape dimensions with a view to the determination of ancestry origin of South-east Nigerians. The research was carried on 1200 adult population comprising of 662 male and 572 female of age range from 18 to 30 year structured according to US Anthropometric reference data and chosen randomly from South-east geopolitical zone of Nigeria in two geographical Ancestral divisions of the – uplander ancestral tribe and the plateau ancestral tribe predominantly across inhabitants of rural communities of the region. Measurements of foot length (FL) and foot breadth (FB) were done, while two parameters were calculated as: Foot Index calculated as Foot breadth / Foot length x 100; and Foot shape was determined by calculation of foot index as Slender type: $FI^* < FI - SD$ (X-SD), Standard type: $FI - SD < FI^* < FI + SD$ (X±SD), Broad type: $FI^* > FI + SD$ (X+SD). Data analysis included descriptive and inferential statistics of mean and standard deviation. Also Anova-test was done to compare the foot size dimensions on the right and left side value. Confidence level was set at 95%, as P-values 0.005 were considered significant. Result showed ancestral differences to be highly significant ($P < 0.005$) with Uplander males having higher values than the females. This study observed that foot length, showed positive correlation and significantly predicted ancestry with better accuracy ($P < 0.005$) while foot breadth and toe shape had varied correlations and predicted ancestry but with low accuracy ($p > 0.005$). By this study these parameters have better correlation with ancestry of an individual and can be accurately used in its prediction. Regarding the foot shape, proportion of standard and broad foot was higher among the males of Uplanders; however, the slender foot types were higher among the females of Plateaus which should be considered in shoe industries and forensic investigations. The females had the better prediction for ancestry compared to the males. Conclusively the study showed that foot parameters are morphometrically and morphologically ancestral specific. This study confirms that correlation of the factors and parameters are better in young female Plateaus than Uplanders but better in male Uplanders at all age groups.

Keywords: Foot dimensions, Foot shape, Foot length, Foot breadth, Toe shape, Foot Index, Ancestry, tribe.

INTRODUCTION

Determination of personal identity is the first and the most important step in forensic science from number system to advanced biometrics. Identification is a two-stage process, the first stage involves the construction of a biological profile and the second is an attempt at a positive match.

Forensic podiatry a novel research branch of anthropometry involving human identification of the foot through understanding and measurement of the morphological shapes and dimensions is of great application during calamity or disaster as well as our day to day life. Sex, age, stature, and ancestry/ethnicity are considered the pillars of identity or primary

characteristics determined to establish the biological profile of an individual and one of the principal biological traits to be established from skeletal remains is the sex of the individual¹.

Elliot and Collard² assert that “there is a pressing need for bioarchaeologists and forensic anthropologists to develop more reliable methods for determining the ancestry of unidentified human remains”. If ancestry determination is going to continue to be an integral component of biological profiles of unknown human remains especially foot samples with infinite variation of morphology, then the methodology must become standardized, consistent, population specific to increase validity. Dimensional relationship between

body segments of foot measurement and the whole body has been used to compare and highlight variations between different ethnic groups and to relate them to locomotor patterns from shapes, energy expenditure from body mass, and lifestyle from functional relation. In view of the importance of foot morphometric differences many studies on the determination of body height via foot measurements in forensic sciences has been recorded^{3,4}. However, it has not been sufficiently established whether if possible tribal identification can be assigned through the analysis of a foot or of a partial foot torn off from the body^{5,6}. Thus, the number of studies to estimate sex through shoe dimensions is extremely limited⁶ and then particularly ancestral/ethnic identity hence our justification to evaluate foot parameters for its possibility in addition to the need for validity of foot indices in establishing relationship between bio-identity and ancestral diversity using a socially visible geographical group. The main aim of this research study is to anthropologically evaluate the parameters of foot indices with a view to the determination of ancestry/ethnic origin of the people of South-east Nigeria; with the specific aim to comparatively evaluate the indices in the stratified groups of South-east Nigerians with view to identifying ancestral morphological peculiarities, and to determine statistically and morphometrically foot shape index and thus establish foot shape pattern of the south-east Nigerians as an index of ancestry from its cross population.

MATERIALS AND METHODS

The research was carried on 1200 adult population comprising of 662 male and 572 female of age range from 18 to 30 year. The samples were chosen randomly from South-east geopolitical zone of Nigeria in two geographical Ancestral divisions by River Niger as – Uplander ancestral tribe predominantly grouped as Akwa-Nsukka block (eastern); and the Plateau ancestral tribe predominantly grouped as Afikpo-Owerri block (western) across inhabitants of selected rural communities of the region. Exclusion criteria included subjects under 18 and above 30 years of age and with apparent foot anomalies, inflammation, orthopedic deformities, developmental disorder and surgery (if any) which have affected the foot growth.

The present study was conducted after taking approval for human population study. Before carrying out the experiments, the subjects were informed of requirements and procedures of the measurements with assurance for confidentiality of information for openness in line with standard protocol. Instruments used include plain sheet of paper, a foot place, digital caliper, marker, rigid transparent meter rule and a steel measuring tape.

Measurements of foot dimensions were taken as: foot length (FL) and foot breadth (FB), while three parameters were calculated as follows: Foot Index calculated as Foot breadth / Foot length x 100; Toe shape calculated as toe length / foot length x 100; and Foot shape was determined by calculation of foot index into Slender type: $FI < FI - SD$ ($X - SD$), Standard type: $FI - SD < FI < FI + SD$ ($X \pm SD$), Broad type: $FI > FI + SD$ ($X + SD$). Methods of data analysis include descriptive and inferential statistics of mean and standard deviation. Anova-test was done to compare the foot size dimensions on the right and left side value. Confidence level was set at 95%, as P-values 0.005 were considered significant.

RESULTS

Result showed Ancestral Sex differences to be highly significant ($P < 0.005$) with males having higher values than the females as follows: Male Uplander - FL, 236.58 ± 5.56 mm and 236.80 ± 5.54 mm; FB, 91.69 ± 4.13 mm and 91.76 ± 4.14 mm, while Female - FL was 233.00 ± 6.04 mm and 233.07 ± 6.11 mm; FB was 88.82 ± 5.25 mm and 88.87 ± 5.26 mm. The foot length (FL) and foot breadth (FB) showed ancestral difference as well with relatively same for age group (21 – 35 years) with just a difference of between 1mm – 2mm across age group and ancestral tribes. This study observed that foot length (FL) showed positive correlation and significantly predicted ancestry with better accuracy ($p < 0.005$) while foot breadth (FB) and toe shape had varied correlations and predicted sex and ancestry but with low accuracy ($p > 0.005$). By this study these parameters have better correlation with ancestry of an individual and can be accurately used in its prediction.

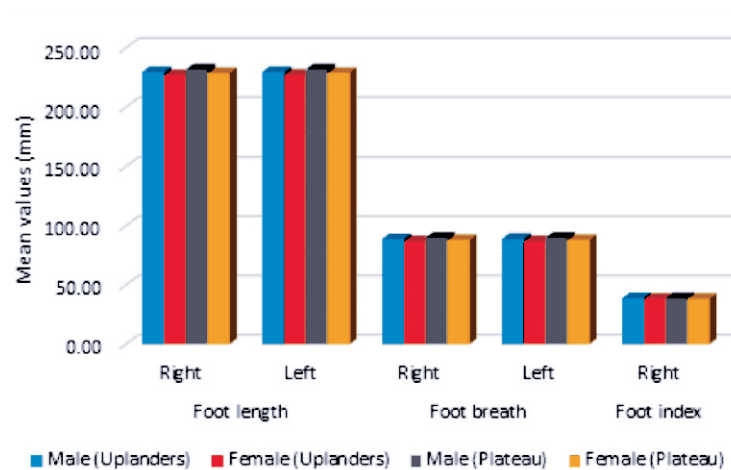


Figure 1: Chart showing comparative Foot length and Foot breadth of male and female ancestral tribes

Regarding the foot shape, proportion of broad foot was higher among the males of Uplanders; while the slender foot types were higher among the males of Plateaus which should be considered in shoe industries and forensic investigations. However, the percentage proportion of standard foot bearers in female Plateaus were less than of Female Uplanders as seen as figure 2.

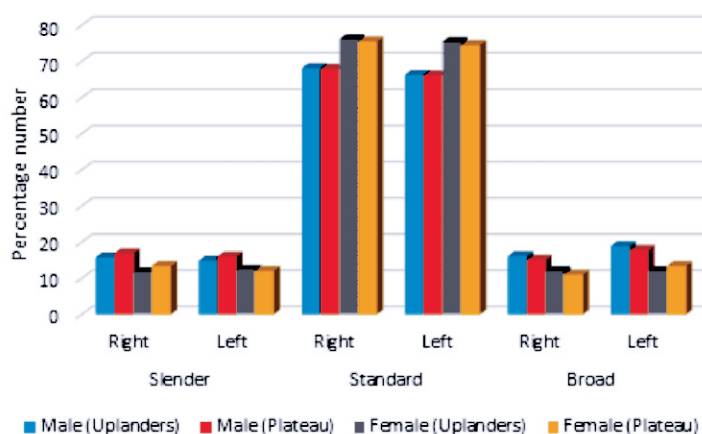


Figure 2: Chart showing Foot shape patterns of male and female ancestral tribes

Table 1: Inference statistics showing foot shapes percentage prevalence of South-east Uplander tribe

Shape	Males		Females	
	No (323)	% (100)	No (273)	% (100)
Slender (X-1SD)				
Rt	51	15.79	32	11.72
Lt	48	14.86	34	12.45
Standard (X±SD)				
Rt	220	68.11	208	76.19
Lt	214	66.25	206	75.46
Broad (X+1SD)				
Rt	52	16.10	33	12.09
Lt	61	18.89	33	12.09

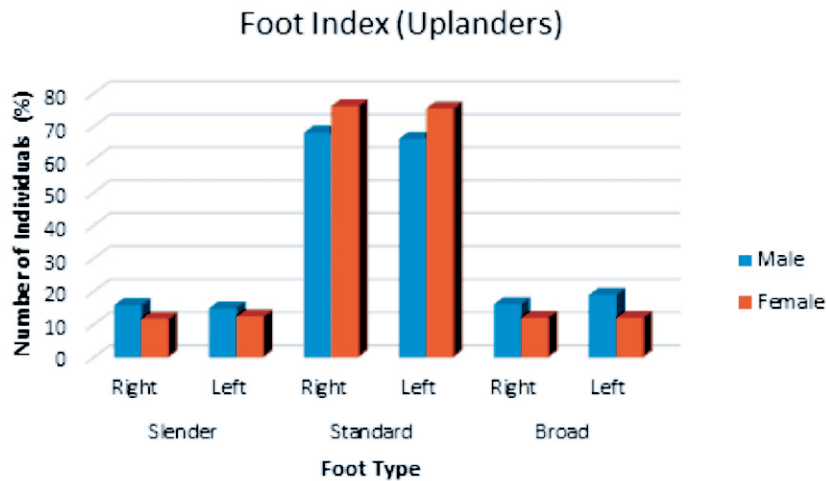


Figure 3: Chart of Foot shape Type for male and female South-east Uplander ancestral tribe

Table 2: Inferential statistics showing foot shape percentage prevalence of South-east Plateau tribe

Shape	Males		Females	
	No (337)	% (100)	No (298)	% (100)
Slender (X-1SD)				
Rt	57	16.91	40	13.42
Lt	54	16.02	36	12.08
Standard (X±SD)				
Rt	229	67.95	225	75.50
Lt	223	66.17	222	74.50
Broad (X+1SD)				
Rt	51	15.13	33	11.07
Lt	60	17.80	40	13.42

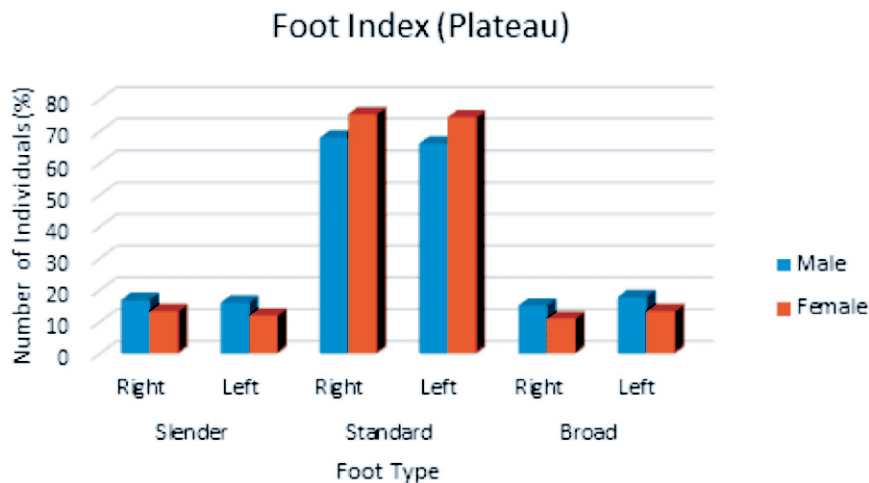


Figure 4: Chart showing Foot shape Type of male and female South-east Plateau ancestral tribe

DISCUSSION

Table 1 of this study is in consistent with earlier study by Fawehinmi and Paul⁷ that studied the foot length of Igbos and Hausas and found the mean foot length as 27.23±1.53cm for Igbo male and 25.33±2.37cm for Igbo females and mean foot length for the Hausa males was 27.24±3.04cm and 26.25±1.19cm for Hausa females as well as Bobmanuel and Didia⁸ on sexual dimorphism among adult Nigerians. Therefore, in keen comparison, it was observed that male Uplanders were slightly higher in length than the Plateaus of same age group of (21 – 25 years). However, the females of same age group were lower in the Uplander samples as against the Plateaus.

All the parameters studied were significantly higher ($P<0.005$) in males than females both on the right foot and left foot. This shows that there is a sex dimorphism in foot length with respect to the South Easterners. The foot length in this study was slightly lower than work of Patel *et al.*⁹, which estimated foot length in Gujarat region of India for male and female in their study were 24.44 cm and 22.34cm respectively.

Sultan *et al.*¹⁰, reported lower values among the Bangalees (7.1±1.1cm) and Santhals (7.0±1.1cm). The foot dimension in males and females in this study is comparatively larger than Caucasian values¹¹. 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. It was 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 loss¹². Agnihotri *et al.*¹³, reported a similar trend among Mauritius populations. However opposite findings were reported by different workers in different populations^{13,14,15}. These could be due to environmental and genetic factors.

The establishment of toe length as a viable and accurate dimension of sex and ancestral identity in our study also agrees with the work of Alabi *et al.*¹⁶, on the use of Regression analysis for Stature Prediction in Nigerian tribes From Toe Length and Toe-Length Ratios which opines that toe length gives the most accurate predictive rate among the Igbos more than other tribes of Hausa and Yorubas from the variation in mean values observed between the ethnic groups.

Table 1 and 2 shows the inferential data for foot shape patterns which puts male Uplanders for slender foot at 15.79% and 14.86%; and females at 11.72% and 12.45% right and left respectively. Male Broad foot at 16.10% and 18.89%; female at 12.09% and 12.09% right and left foot respectively. Male Standard foot at 68.11% and 66.25%; female at 76.19 and 75.46% right and left respectively. In comparison with the Plateaus, male slender foot was 16.91% and 16.02%; female was

13.42% and 12.08% right and left respectively. Male broad foot was 15.13% and 17.80%; female was 11.07% and 13.42%. Male standard foot was 67.95% and 66.17% and female was 75.50% and 74.50% right and left foot respectively. Beside, Obikili and Didia¹⁷ in their study on the Nigeria population also found that males have broader and longer foot dimensions than females.

This present study therefore shows that there was a greater percentage of standard and broad foot for the Uplanders in both males and females right and left foot while the Plateaus only showed a greater percentage for slender foot. From Table 1 and 2, with reference to the number of samples, females show higher percentage of slender and standard foot than males. Thus Slender foot is seen as a prevalent foot index for South eastern Female Uplanders $p<0.005$. This is thus a good index for ancestral tribe comparison of the South-easterners. From Table, Plateaus have higher percentage of male slender and broad foot than females. Hence broad foot is an index of foot dimension prevalent among South eastern Male Plateaus with a significance of $p<0.005$.

From the result of Table Foot shape was categorized according to foot index. In the present study, the proportion of broad foot was higher among the males (50.7%) than the females (23.0%) whereas slender and standard foot was higher among the females (21.5% & 55.3%) than the males (16.9% & 32.3%) respectively. The higher percentage of broad foot in males; slender and standard foot in females may be genetic and weight bearing functions among the male Plateaus who are predominantly famers and traders. Ashizawa *et al.*¹⁸ reported in their respective study that males have longer and broader feet than females for a given stature.

Table 2 shows that male Plateaus have more of slender and standard foot shapes than broad foot. This higher slender foot shape percentage was seen to be more in the younger age group of (18 – 25 years). The female Plateaus also show higher percentage of slender and standard foot shape to broad foot. However the percentage proportion of standard foot bearers in female Plateaus were less than than of Female Uplanders; So also is Plateau broad foot shape bearers less than in Female Uplanders as observed in both younger and older age groups.

From the findings, correlation coefficient between Toe Length and Foot Length, was strong in both ancestral tribe in males and females. It was also significant between Foot Length and Foot arch Length in both ancestral tribe, males and females and with Foot Index significant alone in the Plateaus. This means there is a strong bond between Foot Length and Toe Length, and Foot Length and Foot arch Length if either of the dimensions is known the other can be calculated and this would be of utmost important to Anthropologist and Forensic experts. Thus if any of these significant foot dimensions or foot anthropometry (Foot Length,

Toe length, Foot arch length, and Foot Index) has been established or known the other could be generated from the regression equations constructed by applying simple substitution. This indicated that the foot length, toe length and foot arch length provides the highest reliability and accuracy in estimating sex and ancestry of South east individuals.

This is in agreement with the findings of Krishan and Sharma¹⁹ that estimated stature from dimensions foot in North Indian population and observed that correlation between stature and all the measurements of foot were positive and statistically significant.

The present study agree with researchers who have identified some factors which affect this anatomical data as feeding pattern/ nutritional qualities, geographical location, physical activity and racial difference²⁰. Therefore it is most welcomed to define the extent of relationship of the various anatomical parts for prediction. Also in view of the fact that populations across the globe have diverse ethnic variations, it is expected that the anthropometric characteristics will differ in different geographical locations; thus, Trotter²¹ and Arora²² warns that the estimation models derived for any defined geographical region; as well as ethnic groups should not be applied to another ethnic group even of the same region.

CONCLUSION

Conclusively the study showed that foot parameters are morphometrically and morphologically sex and ethnic specific. This study confirms that parameters are better in younger female Plateaus than Uplanders but better in male Uplanders at all age groups. The study thus provides anthropological bio-profile from South-east populations which are of significant relevance in demographic and epidemiologic studies, ergonomic and orthotic product designs and forensic analysis. Secondly, establishment of foot shape index for the morphologic identification of individuals within the stratified South-east cross population for security and health benefits. Also, the establishment of population specific foot shape types could also be used to exploit the multiphase advanced anthropological concepts and opportunities of establishing the relationship between specific population identities and health implication.

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