EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 4
Issue: 8
895-900
Year: 2017

FOOT MORPHOMETRY IN THE DIFFERENTIATION AND DETERMINATION OF SEX AMONG IGBO INDIGENE OF IMO STATE EXTRACTION IN NIGERIA

Osuchukwu I. William*[1], Paul W. Chikwuogwo[2] and Aigbogun (Jr) O. Eric[3]

[1]Department of Prosthetics and Orthotics School of Health Technology Federal University of Technology Owerri, Imo State, Nigeria.
[2,3]Department of Human Anatomy Faculty of Basic Medical Sciences College of Health Sciences, University of Port-Harcourt Rivers State, Nigeria PMB 5323

***Corresponding Author: Osuchukwu I. William**
Department of Prosthetics and Orthotics School of Health Technology Federal University of Technology Owerri, Imo State, Nigeria.

Article Received on 20/06/2017 **Article Revised on 10/07/2017** **Article Accepted on 31/07/2017**

ABSTRACT
Background: In the evaluation and estimation of the big four; age, race, sex and stature, anthropometry has been of great assistance and a dependable tool. The foot is always wholly or partly available in situation involving mass disaster, therefore may become essential in predicting the any or all of the big fours. **Objectives:** This study was therefore carried out to estimate sex from foot morphometry of Igbo indigenes of Imo extraction in Nigeria. **Materials and Methods:** 300males and 246 females were used in this study. The following foot parameters (foot length [FL] foot breadth [FB], foot height [FH] medial arch length [MAL] and navicular height [NH]) were measured using standard protocols. SPSS version 23 (IBM, USA) Discriminant Functional Analysis (DFA) was used the possibility and level of accuracy the measured foot dimensions could be used to achieve sex categorisation. **Results:** The result showed that all foot dimensions were significantly greater in male than in females (P<0.01). In the development of the DF model, the dimensions which contributed the most to the outcome of the model were RFL=0.822, RFH=0.755, LFH=0.723 and LFL=0.706 while RMFB, LMFB, LMAL, and RFFB, had average prediction coefficient of 0.50-0.588 and RNH, LNH, RHFB and LHFB had prediction coefficients less than 0.40. The prediction model provided a centroid mean of 0.406 for male and -0.495 for female; with an accuracy of 65.2% after cross-validation. **Conclusion:** Foot dimensions exhibits significant sex-discriminatory characteristics; but it cannot be completely rely upon as an independent factor due to its average prediction accuracy. However, the dimensions can be used as an adjunct in medicolegal investigations requiring sex determination.

KEYWORD: Foot morphometry, Sex differentiation, Discriminant Functional Analysis, Igbo indigenes.

INTRODUCTION
Anthropometric studies in our recent world have been of great significance, and its applications in various human endeavours covers a wide span ranging from clothing and footwear design, anthropology, predisposition to disease, anthropology, ergonomics and equipment design, criminal investigation, to forensic medicine.[1] In the evaluation and estimation of the big four; age, race, sex and stature, anthropometry has been of great assistance and a dependable tool.

The foot is an essential anatomical structure which forms the platform for standing erect and maintaining balance.[2,3] The foot are often protected by footwear to avoid damage and loss of proper function; this protection makes the foot less susceptible to damage in cases of mass disaster[4] therefore making it wholly or partly available and therefore may become the most essential in predicting the any or all of the big fours.

Studies have shown that foot dimensions are actually different in males and females[5-10] with the males having significantly greater values when compared to their female counterpart.[5-9] however, Olasunkanmi[10] reported larger foot breadth in females when compared to males. The marked difference in foot dimension in a particular ethnic group or race has suggested its sex-discriminatory characteristics. Therefore this study carried out to determine the sex-discriminatory characteristics of foot dimensions among Igbo indigenes of Imo extraction in Nigeria.

MATERIALS AND METHODS
This study was carried out in Imo State, Nigeria. A total of 546 subjects (300 males and 246 females) who were

physically healthy and free of any form of foot injury, abnormality or reconstructive surgery were used for the study. Eight (8) foot morphometric data; foot length (FL), Foot breadth measured in three parts; fore foot breadth [FFB], mid foot breadth [MFB], hind foot breadth [HFB], foot height (FH), navicular height (NH) and medial arch length (MAL) for both feet (left [L] and right [R]) were obtained by direct linear measurement. Ethical approval was obtained from the Ethical Committee of the University of Port Harcourt, Rivers State, Nigeria.

Landmarks for the measured foot dimensions were as follows;

Foot Length (FL): Measured as the distance from the tip of the longest toe to the most posterior part of the heel. The foot length was marked on sheet of paper and then measured with a straight ruler calibrated in centimetres.

Foot Breadth (FB): Measured in three aspects which include; the fore foot breadth (FFB), mid foot breadth (MFB) and the hind foot breadth (HFB), all measured with a 150mm digital venire calliper. The fore foot breadth (FFB) was measured as the distance between the medial border (around the head of the first metatarsal bone) and the lateral border (around the head of the fifth metatarsal bone) of the foot. The mid foot breadth (MFB) was measured as the distance between the medial border and the lateral border of the foot at its mid region.[11] The hind foot breadth (HFB) was measured as the distance between the medial border and the lateral border of the foot around the hind region of the foot.

Foot Height (FH): Measured as the vertical distance from the medial malleolus of the tibia bone down to the ground or surface on which the subject is standing. This point (the medial malleolus) was noted and marked with an erasable marker, and then the vertical distance was measured from the standing surface to the marked point using a ruler calibrated in centimetre.

Navicular Height (NH): Measured as the vertical distance from the navicular bone to the ground or surface which the subject is standing.[12] The navicular tuberosity was palpated and was marked with an erasable marker, and then the vertical distance was measured from the standing surface to the marked point (around the navicular bone) using a ruler calibrated in centimetre.

Medial Arch Length (MAL): The medial arch length was defined and measured as the length or distance in the medial part of the foot, measured from the medial border of the head of the first metatarsal bones to the medial border around the region of the calcaneal tuberosity.

Statistical analysis

Statistical analyses were carried out using Statistical Package for Social Sciences (SPSS version 23; IBM®). W laterality while Discriminant Function Analysis (DFA) was used to determine the possibility of sex categorization. Only the variables that were statistically significant were entered into the DFA. These variables were analysed at 95% confidence level.

Data analysis

The results were displayed in a tabular form in the tables below based on the anthropometric measurements of the foot parameters. The mean (SD) values, maximum and minimum ranges for the measured foot parameters for both males and females were captured in Table1, while test of mean difference for foot parameters of male and females were displayed in Table2. The DFA model outcome (in Tables 3-8) indicated the only variables which were significantly different in both sexes, and were entered into the model (Table 3). The canonical correlation which quantifies the contribution by proportion of the variables to the prediction model was displayed in Table 4. The overall model acceptability (R^2) of the model is indicated by 0.761^2, which suggests that the variables in the model explains 57.9% of the effect; that is either male or female groups (Table 4.) The set of predictor variables entered into the model (FL, FFB, MFB, HFB, FH, NH and MAL) made statistically significant predictions in their outcomes (Wilk's Lambda = 0.422, $\chi 2_{(df=9)}$ = 28.932, P<0.001).

RESULTS

The mean values and t-test of mean difference of foot dimensions of male and females were presented inTable1. The Discriminant Function Analysis (DFA) model outcome for evaluating sex categorization were presented in Table 2-7, while Summary correctly and cross-validated classification into group membership was presented in Table 8.

Descriptive characteristics of measured foot dimension

From Table 4.1, the mean(±S.D) of the measured right foot (RF) dimension was as follows; RFL (M=268.32±12.3mm, F=258.48±14.37mm), RFFB (M=98.60±8.08mm, F=95.15±6.15mm), RMFB (M=82.43±6.52mm, F=78.90±6.83mm), RHFB (M=64.70±6.51mm, F=62.79±5.71mm), RFH (M=69.22±8.84mm, F=63.61±7.43mm), RNH (M=47.60±7.12mm, F=45.28±6.15mm), RMAL (M=169.18±13.33mm, F=162.21±11.95mm). For the left foot (LF) the mean(±S.D) values were as follows; LFL (M=267.83±12.25mm, F=259.44±14.26mm), LFFB (M=98.56±5.93mm, F=95.29±6.24mm), LMFB (M=82.17±6.64mm, F=78.57±6.97mm), LHFB (M=64.49±7.12mm, F=62.79±6.05mm), LFH (M=68.47±8.79mm, F=63.11±7.48mm), LNH (M=47.25±6.99mm, F=45.13±6.40mm), LMAL (M=168.90±13.12mm, F=162.64±11.44mm).The t-test analysis showed that all measured right and left foot dimensions were found significantly greater in males when compared to females (P<0.001) (Table 1).

Table 1: Mean values and test of mean difference of the measured foot parameters of males and females.

Parameter	Male [300]	Female [246]	t-test comparison of mean difference	Total [546]
	Mean±S.D	Mean±S.D	t-value (P-value)	Mean±S.D
RFL (mm)	268.32±12.3	258.48±14.37	8.62 (P<0.01)	263.88±14.14
LFL (mm)	267.83±12.25	259.44±14.26	7.4 (P<0.01)	264.05±13.83
RFFB (mm)	98.60±8.08	95.15±6.15	5.52 (P<0.01)	97.04±7.47
LFFB (mm)	98.56±5.93	95.29±6.24	6.26 (P<0.01)	97.09±6.28
RMFB (mm)	82.43±6.52	78.90±6.83	6.17 (P<0.01)	80.84±6.88
LMFB (mm)	82.17±664	78.57±6.97	6.16 (P<0.01)	80.55±7.02
RHFB (mm)	64.70±6.51	62.79±5.71	3.6 (P<0.01)	63.84±6.23
LHFB (mm)	64.49±7.12	62.79±6.05	2.96 (P<0.01)	63.72±6.71
RFH (mm)	69.22±8.84	63.61±7.43	7.91 (P<0.01)	66.69±8.69
LFH (mm)	68.47±8.79	63.11±7.48	7.58 (P<0.01)	66.05±8.64
RNH (mm)	47.60±7.12	45.28±6.15	4.02 (P<0.01)	46.56±6.79
LNH (mm)	47.25±6.99	45.13±6.40	3.67 (P<0.01)	46.29±6.81
RMAL(mm)	169.18±13.33	162.21±11.95	6.37 (P<0.01)	166.04±13.18
LMAL(mm)	168.90±13.12	162.64±11.44	5.87 (P<0.01)	166.08±12.77

Note: R; Right, L; Left, FL; Foot length, FFB; Fore foot breadth, MFB; Mid foot breadth, HFB; Hind foot breadth, FH; Foot height, NH; Navicular height, MAL; Medial arch length. S.D, Standard deviation; t-value, t-test calculated value; P-value, probability value.

Sex Categorization Using Discriminant Functional Analysis (DFA)

Table 2: Tests of equality of group means for parameters entered into the model.

Parameters	Wilks' Lambda	F	df1	df2	P-value	Inf
RFL (cm)	0.880	74.288	1	544	<0.001	S
LFL (cm)	0.909	54.696	1	544	<0.001	S
RFFB (mm)	0.947	30.450	1	544	<0.001	S
LFFB (mm)	0.933	39.220	1	544	<0.001	S
RMFB (mm)	0.935	38.010	1	544	<0.001	S
LMFB (mm)	0.935	37.988	1	544	<0.001	S
RHFB (mm)	0.977	12.934	1	544	<0.001	S
LHFB (mm)	0.984	8.778	1	544	0.003	S
RFH (cm)	0.897	62.598	1	544	<0.001	S
LFH (cm)	0.904	57.447	1	544	<0.001	S
RNH (cm)	0.971	16.187	1	544	<0.001	S
LNH (cm)	0.976	13.465	1	544	<0.001	S
RMAL (cm)	0.931	40.559	1	544	<0.001	S
LMAL (cm)	0.940	34.454	1	544	<0.001	S

Note: R; Right, L; Left, FL; Foot length, FFB; Fore foot breadth, MFB; Mid foot breadth, HFB; Hind foot breadth, FH; Foot height, NH; Navicular height, MAL; Medial arch length. Df=degree of freedom, Inf.=Inference (S; Significance, NS; Not Significant).

Table 3: Tests of equality in population covariance matrices and canonical correlation.

Box's M Equality In Covariance			Eigenvalue		
			Function	Eigenvalue	Canonical Correlation
Box's M		352.884			
F	Approx.	5.588	1	1.372	0.761
	df1	45			
	df2	2900.974			
	P-value	<0.001			

Table 4: Wilks' Lambda test for predictability into group membership.

Test of Function(s)	Wilks' Lambda	Chi-square	df	P-value	Inference
1	0.422	28.932	9	<0.001	S

Note: S; Significant.

Table 5: Canonical discriminant function coefficient structured, standardized and unstandardized.

Box's M Structure Matrix Coefficients		standardized Canonical Discriminant Function Coefficients	Unstandardized Canonical Discriminant Function Coefficients
Variables	Function [1]	Function	Function [b]
RFL (mm)	0.822**	0.721	0.054
RFH (mm)	0.755**	0.143	0.017
LFH (mm)	0.723**	0.322	0.039
LFL (mm)	0.705**	0.322	-0.017
RMAL (mm)	0.607**	0.001	0.000
LFFB (mm)	0.597*	0.127	0.021
RMFB (mm)	0.588*	0.094	0.014
LMFB (mm)	0.588*	0.356	0.052
LMAL (mm)	0.560*	-0.101	-0.008
RFFB (mm)	0.526*	-0.03	-0.004
RNH (mm)	0.384	0.186	0.028
LNH (mm)	0.35	-0.187	-0.028
RHFB (mm)	0.343	0.156	0.000
LHFB (mm)	0.283	-0.36	-0.054
Constant			-17.359

Note: R; Right, L; Left, FL; Foot length, FFB; Fore foot breadth, MFB; Mid foot breadth, HFB; Hind foot breadth, FH; Foot height, NH; Navicular height, MAL; Medial arch length.

Variables that are making; **strong predictions, *average prediction (Bolded red values contributed above 50% of outcome).

Function[1] - Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions.

Function[b] – Coefficients used for computing group membership value.

Table 6: Functions at Group Centroids.

Sex	Function 1
Male	0.406
Female	-0.495

Unstandardized canonical discriminant functions evaluated at group means.

Table 7: Classification function coefficients.

Parameter	Sex: Male	Sex: Female
RFL (mm)	0.765	0.716
RFH (mm)	0.871	0.887
LFH (mm)	-0.198	-0.194
LFL (mm)	1.654	1.635
RMAL (mm)	0.485	0.472
LFFB (mm)	-0.407	-0.454
RMFB (mm)	0.316	0.293
LMFB (mm)	-0.170	-0.121
LMAL (mm)	-0.172	-0.188
RFFB (mm)	-0.423	-0.458
RNH (mm)	0.378	0.353
LNH (mm)	0.066	0.092
RHFB (mm)	-0.023	-0.023
LHFB (mm)	-0.277	-0.270
Constant	-264.470	-249.056

Note: R; Right, L; Left, FL; Foot length, FFB; Fore foot breadth, MFB; Mid foot breadth, HFB; Hind foot breadth, FH; Foot height, NH; Navicular height, MAL; Medial arch length.

Table 8: Percentage predictability for group membership.

		Sex	Predicted Group Membership: Male	Predicted Group Membership: Female	Total
Original [a]	Count (%)	Male	229 (76.3)	71 (23.7)	300 (100)
		Female	105 (42.7)	141 (57.3)	246 (100)
Cross-validated [b]	Count (%)	Male	219 (73.0)	81 (27.0)	25 (100)
		Female	109 (44.3)	137 (55.7)	15 (100)

[a] 66.8% of original grouped cases correctly classified
[b] 65.2% of cross-validated grouped cases correctly classified

From Table 2, all variables entered into the model were significantly different. The canonical correlation which quantifies the contribution by proportion of the variables to the prediction model was displayed in Table 3. The overall model acceptability (R^2) of the model is indicated by 0.761^2, which suggests that the variables in the model explains 57.9% of the effect; that is either male or female groups (Table 3). The set of predictor variables entered into the model (FL, FFB, MFB, HFB, FH, NH and MAL) made statistically significant predictions in their outcomes (Wilk's Lambda = 0.422, $\chi2_{(df=9)}$ = 28.932, P<0.001) (Table 4), as the foot dimensions with significantly high predictor capability for sex grouping were RFL (0.822), RFH (0.755), LFH (0.723), LFL (0.705), RMAL (0.607) and LFFB (0.597) while RMFB, LMFB, LMAL, and RFFB, had average prediction coefficient (0.50-0.588); however, RNH, LNH, RHFB and LHFB had prediction coefficient less than 0.40 (Table 5).

In Table 6, the DFA grouping can be interpreted in terms of the sex-specific resultant group mean value of the predictor variables. These group means were referred to as centroids. The execution of the model using the data from this study, the centroid mean for male was 0.406 while female produce a mean of -0.495. Table 7 presents the Coefficients of Linear Discriminant Function that which explain how sex can be predicted using the group means of the predictor variables. The discriminant model for sex categorization was described as;

Male (foot dimensions) = -264.47 + 0.765(RFL) + 0.871(RFH) - 0.198(LFH) + 1.654(LFL) + 0.485(RMAL) - 0.407(LFFB) + 0.316(RMFB) - 0.170(LMFB) - 0.172(LMAL) - 0.423(RFFB) + 0.378(RNH) + 0.066(LNH) - 0.023(RHFB) - 0.277(LHFB).

Female (foot dimensions) = -249.06 + 0.716(RFL) + 0.887(RFH) - 0.188(LFH) + 1.635(LFL) + 0.472(RMAL) - 0.454(LFFB) + 0.293(RMFB) - 0.121(LMFB) - 0.121(LMAL) - 0.458(RFFB) + 0.353(RNH) + 0.092(LNH) - 0.023(RHFB) - 0.277(LHFB).

The classification results in Table 8 showed that 66.8% (66.8%) of the total data were accurately classified correctly, into groups representing male or female using the foot dimension; however, upon cross-validation, only 65.2% were correctly grouped.

DISCUSSION

This study examined the possibility of differentiating sex of Igbo indigenes of Imo extraction using foot dimensions as a data component of the DFA predictive model. From this study, it was clearly observed that all male values where significantly greater than those of their female counterparts. Most researchers[5-11] reported similar findings except Olasunkanmi[10] who reported a larger foot breadth in Yoruba females when compared to Yoruba males. The values obtained from this model are suggestive of notions which includes; are the variables so different that they can significantly discriminating sex? And to what extend can the prediction be regarded as being accurate? These are the vital questions that such morphometric investigation should answer.

To answer the above question, DFA was used in this study to evaluate the predictability and to see how accurate the model is, using the measured foot parameters that were significant for sex differences. The analysis showed that the model was a good fit for prediction and the predictions made were significant. However, the strength of this model in its ability to accurately classify the measured parameters into sex was low when compared to the established 95% acceptable level acknowledged researchers[12-15] and when compared other anthropometric measurements of other body parts which had produced accuracy of up to 90%.[16-17] Despite the low accuracy in sex prediction observed for the studied foot parameters, we are still optimistic about the assistive role foot dimensions could play in the determination and differentiation of sex.

CONCLUSION

Foot dimensions are undoubtedly different between sexes, but it cannot be completely rely upon as an independent determinant for sex categorisation due to its average prediction accuracy. However, the dimensions can be used as an adjunct in medicolegal investigation requiring sex determination.

ACKNOWLEDGEMENT

The authors wish to acknowledge the Dr. J. Ekezie, and Mr. C.C. Eke for contributions towards the completion of this research.

REFERENCES

1 Utkualp N, Ercan I. Anthropometric measurements usage in medical sciences. BioMed Research International, (Article ID 404261), 2015; 1-7.
2 Agnihotri AK, Soodeen-Lalloon AK. Estimation of stature from fragmented human remains. Anthropol, 2013; 1(2): 1-2.
3 Ellis H. Clinical Anatomy (11th Ed.). Blackwell Publishing, Oxford, 2006; 225-237.
4 Moore KL, Dalley AF, Agur AMR. Clinically Oriented Anatomy (7th Ed.), 2014; 522-656.
5 Agnihotri A, Shukla S, Purwar B. Determination of sex from the foot measurements. The Internet Journal of Forensic Science, 2006; 2(1): 1-4.
6 Reena S., Minu B., Mrinal B Sex estimation from foot anthropometry in Haryanvi Jats and north Indian mixed population; J. Punjab Acad Forensic Med Toxicol, 2012; 12(1): 13-19.
7 Chiroma SM, Attah MO, Taiwo IO, Buba HS, Dibal NI, Jacks TW. Metric Analysis of the Foot of Yoruba Students at the University of Maiduguri, Nigeria. IOSR-JDMS, 2015; 14(8): 63-67.
8 Paiva de Castro A., José RR, Thaís RA. The Effect of Gender on Foot Anthropometrics in Older People. J Sport Rehabil, 2011; 20: 277-286
9 Ashizawa K, Kumakura C, Kusumoto A, Narasaki S. Relative foot size and shape to general body size in Javanese, Filipinas and Japanese with special reference to habitual foot wear types; Ann Hum Biol, 1997; 24(2): 117-129.

10 Olasunkanmi SI. Anthropometric Data of Hand, Foot and Ear of University Students in Nigeria. Leonardo Journal of Sciences, 2009; 15: 15-20.
11 Manna I, Pradhan D, Ghosh S, Kar SK, Dhara P. A comparative study of foot dimension between adult male and female and evaluation of foot hazards due to using of footwear. J Physiol Anthropol Appl Human Sci, 2001; (4): 241-246.
12 Iscan MY, Miller-Shaivitz P. Determination of sex from the tibia. Am J.Phys Anthropol, 1984; 64: 53-57.
13 Iscan MY. Ding S. Sexual dimorphism in the Chinese femur. Forensic Sci Int, 1995; 74: 79-87.
14 Iscan MY. Forensic anthropology of sex and body size. Forensic Sci Int, 2005; 147: 107-112.
15 Ibeachu PC, Aigbogun (Jr) E, Didia BC, Fawehinmi HB. Determination of Sexual Dimorphism by Odontometric Study Using Discriminant Function Analysis of Adult Ikwerre Dental Cast. SJAMS, 2015; 3(4): 1732-1738.
16 Ekezie J, Ndubuka GI, Okeke SN, Osuchukwu IW. A study of correlations and estimation of stature from foot trace and shoe trace dimensions. Int J Forens Sci, 2016; 1(3): 1-13.
17 Watson A, Ganesh P, Joseph OR. Impact of anthropometric measures on medial arch height in half marathon runners. Eur J Sports Exerc Sci., 2014; 3(3): 37-41.