ORIGINAL ARTICLE

Evaluation of sexual dimorphism by discriminant function analysis of toe length (1T–5T) of adult Igbo populace in Nigeria

Stephen A. Alabi[1,2], Blessing C. Didia[2], Gabriel Sunday Oladipo[2], Eric O. Aigbogun Jr.[2]

[1]Department of Human Anatomy, Faculty of Basic Medical Sciences, University of Ilorin, Ilorin, [2]Department of Human Anatomy, Faculty of Basic Medical Sciences, University of Port Harcourt, Port Harcourt, Nigeria

ABSTRACT

Background: Sex determination is an important and one of the foremost criteria in establishing the identity of an individual, and this is achieved by investigating various anatomical structures to establish sex discriminatory features. The present study conducted baseline data for the toe with a view of finding discriminatory sex characteristics. **Materials and Methods:** A total of 420 subjects were studied by direct linear measurements of the toe length (big toe [1T] to the fifth toes [5T]) of both feet using a digital Vernier caliper with accuracy of 0.01 mm. Statistical Package for Social Sciences (IBM, version 23, Armonk, New York, USA), Levene's ANOVA outcome informed the use of *t*-tests to compare mean differences. Discriminant function analysis (DFA) was used to evaluate the possibility of sex categorization. The significance level was set at 95%. **Results:** The mean ± standard deviation values of the right (R) toes for the males were 49.63 ± 4.43 mm (1T), 36.92 ± 5.14 mm (2T), 30.35 ± 4.95 mm (3T), 25.55 ± 3.97 mm (4T) and 22.21 ± 2.94 mm (5T), whereas the female values were 45.73 ± 4.07 mm (1T), 33.31 ± 4.66 mm (2T), 26.63 ± 4.02 mm (3T), 22.89 ± 3.43 mm (4T), and 19.77 ± 2.70 mm (5T). The left male values were 49.16 ± 4.32 mm (1T), 36.82 ± 5.16 mm (2T), 30.88 ± 4.91 mm (3T), 26.13 ± 3.99 mm (4T), and 22.46 ± 3.24 mm (5T), whereas the female values were 45.33 ± 4.05 mm (1T), 33.05 ± 4.70 mm (2T), 27.27 ± 4.29 mm (3T), 23.10 ± 3.36 mm (4T), 19.81 ± 2.59 mm (5T). From the results, males displayed significantly higher mean values than females in all measured parameters ($t = 2.405$, $P = 0.018$) with no asymmetry ($P > 0.05$); although T3 and T4 were larger on the left foot. The DFA model when tested with the present data derived a significant "F" likelihood ratio test ($P < 0.001$), a Wilks' lambda predictability value of 0.759 having a model accuracy of 69.5% with a better prediction for female (70%) than males (69%). **Conclusion:** The use of toe length alone may not be effective for sex differentiation; however, it can serve as an adjunct in forensic investigation involving sex identification.

Key words: Discriminant function analysis, Igbo, sexual dimorphism, toe length

Address for correspondence:
Dr. Stephen A. Alabi,
Department of Human Anatomy,
Faculty of Basic Medical Sciences,
University of Ilorin, Ilorin, Nigeria.
E-mail: dradealabi@gmail.com

INTRODUCTION

The application of somatometry (a significant aspect of anthropometry) in the identification of human remains led to the formation of term "forensic anthropometry." The ultimate aim of using anthropometry in forensic medicine/science is to assist the law enforcement agencies achieve "personal identity" in cases of unknown human remains;[1] which involves the combination of different procedures. However, those set of physical characteristics, functional or psychic, normal or pathological that defines an individual can be regarded as identity.[2]

In establishing the identity of an individual, sex determination is an important and one of the foremost

Access this article online	
Quick Response Code:	Website: www.nigeriamedj.com
	DOI: 10.4103/0300-1652.188351

How to cite this article: Alabi SA, Didia BC, Oladipo GS, Aigbogun EO. Evaluation of sexual dimorphism by discriminant function analysis of toe length (1T-5T) of adult Igbo populace in Nigeria. Niger Med J 2016;57:226-32.

requirement;[3] as it statistically excludes approximately half of the population under innvestigation[4] and narrows down the search for the identity of an individual.[5] Sex is considered one of the easiest discriminants from skeletal material and the most reliable if essential parts of the skeleton are available in good condition.[5,6] However, identification of dismembered or scattered human remains; frequently found in case of mass disasters and criminal mutilation still remains a challenge to medicolegal experts.[3] Supportively, some characteristics such as weight, height, and body mass index gives a better imaginable pictorial view of the individual, and aid anthropological studies.[6]

Various studies have established sexual differences from different human bones such as the skull, pelvis,[7,8] long bones, scapula,[9,10] clavicle, and smaller bones such as metatarsals, metacarpals, phalanges,[3] patella, vertebrae, ribs, and other vital structures such as dentition.[11] The most widely applied statistical model in sex determination is the discriminant function analysis (DFA) established by Fisher.[12,13] This model encouraged many forensic scientists to assess their anthropometric data accordingly and critically.[6,11]

MATERIALS AND METHODS

A total of 420 subjects within the age range; 18–65 years, equally distributed into males and females of Igbo descent, traced to paternal and maternal grandparents were selected. The Igbo population was estimated from the percentage contribution of the various ethnic groups to the Nigerian population, while the sample size was determined by proportion using Fisher's formula for large population (>10,000) or infinite population; $SS = \frac{Z^2 \times p \times q}{d^2}$.[14,15]

Subjects were selected by multistage stratified sampling technique. Structured questionnaires were used to determine sociodemographical status of the subjects and written informed consent was obtained from each participant. All subjects were healthy individuals free of deformity, injury, fracture, amputation or any surgical procedures carried out on the toes. Ethical clearance was obtained from the University of Port Harcourt Ethical Committee prior to the commencement of the study.

Anthropometric determination of toe length was carried out using a digital Vernier caliper with precision of 0.01 mm. The following toe measurements were taken; 1T-great toe (hallux), 2T-long toe (second toe), 3T-middle toe (third toe), 4T-ring toe (fourth toe), and 5T-little toe (fifth toe) for both foot. The toe length was defined by the distance from the tip of the toe till the proximal metatarsophalangeal crease of that toe; when fully extended [Figure 1]. Measurements were taken trice and the average tabulated as the value for the measured length.

Statistical analysis

Statistical Package for Social Sciences (IBM, version 23, Armonk, New York, USA) ANOVA and unpaired *t*-test was used in assessing the sex differences in the measured parameters, and univariate DFA was used to ascertain the possibility of classifying the parameters into group membership. Only statistically significant or close to significant variables were selected for DFA. The confidence level was set at 95%; hence, $P \leq 0.05$ was considered to be statistically significant.

DATA ANALYSIS

The results were presented based on the anthropometric measurements of toes length (1T–5T) for both feet. Continuous data were represented as mean (standard deviation [SD]), whereas frequency (%) for other categorical data. The sociodemographic characteristics of the subjects were represented in Table 1. The values observed from the anthropometric measurements were tabulated and the mean (SD) values, and range (minimum – maximum) were determined for the sex (male and female) [Table 2] with side specific differences (left and right) evaluated. The Levene's ANOVA; prompting specific *t*-test was used to compare the mean difference (MD) in the values obtained for sex with 95% confidence interval for observed MDs [Tables 3 and 4]. The DFA was presented in tables using foot parameters. The models are described in Tables 5-10 with it summary membership classification in Table 11.

RESULTS

The study comprised 420 subjects, of equal proportion of males (50%) with mean (SD) age of 25.26 ± 6.06 years and females (50%) with mean age of females 24.55 ± 5.79. A larger proportion of males (197; 51.4%) and females

Table 1: Sociodemographic characteristics of the population

Variables	Sex (*n*)		Total
	Male (210)	Female (210)	
Age (years)[a]	25.26±6.06	24.55±5.79	24.91±5.93
Marital status[b]			
Single	197 (51.4)	186 (48.6)	383 (91.2)
Married	13 (35.1)	24 (64.9)	37 (8.8)
State of origin[b]			
Abia	39 (51.3)	37 (48.7)	76 (18.1)
Anambra	17 (41.5)	24 (58.5)	41 (9.8)
Ebonyi	4 (44.4)	5 (55.6)	9 (2.1)
Enugu	5 (29.4)	12 (70.6)	17 (4.0)
Imo	145 (52.3)	132 (47.7)	277 (66.0)
Academic qualification[b]			
Primary	1 (33.3)	2 (66.7)	3 (0.7)
Secondary	14 (38.9)	22 (61.1)	36 (8.6)
Tertiary	189 (51.8)	176 (48.2)	365 (86.9)
Others	6 (37.5)	10 (62.5)	16 (3.8)

Data are provided as [a]mean±SD or [b]frequency (%). SD – Standard deviation

Table 2: Anthropometric characteristics of the measured foot dimension (toe length)

Sex	Right foot (mm)					Left foot				
	R.1T	R.2T	R.3T	R.4T	R.5T	L.1T	L.2T	L.3T	L.4T	L.5T
Male										
Mean±SD	49.63±4.43	36.92±5.14	30.35±4.95	25.55±3.97	22.21±2.94	49.16±4.32	36.82±5.16	30.88±4.91	26.13±3.99	22.46±3.24
SE	0.31	0.35	0.34	0.27	0.2	0.3	0.36	0.34	0.28	0.22
Minimum	38.69	25.15	19.09	16.49	15.44	39.86	21.46	16.64	16.78	15.19
Maximum	66.06	54.34	50.97	37.5	31.83	60.08	50.61	47.57	38.69	38.89
Female										
Mean±SD	45.73±4.07	33.31±4.66	26.63±4.02	22.89±3.43	19.77±2.70	45.33±4.05	33.05±4.70	27.27±4.29	23.10±3.36	19.81±2.59
SE	0.28	0.32	0.28	0.24	0.19	0.28	0.32	0.3	0.23	0.18
Minimum	30.42	19.78	14.07	14.65	13.15	33.55	19.84	15.23	14.31	12.87
Maximum	59.71	45.38	37.87	36.89	27.15	58.15	43.99	40.3	31.13	32.31
Total										
Mean±SD	47.68±4.68	35.11±5.22	28.49±4.87	24.22±3.94	20.99±3.07	47.25±4.60	34.93±5.28	29.07±4.95	24.61±3.99	21.14±3.22
SE	0.23	0.25	0.24	0.19	0.15	0.22	0.26	0.24	0.19	0.16
Minimum	30.42	19.78	14.07	14.65	13.15	33.55	19.84	15.23	14.31	12.87
Maximum	66.06	54.34	50.97	37.5	31.83	60.08	50.61	47.57	38.69	38.89

SD – Standard deviation; SE – Standard error of mean

Table 3: Comparative (*t*-test) analysis of measured toe length (by side)

Parameter by sides (mm)	*T*-test for equality of means							
	df	*t*	*P*	Inference	MD	SED	95% CI of the difference	
							Lower	Upper
T1								
Male (right vs. left)	418	1.477	0.140	NS	0.719	0.487	−0.238	1.676
Female (right vs. left)	418	1.019	0.309	NS	0.404	0.396	−0.375	1.182
T2								
Male (right vs. left)	418	0.203	0.839	NS	0.102	0.502	−0.886	1.089
Female (right vs. left)	418	0.563	0.574	NS	0.257	0.457	−0.641	1.155
T3								
Male (right vs. left)	418	−1.099	0.272	NS	−0.529	0.481	−1.475	0.417
Female (right vs. left)	418	−1.582	0.114	NS	−0.642	0.406	−1.439	0.156
T4								
Male (right vs. left)	418	−1.485	0.138	NS	−0.577	0.388	−1.340	0.187
Female (right vs. left)	418	−0.588	0.557	NS	−0.205	0.348	−0.889	0.480
T5								
Male (right vs. left)	418	−0.392	0.695	NS	−0.125	0.319	−0.752	0.502
Female (right vs. left)	418	0.174	0.862	NS	0.051	0.294	−0.526	0.628

df – Degree of freedom; *t* – *T*-test calculated value; *P* – Probability value; MD – Mean difference; SED – Standard error of the difference; CI – Confidence interval; S – Significant; NS – Not Significant

(186; 48.6%) were single while the rest, married (22.77%) at the time of the study. Moreover, 86.9% (365) of the population had above secondary education [Table 1].

The mean ± SD values of the right (R) toes (big toe or fist toe [1T] to the fifth toes [5T]) for the male were 49.63 ± 4.43 mm (1T), 36.92 ± 5.14 mm (2T), 30.35 ± 4.95 mm (3T), 25.55 ± 3.97 mm (4T), and 22.21 ± 2.94 mm (5T), whereas the female values were 45.73 ± 4.07 mm (1T), 33.31 ± 4.66 mm (2T), 26.63 ± 4.02 mm (3T), 22.89 ± 3.43 mm (4T), and 19.77 ± 2.70 mm (5T).

The mean ± SD of the left (L) toes (big [1T] to the fifth toes [5T]) for males 49.16 ± 4.32 mm (1T), 36.82 ± 5.16 mm (2T), 30.88 ± 4.91 mm (3T), 26.13 ± 3.99 mm (4T), and 22.46 ± 3.24 mm (5T), whereas the female values were 45.33 ± 4.05 mm (1T), 33.05 ± 4.70 mm (2T), 27.27 ± 4.29 mm (3T), 23.10 ± 3.36 mm (4T), 19.81 ± 2.59 mm (5T) [Table 3].

The right toe values for the 1T and 2T were larger than those left in both sexes with MD ± standard error of T1 = 0.719 ± 0.487 mm for males and 0.404 ± 0.396 mm for females, T2 = 0.102 ± 0.502 mm for males and 0.257 ± 0.457 mm for females, whereas the left side of T3 and T4 were larger than the right in both sexes (T3 = 0.529 ± 0.481 mm for males, 0.642 ± 0.406 mm for females). The male left side was larger than the right for T5 (T4 = 0.125 ± 0.319 mm), whereas female had a relatively equal length for 5T (0.051 ± 0.294 mm) [Table 4].

Table 4: Comparative (*t*-test) analysis of measured toe length (by gender)

Parameters	Levene's test for equality of variances			*T*-test for equality of means							
	F	*P*	Inference	df	*t*	*P*	Inference	MD	SED	95% CI of difference	
										Lower	Upper
Age (years)	0.829	0.047	EVA	418.00	1.227	0.221	NS	0.71	0.58	−0.43	1.85
Right T1 (mm)	1.126	0.289	EVA	418.00	9.390	<0.01	S	3.90	0.42	3.08	4.72
Right T2 (mm)	2.160	0.142	EVA	418.00	7.549	<0.01	S	3.61	0.48	2.67	4.55
Right T3 (mm)	3.363	0.067	EVNA	401.03	8.475	<0.01	S	3.73	0.44	2.86	4.59
Right T4 (mm)	5.704	0.017	EVNA	409.62	7.352	<0.01	S	2.66	0.36	1.95	3.37
Right T5 (mm)	1.721	0.190	EVA	418.00	8.859	<0.01	S	2.44	0.28	1.90	2.98
Left T1 (mm)	1.376	0.241	EVA	418.00	9.379	<0.01	S	3.83	0.41	3.03	4.63
Left T2 (mm)	1.772	0.184	EVA	418.00	7.821	<0.01	S	3.77	0.48	2.82	4.71
Left T3 (mm)	2.252	0.134	EVA	418.00	8.032	<0.01	S	3.62	0.45	2.73	4.50
Left T4 (mm)	5.888	0.016	EVNA	406.32	8.420	<0.01	S	3.03	0.36	2.33	3.74
Left T5 (mm)	3.739	0.054	EVA	418.00	9.282	<0.01	S	2.66	0.29	2.09	3.22

F – Fisher's calculated value; EVA – Equal variance assumed; EVNA – Equal variance not assumed; df – Degree of freedom; *t* – *T*-test calculated value; *P* – Probability value; MD – Mean difference; SED – Standard error of the difference; CI – Confidence interval; S – Significant; NS – Not significant

Table 5: Table tests of equality of group means

	Wilks' lambda	*F*	df1	df2	Significant	Inference
Right T1 (mm)	0.826	88.174	1	418	<0.001	Significant
Right T2 (mm)	0.880	56.991	1	418	<0.001	Significant
Right T3 (mm)	0.853	71.819	1	418	<0.001	Significant
Right T4 (mm)	0.886	53.536	1	418	<0.001	Significant
R ightT5 (mm)	0.841	78.802	1	418	<0.001	Significant
Left T1 (mm)	0.878	57.984	1	418	<0.001	Significant
Left T2 (mm)	0.893	49.986	1	418	<0.001	Significant
Left T3 (mm)	0.866	64.508	1	418	<0.001	Significant
Left T4 (mm)	0.856	70.341	1	418	<0.001	Significant
Left T5 (mm)	0.861	67.507	1	418	<0.001	Significant

Table 6: Table tests of equality in population covariance matrices and canonical correlation

Box's M equality in covariance		Eigen value		
		Values	Eigen value	Canonical correlation
Box's M	230.5338086			
F				
Approximately	4.086737342	1	0.318	0.491
df1	55			
df2	564,238.056			
Significant	<0.0001			

Table 7: Wilks' lambda test for predictability into group membership

Test of function (s)	Wilks' lambda	χ^2	df	*P*	Inference
1	0.759	113.892	6	<0.001	Significant

Levene's analysis of variance in mean showed that R.3T ($F > 3.363$, $P = 0.067$), R.4T ($F > 5.704$; $P = 0.017$) [Figure 1], and L.4T ($F > 5.888$; $P = 0.016$) had varied significantly in both sex which prompted the assumption of unequal variance analysis of MD for the aforementioned variables, whereas for others, equal variances were assumed. The *t*-test analysis of MD revealed significantly higher mean values for males when compared to females for all measured toe length ($t > 7.00$; $P < 0.01$) [Table 5]. Graphical illustration of the changes in mean values of the toe in both sexes is highlighted in Figure 2.

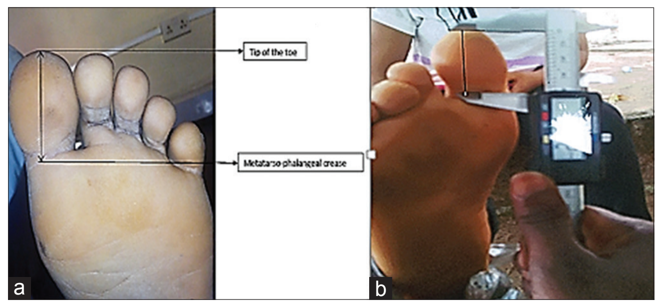

Figure 1: (a) Landmark for first (big) toe length (b) actual measurement using digital vernier caliper

The DFA was carried out using parameters that exhibited significant difference. The test of equality of group means in Table 5 indicates significant difference in the mean values of males and female ($P < 0.001$). Table 6 Box's M tests null hypothesis of equal population covariance matrices. The canonical correlation is the multiple correlations between the predictors and the discriminant function. With only one function, it provides an index of overall model fit, which is interpreted as being the proportion of variance explained (R^2). A canonical correlation of 0.491 suggests the model explains 23.24% of the variation in the grouping variable (that is; whether a value is male or female). Table 7 reveals that all the predictors add some predictive power to the discriminant function as all are statistically significant with $P < 0.001$.

These unstandardized coefficients (b) in Table 8 are used to create the discriminant function (equation). It operates just like a regression equation. In this case, we have [Table 8]: $D = (0.097 \times R.1T) + (0.137 \times R.5T) + (0.076 \times R.3T)$

Table 8: 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[a]	Function	Function[b]
Right T1	0.815**	0.413	0.097
Right T5	0.771**	0.398	0.137
Right T3	0.736**	0.344	0.076
Left T4	0.728**	0.119	0.032
Left T5	0.713**	0.269	0.080
Left T3	0.697**	0.104	0.022
Left T1	0.661**	0.099	0.020
Right T2	0.655**	0.003	0.001
Right T4	0.635*	−0.409	−0.108
Left T2	0.614*	−0.092	−0.017
Constant			−10.572

Variables that are making; **strong predictions; *average prediction. [a]Function - Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions; [b]Function - Coefficients used for computing group membership value

Table 9: Functions at group centroids

Sex	Function[a]
Male	0.562
Female	−0.562

[a]Unstandardized canonical discriminant functions evaluated at group means

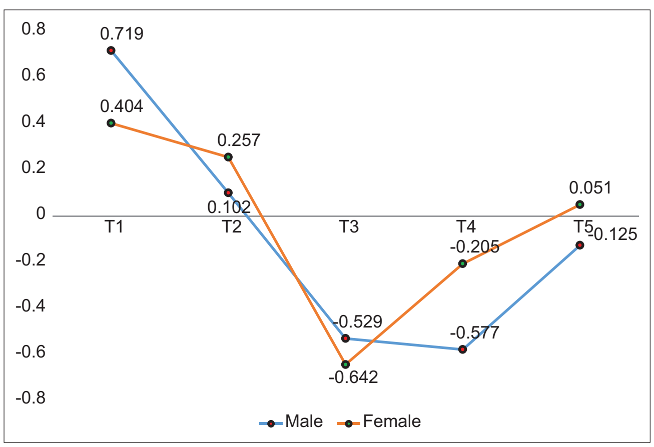

Figure 2: Plot of mean difference of right and left side (R-L) of the toe length (for male and female, only T1 and T2 had a right dominance with 3T, 4T having left dominance, whereas 5T in male was dominant in left and almost equal in females; the differences observed was not significant; $P > 0.05$)

+ (0.032 × L.4T) +0.080 × L.5T) + (0.022 × L.3T) + (0.020 × L.1T) + (0.001 × R.2T) + (−0.108 × R.4T) + (−0.017 × R.4T) − 10.572. The discriminant function coefficients or standardized form beta both indicate the partial contribution of each variable to the discriminate function controlling for all other variables in the equation. These values are used to assess each individual variable's unique contribution to the discriminate function and therefore provide information on the relative importance of each variable. In Table 9, the interpretation of the DFA

Table 10: Classification function coefficients

	Sex	
	Male	Female
Right T1 (mm)	1.913	1.804
Right T2 (mm)	0.200	0.199
Right T3 (mm)	−0.003	−0.088
Right T4 (mm)	−0.557	−0.436
Right T5 (mm)	1.019	0.865
Left T1 (mm)	0.730	0.707
Left T2 (mm)	−0.110	−0.090
Left T3 (mm)	0.116	0.091
Left T4 (mm)	−0.150	−0.186
Left T5 (mm)	0.413	0.322
Constant	−76.310	−64.424

Table 11: Percentage predictability for group membership

Prediction (%)	Sex	Predicted group membership		Total
		Male	Female	
Original[a]	Male	152 (72.4)	58 (27.6)	210 (100)
	Female	57 (27.1)	153 (72.9)	210 (100)
Cross-validated[b]	Male	145 (69.0)	65 (31.0)	210 (100)
	Female	63 (30.0)	147 (70.0)	210 (100)

[a]72.6% of original grouped cases correctly classified, [b]69.5% of cross-validated grouped cases correctly classified

results of each group can further be described in terms of its profile using the group means of the predictor variables. These group means are called centroids. These are displayed in the group centroids [Table 9]. In this study, the males have a mean of 0.562, whereas female produce a mean of−0.562. Cases with scores near to a centroid are predicted as belonging to that group.

The coefficients of linear discriminant function which is also called "classification functions," in Table 10 interprets the Fisher's theory for each observation, have following form $P_k = P_{k0} + P_{k1} \times_1 + P_{k2} \times_2 + ... + P_{km} X_m$. Where; P_k is the classification score for group k and P's are the coefficients in Table 10. For one observation, we can compute its score for each group by the coefficients according to equation (above).

Table 5 shows the level of difference in the observed values of males and females with $P < 0.01$ indicating a statistically significant difference. The Box's M covariance matrix showed inequality in the group variance did not meet the assumption of equal group variance, which indicates a larger discrepancy in the predictor variables. The magnitude of the actual effect of the predictors (canonical coefficient) and the outcome is the square of the coefficient (0.491);[2] this indicates that the relationship between the predictor variable and the prediction outcome is 0.232 which suggests the model explains 23.24% of the variation in the grouping variable, that is, whether the values are male or female [Table 6]. However, the group of predictor variables (R.1T, R.2T, R.3T, R.4T, R.5T, L.1T, L.2T, L.3T, L.4T, and L.5T) will make predictions that are statistically significant in their outcomes (Wilk's lambda = 0.759, $P < 0.001$) [Table 7], as the variables that seems to have the highest predictor capability which can be used to classify into group membership are R.1T (0.82), R.5T (0.77), R.3T (0.74) with other values falling between 0.70 and 0.66 [Table 8].

The classification results [Table 11] reveal that 72.6% of toe measurements were classified correctly into "male" or "female" groups using the various parameters; upon cross validation, accurate prediction fell to 69.5%. This overall predictive accuracy of the discriminant function is called the "hit ratio." Upon reclassification, what is an acceptable hit ratio? You must compare the calculated hit ratio with what you could achieve by chance. If two samples are equal in size, then you have a 50/50 chance anyway. This research would accept a "hit ratio" that is 30% larger than that due to chance.

DISCUSSION

Forensic anthropometry will require series of systematized measuring techniques that express quantitatively the dimensions of the human body and skeleton[16] in order to present findings as evidences in the course of any investigation. Some authors have used fragments of the long bones; upper or lower end to evaluate sex.[1,3] Most of the time, long bones have been used in the determination of stature because they relatively give more accurate prediction.[1]

Sex is considered as one of the easiest determinations from the skeletal material and one of the most reliable if essential parts of the skeleton are available in good condition.[5,6] The most often chosen bones for the determination of sex are the pelvis and the skull although the round heads of the ball joints also provide very reliable means of determining sex.[7,8] Sex determination is also supposed to be reliable when up to 95% accuracy can be achieved.[6-8]

There are remarkable scholarly publications on the sexual dimorphic characteristics of the hand bones;[17,18] noteworthy is the use of the 2nd digit: 4th digit ratio[19-21] with its dimorphic characteristics attributed to hormonal difference.[22,23] However, such cannot be said about the toe as successive decrease in toe length was observed (1T–5T).

Research on the use of toe length to differentiate sex is rather scarce; thus, making this study a pioneer one. Indications from the analysis highlights nonasymmetric difference in toe length with significant sex-related anthropometric difference in all toes (1T–5T). From the difference observed in toe measurements, there may be indication of foot dominance correlating with big toe length in association with foot length; as the right big toe (1T) was larger than the left in most subjects, whereas the reverse was observed for the third toe (3T), fourth toe (4T); and small toe (5T) in males. The graphical illustration shows how the MDs in both sex changes with toe; indicating sex discrimination.

The use of DFA was to evaluate the accurateness and predictability of the model using the observed significant measured variables. The strength of such model is the ability to classify above 80% of the measured parameters into groups (sex) although a 95% accuracy bench mark have been established.[6-8]

The model accuracy for discriminant model for sex categorization in this study seems quite low; although with a better prediction for female (70%) than males (69%). This result indicates cautious prediction into group membership using this model taking into consideration; errors (*e*) which may have occurred that resulted in the deviation from high discrimination.

CONCLUSION

Evidence from this study clearly indicates sex-associated difference in foot parameters. DFA successfully predicted 69.5% of the data into groups (sex) and the prediction statistically significant; thus suggestive of forensic attributes. However, such predictive value seems quite low; hence, the use of toe dimensions alone may not be effective for sex differentiation. The findings argue that a single set of foot dimensions may not be applicable in sex grouping. Therefore, toe length can serve as adjunct in sex identification.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Krishan K. Anthropometry in forensic medicine and forensic science 'forensic anthropometry'. The internet. J Forensic Sci 2006;2:10-5.
2. Gopichand PV, Kaushal S, Kaur G. Personal identification using lip prints (cheiloscopy) – A study in 500 Punjabi females. J Indo Pac Acad Forensic Odon 2009;1:20-2.
3. Kanchan T, Krishan K. Anthropometry of hand in sex determination of dismembered remains – A review of literature. J Forensic Leg Med 2011;18:14-7.
4. Pekka S, Knights B. Forensic Pathology, Infanticide, Still Birth and Fatal Child Abuse. 3rd ed. London: Edward Arnold (Publisher) Ltd.; 1996. p. 460-1.
5. Krogman WM, Iscan YM. The Human Skeleton in Forensic Medicine. 2nd ed. Springfield, Illinois, U.S.A.: Charles C. Thomas Pub Ltd.; 1986. p. 30-5.
6. Iscan MY. Forensic anthropology of sex and body size. Forensic Sci Int 2005;147:107-12.
7. Iscan MY, Miller-Shaivitz P. Determination of sex from the

tibia. Am J Phys Anthropol 1984;64:53-7.
8. Iscan MY, Shihai D. Sexual dimorphism in the Chinese femur. Forensic Sci Int 1995;74:79-87.
9. Bainbridge D, Santiago GT. A study of the sex differences in the scapula. J R Anthropol Inst 1956;86:109-34.
10. Di Vella G, Campobasso CP, Dragone M, Introna F Jr. Skeletal sex determination by scapular measurements. Boll Soc Ital Biol Sper 1994;70:299-305.
11. Ibeachu PC, Aigbogun E Jr., Didia BC, Fawehinmi HB. Determination of sexual dimorphism by odontometric study using discriminant function analysis of adult Ikwerre dental cast. SJAMS 2015;3:1732-8.
12. Fisher RA. The statistical utilization of multiple measurements. Ann Eugen 1936;8:376-86.
13. Fisher RA. The precision of discriminant function. Ann Eugen 1940;10:422-9.
14. Cochran WG. Sampling Techniques. 2nd ed. New York: John Wiley and Sons, Inc.; 1963. p. 2-5.
15. Yamane T. Statistics – An Introductory Analysis. 2nd ed. New York: Harper and Row; 1967. p. 15-20.
16. Douglass H, Ubelakers S. Anthropology and medicine. Introd Forensic Anthropol 2006;3:12.
17. Lippa RA. Are 2D: 4D finger-length ratios related to sexual orientation? Yes for men, no for women. J Pers Soc Psychol 2003;85:179-88.
18. Eshak GA, Ahmed HM, Abdel Gawad EA. Gender determination from hand bones length and volume using multidetector computed tomography: A study in Egyptian people. J Forensic Leg Med 2011;18:246-52.
19. Manning JT, Scutt D, Wilson J, Lewis-Jones DI. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. Hum Reprod 1998;13:3000-4.
20. Oladipo GS, Olotu EJ, Gwunireama IU. Second to fourth digit ratio (2D: 4D) of Igbos and Urhobos. J Biomed Afric 2006;4:53-4.
21. Gwunireama IU, Ihemelandu EC. Geographical influence of digit ratio (2D: 4D): A case study of Andoni and Ikwerre ethnic groups in Niger Delta, Nigeria. J App Biosci 2010;27:1736-5.
22. Wang Y. Is obesity associated with early sexual maturation? A comparison of the association in American boys versus girls. Pediatrics 2002;110:903-10.
23. Lutchmaya S, Baron-Cohen S, Raggatt P, Knickmeyer R, Manning JT. 2nd to 4th digit ratios, fetal testosterone and estradiol. Early Hum Dev 2004;77:23-8.