International Journal of Anatomy and Research,
Int J Anat Res 2019, Vol 7(2.1):6336-42b. ISSN 2321-4287
***DOI:** https://dx.doi.org/10.16965/ijar.2019.109*

Original Research Article

THE CLAVICLE AS A FORENSIC TOOL: SEX-DISCRIMINATORY CHARACTERISTICS IN CADAVERIC SAMPLES OF NIGERIA ORIGIN

Woroma I. Benwoke [1], Eric O. Aigbogun (Jr.) *[2], Emmanuel Bienonwu [3], Tamuno-Olobo Johnbull [4].

[1] Department of Anatomy, College of Health Sciences, Pamo University of Medical Sciences, Rivers State, Nigeria.

*[2] Department of Anatomy, College of Health Sciences, University of Port-Harcourt, Rivers State, Nigeria.

[3] Department of Anatomy, College of Health Sciences, Igbinedion University Okada, Edo State, Nigeria.

[4] Department of Anatomy, College of Health Sciences, Niger Delta University, Bayelsa State, Nigeria.

ABSTRACT

One of the simplest values that can be determined from the skeleton is sex; the accuracy is greater if essential parts are intact. Discriminant functional analysis is the most popular statistical method implored in sex determination and this has encouraged the accurate assessment of anthropometric data. This study was carried out to evaluate the sex-discriminatory characteristics of the clavicle of Nigerian origin. 45 clavicles (comprising of 25 males and 20 females) of both sides were macerated from dissected cadavers from the Anatomy Departments of the University of Port Harcourt Rivers State, Igbinedion University Okada, Ambrose Ali University Ekpoma both in Edo State and Nnamdi Azikiwe University Enugu State. Clavicles with signs of deformity and/or fracture were excluded. Parameters obtained from the clavicle included; length, weight mid-shaft circumference, robustness index, angles, and volume. The measurements obtained were subjected to SPSS (IBM version 23.0, Armonk, USA) paired sample t-test and Pearson's correlation analysis to evaluate side difference and level of correlates respectively while Discriminant Function Analysis (DFA) was used to evaluate the accuracy of the parameters in estimating sex. Confidence level was set at 95%, and P-value <0.05 was taken to be significant. The result showed high sex differences in the measurement (P<0.01) as well as sex-differentiated correlation in the left and right clavicular measurement (r^2; 79 – 98%; P<0.01), The parameters of the right and left clavicle were highly significant with positive correlation at varying degree for total population studied. The extent of correlation (80-99%) between the L & R clavicular measurements informed the need for side-specific DFA. The R & L clavicles produced centroid values of 1.522 and 1.290 for males and –2.537 and -2.150 for females respectively. The accuracy in predicting group membership using the right clavicular parameters was 91.5% while the left was 87.0%, with a better prediction for females. The estimation of sex from the clavicle of Nigerian origin is at least 87% possible using the studied clavicular characteristics.

KEY WORDS: Clavicle, Cadaver, Discriminant Function Analysis, Nigeria, Sex.

Address for Correspondence: Aigbogun (Jr.) Eric, Department of Anatomy, Faculty of Basic Medical Sciences, College of Health Sciences, University of Port Harcourt, Rivers State, Nigeria.
E-Mail: eric_aigbogun@uniport.edu.ng.

Access this Article online	Journal Information
Quick Response code	International Journal of Anatomy and Research ICV for 2016 90.30 ISSN (E) 2321-4287 | ISSN (P) 2321-8967 https://www.ijmhr.org/ijar.htm DOI-Prefix: https://dx.doi.org/10.16965/ijar
DOI: 10.16965/ijar.2019.109	**Article Information** Received: 10 Jan 2019 Accepted: 15 Feb 2019 Peer Review: 10 Jan 2019 Published (O): 05 Apr 2019 Revised: None Published (P): 05 Apr 2019

INTRODUCTION

The clavicle is a long bone that lies in the front of the chest wall. It forms the anterior portion of the shoulder girdle, and curves somehow like the italic letter "*f*" [1]. Although the bone is considered small but is able to bear significant force by the action of the muscles and ligaments that attaches to it [2]. It has a shaft and two ends which are sternal and acromial ends [3]. Most times, especially in forensic studies, one is confronted with the identification of sex of the individual from skeletal remains. Apart from pelvis, skull, tibia, humerus, radius, and ulna, the clavicle also appears to exhibit sexual dimorphism [4]. The male bones are more massive and heavier than female bones, structures like crest, ridges, tuberosities, and lines of muscle attachment and ligaments are more strongly marked in males; this is a general rule that governs the size of joints and the articular surface of the bones [5]. The clavicle shows much restraint to environmental factors and by findings has been proven reliable in gender determination [6]. The use of the clavicle for sex determination is still found to be inadequately represented in the forensics. In forensic studies, it has been stated that when 100% accuracy is required there should be no overlapping of the values for both sexes, the male bones overlap from hypo-masculine to hyper-masculine whereas, the female bone tends to have a range of hypo-feminity; thus, the overlapping causes difficulty in sex determination [7-9].

A number of studies targeted at using bony parts to determine sex have relied on models produced form discriminant functional analysis. Fisher[10] established the discriminant function analysis (DFA) and it has become the most widely utilized statistical model for sex grouping or categorization [11,12]. This method has encouraged forensic scientists to assess anthropometric data accurately[12]; however, various authors have tried to set acceptable realistic accuracy levels for sex discrimination, with the suggestion of not less than 80% [10-15] for an anatomical part to be considered reliable for sex discrimination.

The establishment of sex from morphometric measurements have proven to be very reliable in the identification of dismembered remains; in part or whole. Nearly all skeletal parts of the human body have been investigated for sex discriminatory characteristics; however, the most often referenced bone with significantly high reliability for sex grouping or differentiation are the pelvis and the skull[5,11-13,16-18] while average to high accuracy observed for irregular bones such as; the scapula, phalanges, ribs, patella, and clavicle [6-8,15,19-24]. Thus, the present study evaluated some clavicular measurements and estimated sex using DFA in cadaveric samples of Nigerian origin.

MATERIALS AND METHODS

A total of 45 clavicles extracted from adult human bodies of known sex (25 males and 20 females) of right and left clavicles were sourced from Anatomy Departments of the following Universities in Nigeria, University of Port Harcourt Rivers State, Igbinedion University, Okada, Ambrose Ali University Ekpoma, Edo State and Nnamdi Azikiwe University, Akwa, Anambra State.

The clavicular bones were carefully macerated, prepared, and dried from bodies ascertained to be adult within the age range of 25-45 years. The clavicles were further examined for complete ossification and normal morphology. Bones with signs of deformity, degradation, and/or fracture were excluded.

All measurements were taken in triplicates and the mean values reported as the standard measurement for each parameter. The following measurements were taken:

· **Length:** Maximum length of each clavicle was measured in millimeters using a venire caliper. The measurement was taken from sternal to acromial ends.

· **Mid-shaft Circumference:** To measure the length of the clavicle, a mark was done with a pencil at the middle distance between two ends of the clavicle. At this mid-point, circumference was measured in millimeters with a calibrated narrow strip of graph paper.

· **Robustness index (RI):** It was determined using the formula; $\frac{Mid-shaft\ circumference}{Maximum\ length\ of\ clavicle} X\ 100$

· **Weight:** The weight of each clavicle was measured using a digital weighing balance. The clavicular bone was placed on the balance and the figure was read out. Weight is the amount or quantity of heaviness or mass; amount a thing weigh.

· **Medial and lateral angles:** The angles of clavicles were measured in degrees with the help of protractor. To measure the angles, a tracing of the bone was made from its superior aspect. Care was taken to ensure the same orientation in all bones. The midpoint of both ends of sternal and acromial was located and connected by a line (straight). The mid-axis of the tracing was made. Then the two (medial and lateral) angles were constructed to fit the curves of the mid-axis at its greatest convexities and at that point of intersection with a protractor.

· **Total angle:** The total angle was the sum of the medial and lateral angles of that clavicle.

· **The volume of the clavicle:** The volume of the bone was measured in milliliters (ml) by water displacement techniques. A glass cylinder of 500mls capacity having side nozzle at the top, sufficient to accommodate a clavicle was used. The cylinder was filled with water to the brim; it was ensured water doesn't spill through the nozzle. The clavicle was suspended into the cylinder, with a thread at one end of the clavicle. The lowering was done slowly; the amount of water displaced by the bone was accessed using a measuring cylinder and pipette. Average of three measurements were taken for each clavicle; the average value obtained was considered the volume of the clavicle.

Data Analysis: The statistical analysis was performed using Statistical Package for Social Sciences (IBM) Ò Version 23.0; SPSS, Inc., Chicago, IL) and XLSTAT (Version 2015) Statistical package. Continuous Variables were presented in mean (S.D). Paired sample t-test and Pearson's correlation was used to compare the left and right sides, while student t-test was used to determine sex-differences. The sex categori-sation using the measured clavicular parameters was determined using Discriminant Function Analysis (DFA). All analyses were carried out at 95% confidence level; with the significance of the difference accepted at P<0.05.

RESULTS

The results presented are cadaveric measurements used to obtain anthropometric details of the clavicle. Scaled data were represented as mean (S.D). Values were tabulated with respect to side (right = R and left = L) and sex (male = M and female = F). Paired sample t-test, as well as Pearson's correlation analysis, were used to evaluate side difference and level of correlates respectively (Table 1). The extent of sex difference (as well as predictability into group membership) using discriminant function analysis (DFA) of the values obtained from the cadaveric measurements were presented in Tables 2-12.

The result in Table 1 showed high sex differences in the measurement (P<0.01) as well as sex-differentiated correlation in the left and right clavicular measurement (r2 [79 – 98%]; P<0.01). The total (45) measurement (male and female) significantly reduced the interpredictability of corresponding (right and left) measurements reduce the correlation to average (45-67%; P<0.01). All parameters were also significant with varying correlating value for male and female clavicle. The mean values of males were significantly higher in males than females (P<0.001).

Sex categorisation using DFA: The DFA was carried out using the left and right measurement of the clavicle. Test of equality of means in Table 3 showed a significant difference in mean values of both clavicles of both sex (*P*<0.01). The Box's M canonical covariance analysis showed that the values did not meet the expectation of non-covariance (P<0.001); that is, the covariance matrices of the dependent variables are not equal across the groups (Table 4). The within-groups canonical correlations for right and left clavicular parameters in Table 5 showed that the parameters entered into the model accounted for high grouping; R. Clavicle (C_R) [Canonical correlation = 0.896] and L. Clavicle (C_L) [Canonical correlation = 0.863); thus, suggesting that the proportion of variance explained (R^2) by the variables entered into the model was 80.3% for the R. clavicle and 74.5% for the L. clavicle (Table 4).

The group of predictor variables (of the R. & L.

Table 1: Descriptive characteristics and inter-predictability of the clavicle (side).

	Total (N=45)			Male (N=25)			Female (N=20)		
Parameters	**Mean±S.D**	**r**	**P-value (Inf.)**	**Mean±S.D**	**r**	**P-value (Inf.)**	**Mean±S.D**	**r**	**P-value (Inf.)**
R. Length (mm)	143.88±10.6	0.442	*0.001*	146.96±12.05	0.995	*<0.001*	136.13±7.20	0.994	*<0.001*
L. Length (mm)	148.86±9.39		*(S)*	149.08±11.79		*(S)*	137.60±6.99		*(S)*
R. Mid-shaft circumference (mm)	36.47±4.17	0.354	*0.012*	37.43±4.14	0.882	*<0.001*	30.93±1.65	0.963	*<0.001*
L. Mid-shaft circumference (mm)	33.10±4.35		*(S)*	35.90±4.68		*(S)*	30.22±1.58		*(S)*
R. Volume (ml)	23.71±5.56	0.669	*<0.001*	26.85±5.19	0.791	*<0.001*	21.85±1.96	0.972	*<0.001*
L. Volume (mm^3)	25.68±5.31		*(S)*	27.78±5.05		*(S)*	22.53±1.81		*(S)*
R. Medial angle (°)	144.94±11.39	0.673	*<0.001*	150.52±6.92	0.982	*<0.001*	134.13±7.84	0.961	*<0.001*
L. Medial angle (°)	141.90±10.75		*(S)*	148.72±6.96		*(S)*	134.67±6.89		*(S)*
R. Lateral angle (°)	142.26±7.93	0.548	*<0.001*	145.92±5.74	0.936	*<0.001*	136.53±7.85	0.966	*<0.001*
L. Lateral angle (°)	148.18±10.40		*(S)*	148.16±5.47		*(S)*	138.80±7.80		*(S)*
R. Total angle (°)	288.12±19.86	0.669	*<0.001*	296.44±11.98	0.982	*<0.001*	270.67±15.66	0.968	*<0.001*
L. Total angle (°)	290.10±20.62		*(S)*	296.88±11.31		*(S)*	273.47±14.64		*(S)*
R. Weight (g)	24.77±4.21	0.588	*<0.001*	27.33±3.86	0.935	*<0.001*	20.33±3.02	0.987	*<0.001*
L. Weight (g)	27.19±5.60		*(S)*	28.16±4.24		*(S)*	20.42±3.05		*(S)*
R. Robustness index	24.85±2.17	0.737	*<0.001*	25.54±1.99	0.97	*<0.001*	22.65±1.22	0.87	*<0.001*
L. Robustness index	23.35±2.38		*(S)*	24.49±2.45		*(S)*	22.00±1.28		*(S)*

Note: R=Right, L=Left, N=Distribution, S.D=Standard deviation, r=Pearson's correlation, P-value = Probability value, Inf=Inference (S = Significant, NS = Not Significant)

Table 2: Evaluation of the sex difference in left clavicular parameters using student t-test.

Parameter	Right				Left			
	M.D	**S.E.D**	**t-value**	**P-value**	**M.D**	**S.E.D**	**t-value**	**P-value**
Length (mm)	10.83	3.44	3.15	*0.003*	11.47	3.36	3.416	*0.002*
Mid-shaft circumference (mm)	6.5	0.93	6.987	*<0.001*	5.69	1.02	5.565	*<0.001*
Volume (ml)	4.99	1.15	4.324	*<0.001*	5.25	1.11	4.718	*<0.001*
Medial angle (°)	16.39	2.38	6.899	*<0.001*	14.05	2.27	6.203	*<0.001*
Lateral angle (°)	9.39	2.15	4.36	*<0.001*	9.36	2.29	4.082	*<0.001*
Total angle (°)	25.77	4.39	5.867	*<0.001*	23.41	4.13	5.67	*<0.001*
Weight (g)	7	1.17	6.004	*<0.001*	7.75	1.26	6.17	*<0.001*
Robustness index	2.89	0.57	5.076	*<0.001*	2.49	0.69	3.639	*0.001*

Note: M.D = Mean difference, S.E.D = Standard error of the difference, t-value = t-test calculated value, P-value = Probability value, Inf=Inference (S = Significant, NS = Not Significant).

Clavicle) will make predictions that their outcomes are statistically significant (Wilk's Lambda; [C_R=0.255, $\chi^2_{(df=7)}$=47.13, P<0.001], and [C_L=0.197, $\chi^2_{(df=7)}$=55.97, P<0.001] (Table 5), as the C_R parameters that seems to have the most significant capability for predicting group membership was Medial angle (0.555), while Weight, Mid-shaft circumference, Robustness index, Lateral angle, Volume, and length had contributions less than 0.50; however, Total angle was excluded from the equation for failing the tolerance test (with minimum tolerance<0.000). For the C_L, the variables that contributed significantly to the prediction model were Medial angle (0.589), Weight (0.586), and Total angle with other values significantly contribute at a below average (0.430–0.324); however Total angle was excluded from the left model for also failing the tolerance test with minimum values (<0.000) (Table 6).

In Table 7, the DFA results of both groups can additionally be defined by the group means of the predictor variables using the unstandardized canonical discriminant function coefficients. The outcome of the mathematical evaluation produces a group means; referred to as centroids as observed in Table 8. In this study, using the C_R, the males had a mean of 1.522 while female had –2.537 (as mean). While the C_L produced a centroid value of 1.290 for males, -2.150 for females. Upon execution of the mathematical regression equations in Table 7, observations with mean score tending towards a particular centroid are predicted as belonging to the classified group; however, when the difference between the canonical group means is larger, the possibility of attaining more accurate model in classifying the observations increases.

In Table 9 above, the coefficients of linear discriminant function interpret the Fisher's theory, this is also referred to as classification functions, using the clavicular parameters of either the left or the right side. The DFA results explain how sex can be predicted using predictor variables group means; the original classification and the model cross-validation are observed in Tables 10a & b. The right clavicular parameters produced an accurate classification of 91.5% while the left produced 87.0% accurate classification.

The discriminant model for sex categorization was obtained as follows;

Right clavicle:

· **Male** = -1408.353+16.920 (Length) - 71.517 (Mid-shaft circumference) +1.713 (Volume) - 0.067 (Medial angle) + 1.0390 (lateral angle) + 2.999 (Weight) - 106.372(Robustness index).

· **Female** = -1351.094 + 17.254 (Length) - 70.669 (Mid-shaft circumference) + 1.088 (Volume) - 0.503 (Medial angle) + 1.444 (lateral angle) + 1.656 (Weight) - 103.757(Robustness index).

Left clavicle:

· **Male** = -508.815 + 2.291 (Length) - 10.469 (Mid-shaft circumference) + 0.754 (Volume) - 1.235 (Medial angle) + 4.631 (lateral angle) + 0.032 (Weight) - 21.505(Robustness index).

· **Female** = -464.687+2.672 (Length) - 10.178 (Mid-shaft circumference) + 0.351 (Volume) - 1.636 (Medial angle) + 4.682 (lateral angle) - 0.999 (Weight) - 20.467(Robustness index).

Table 3: Box's M statistic (test for homogeneity of covariance matrices).

		C_R	C_L
Box's M		135.827	101.841
F	Approx.	3.772	2.828
	df1	28	28
	df2	3061.289	3061.289
	P-value	**<0.001**	**<0.001**

Note: F = Fisher's test, Approx = Fishers approximate value, df = Degree of freedom, P-value = Probability value.

Table 4: Within-groups canonical correlations for right and left clavicular parameters.

Parameter	Eigen value[a]	Canonical Correlation
Right clavicle	4.065[a]	0.896
Left clavicle	2.920[a]	0.863

[a]Initial canonical discriminant functions were used in the analysis

Table 5: Within-groups canonical correlations for right and left clavicular parameters.

Variable	Wilks' Lambda	Chi-square	Df	P-value	Inf.
Right clavicle	0.255	47.13	7	**<0.001**	S
Left Clavicle	0.197	55.97	7	**<0.001**	S

Table 6: Within-groups correlations between discriminating left and right clavicular parameters and Box's M structured matrix coefficients.

Box's M Structure Matrix Coefficients			
Right clavicle*	Function†	Left clavicle*	Function†
MEDIAL ANGLE (°)	0.555†	MEDIAL ANGLE (°)	0.589†
WEIGHT (g)	0.483	WEIGHT (kg)	0.586†
TOTAL ANGLE (°)[a]	0.472	TOTAL ANGLE (°)a	0.538†
MID-SHAFT CIRCUMFERENCE (mm)	0.466	MID-SHAFT CIRCUMFERENCE (mm)	0.43
ROBUSTNESS INDEX	0.408	LATERAL ANGLE (°)	0.423
LATERAL ANGLE (°)	0.351	VOLUME (ml)	0.367
VOLUME (ml)	0.287	ROBUSTNESS INDEX	0.345
LENGTH (mm)	0.253	LENGTH (mm)	0.324

[a]Failed tolerance test and therefore was excluded from the analysis (space painted brown)

[á]Variables arranged in order of the absolute size of correlation within the discriminant model.

† Average prediction; *Wilk's Lambda p-value <0.01

Table 7: Unstandardized canonical discriminant function coefficients for determining group centroids.

PARAMETRES	Right clavicle	Left clavicle
LENGTH (mm)	-0.082	-0.111
MID-SHAFT CIRCUMFERENCE (mm)	-0.209	-0.084
VOLUME (ml)	0.154	0.117
MEDIAL ANGLE (°)	0.14	0.117
LATERAL ANGLE (°)	-0.1	-0.015
WEIGHT (g)	0.331	0.3
ROBUSTNESS INDEX	0.644	0.302
(Constant)	**-14.739**	**-13.406**

Table 8: Functions at group centroids.

Sex	Right clavicle	Left clavicle
Male#	1.522	1.29
Female#	-2.537	-2.15

unstandardized canonical discriminant functions evaluated at group means

Table 9: Linear discriminant (classification) function for groups.

VARIABLE	Right clavicle[a]		Left clavicle[a]	
	Male	Female	Male	Female
LENGTH (mm)	16.92	17.254	2.291	2.672
MID-SHAFT CIRCUMFERENCE (mm)	-71.517	-70.669	-10.469	-10.178
VOLUME (ml)	1.713	1.088	0.754	0.351
MEDIAL ANGLE (°)	0.067	-0.503	-1.235	-1.636
LATERAL ANGLE (°)	1.039	1.444	4.631	4.682
WEIGHT (g)	2.999	1.656	0.032	-0.999
ROBUSTNESS INDEX	106.372	103.757	21.505	20.467
(Constant)	**-1408.353**	**-1351.094**	**-508.815**	**-464.687**

[a]Unstandardized Classification Function Coefficients

Table 10a: Classification summary (N = 45; M=25, F=20) using right clavicular parameters.

	original classification		cross validation classification	
Grouping	Male (%)	Female (%)	Male (%)	Female (%)
Male	25 (100)←	0(0)	22(88)←	3(12)
Female	0(0)	20(100)←	1(5.0)	19(95)←
N correct	25	20	**22**	**19**
Proportion	1	1	**0.88***	**0.95***

¬**Blue** are representation of the correctly classified values

Original classification N Correct = 45 Proportion Correct = 100

Cross validation N Correct = 41 Proportion Correct = **0.915** (average of cross validation proportion)

Table 10b: Classification summary (N = 45; M=25, F=20) using left clavicular parameters.

	original classification		cross validation classification	
Grouping	Male (%)	Female (%)	Male (%)	Female (%)
Male	24 (96)←	1(4.0)	21 (84)←	4 (16)
Female	0(0)	20(100)←	2 (10)	18 (90)←
N correct	24	20	**21**	**18**
Proportion	0.96	1	**0.84***	**0.90***

¬**Blue** are representation of the correctly classified values

Original classification N Correct = 44 Proportion Correct = 98

Cross validation N Correct = 40 Proportion Correct = **0.87** (average of cross validation proportion)

DISCUSSION

The parameters of the right and left clavicle were highly significant with positive correlation at varying degree for the total population studied. The extent of correlation (80-99%) between the L & R clavicular measurements informed the need for side-specific DFA. This ensured the exclusion of multicollinearity, which may increase r^2 adjusted but reduce the actual model prediction accuracy (r^2-pred).

In this study, DFA was used to determine the accuracy of the clavicle in predicting sex. The left and right clavicle were separately used in prediction into group membership. The model produced the following discriminant canonical function equation;

1. Sex $_{(\text{right clavicle})}$ = -14.739 - 0.082(Length) - 0.209(Mid-shaft circumference) + 0.154(Volume) - 0.14(Medial angle) - 0.10(Lateral angle) + 0.331(Weight) + 0.644(Robustness index)

2. Sex $_{(\text{left clavicle})}$ = -13.406 - 0.111(Length) - 0.084(Mid-shaft circumference) + 0.117(Volume)- 0.117 (Medial angle) - 0.015(Lateral angle) + 0.30(Weight) + 0.302(Robustness index)

Using the current data in this study, the model produced a significant grouping with adjusted canonical centroids of 1.522 to -2.537 for the C_R and 1.290 to -2.150 for the C_L; which implies that, if the equation provides a summative value close to 1.522 for the right clavicle, 1.290 for the left clavicle, the suggestive sex is male, but if the value obtains is close to the negative centroid (-2.150 for the right clavicle and -2.150 for the left clavicle), then the sex is likely female. The model in this study; after cross-validation, using the present data produced model accuracies of 91.5% and 87% for the right and clavicle respectively.

Researches have documented sex discriminatory characteristic of different parts of the human's anatomical structures; with varying degree of reliability and accuracy. Anatomical parts used include the skull[17,18], pelvis [5], long bones[11,12,16], dentition[14], scapula [7,19,20], and smaller bones such as metatarsals, metacarpals, phalanges [15,24, ribs [21,25], and clavicle [6-8,22,23].

Specifically, the clavicle length of the people of North Karnataka Zone predicted sex with an accuracy of 62% for male and 63.30% for females using the right clavicles and 76% for male and 76.50% for females using the left clavicles [22]. Akhlaghi *et al*. [8] reported an accuracy ranging from 73.3%-88.3% using the maximum length and midshaft circumference of the clavicles of Iranian origin, while Ishwarkumar *et al*. [26] using similar dimensions as Akhlaghi *et al*. [8] reported an accurate sex prediction of 89% for KwaZulu-Natal population. The accuracy in s ex-estimation using the Anterior curved length (ACL), Posterior curved length (PCL), Mid clavicular circumference (MC), junction between the medial 2/3rd and lateral 1/3rd (JC), and Mid clavicular anteroposterior diameter (APD) was 93.9 % for males and 93.3% for females with a total accuracy of 93.7% [23]. Although the prediction accuracies varied with different dimensions among the populations, however, the prediction for females were often better [8,22].

Quite impressive, the prediction using this model produced classification (after cross-validation) above the 90% benchmark accuracy postulated by Iscan and Ding [11], Iscan [13], Ibeachu *et al*.,[14] and Alabi *et al*.[16] while the left clavicle was just slightly below (87%). Thus, the prediction into group membership was strong and accurate enough; with a better prediction for females than males.

CONCLUSION

Using the studied clavicular parameters, forensic investigators will be at least 87% confident that sex can be estimated especially when the clavicles are of Nigerian Origin. At this point, one can conclude that positive sex identification from clavicular morphometry is valid, as well as reliable.

ACKNOWLEDGEMENTS

The authors are grateful to all the Heads of Department for their cooperativeness during the research and for providing the required assistance and technical support for the data collection.

Conflicts of Interests: None

REFERENCES

[1]. Kumar R, Madewell JE, Swischuk LE, Marvin ML, David R. The Clavicle: Normal and abnormal. Department of Radiology. The University of Texas Medical Branch. Galveston, TX77550. 1989.

[2]. Chris, Clavicle (Human Collar bone Anatomy Pars, Location and Functions), 2016. Available at www.headthhype.com [Accessed on February 12, 2018].

[3]. Moore K, Arthur F. Clinically oriented Anatomy. 5th Edition. Philadelphia Lippincott William and Wilkins 2006; 728-730, 848-852.

[4]. Krogman WM. The Human skeleton in forensic medicine. Springfield, Illinois, U.S.A Charles C. Thomas Pub Ltd 1962.

[5]. Davivongs V. The Pelvic Girdle of the Australian Aborigines: Sex difference and sex determination. Am J Phys Anthropol 1963; 21: 443-455.

[6]. Chavda HS, Khatri CR, Varlekar PD, Saiyad SS. Morphometric analysis and sex determination from clavicles in Gujarati Population. NJIRM 2013; 4(6): 18-22.

[7]. Papaioannou VA, Kranoti EF, Joveneaux P, Nathena D, Michalodimitrakis M. Sexual Dimorphism of the Scapula and the clavicle in a contemporary Greek Population: Application in Forensic Identification. Forensic Sci Int 2012; 217(1-3) 231.e1-231.e7.

[8]. Akhlaghi M, Moradi B, Hajibeygi M. Sex Determination using Anthropometric dimensions of the clavicle in Iranian population. J Forensic Leg Med 2012; 19(7): 381-385.

[9]. Olivier G. Anthropologic de la clavicula III La clavicule du Françis. Bull soc Anthrop 1951; 2: 121-157.

[10]. Fisher R. The Precision of Discriminate Function Analysis. Ann Hum Genet 1940; 10(1): 422-429.

[11]. Iscan MY, Ding S. Sexual dimorphism in the Chinese Femur. Forensic Sci Int 1995; 74: 79-87.

[12]. Iscan MY, Miller-Shaivitz P. Determination of Sex from the Tibia. Am J Phys Anthropol 1984; 64: 53-57.

[13]. Iscan, MY. Forensic anthropology of sex and body size (Editoral). Forensic Sci Int 2005; 147: 107-112.

[14]. Ibeachu PC, Aigbogun E, Didia BC, Fawehinmi HB. Determination of Sexual Dimorphism by Odontometric Study using Discriminante Function Analysis of Adult Ikwerre Dental cast, SJAMS 2015; 3(4B): 1732-1738.

[15]. 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(4): 226-232.

[16]. Fischer B, Mitteroecker P. Allometry and sexual dimorphism in the Human pelvis. Anat Rec (Hoboken) 2017; 300: 698–705.

[17]. Gouda HS, Bastiia BK. Sexual dimorphism of skull-Morphological and mathematical facet. Indian J Forensic Med Toxicol 2010; 4(2): 52-54.

[18]. Kölzer SC, Kümmell IV, Kölzer JT, Ramsthaler F, Plenzig S, Gehl A, Verhoff MA. Human frontal inclination of the skull as a trait of sexual dimorphism-terminology and quantification. Arch Kriminol 2015; 235(1-2): 11-21.

[19]. Di Vella G, Campobasso CP, Dragone M, Introna FJ. Skeletal sex determination by scapular measurements. Boll Soc Ital Biol Sper 1994; 70(12): 299-305.

[20]. Patel SM, Shah MA, Vora RK, Goda JB, Rathod SP, Shah S. Morphometric analysis of scapula to determine sexual dimorphism. Int J Med Public Health 2013; 3: 207-210.

[21]. Bellemare F, Fuamba T, Bourgeault A. Sexual dimorphism of human ribs. Respir Physiol Neurobiol 2006; 150 (2-3): 233-239.

[22]. Shobha SC, Jatti B, Murthy CR. Identification of sex of human clavicles from North Karnataka zone. Anthropologist 2014; 17(2): 917-920.

[23]. Doshi MA, Reddy BA. Determination of sex of adult human clavicle by discriminant function analysis in Marathwada region of Maharashtra. IJRMS 2017; 5(9): 3859-3864.

[24]. Rogers TL. Sex determination of adolescent skeletons using the distal humerus. Am J Phys Anthropol 2009; 140(1): 143-148.

[25]. Weaver AS, Schoell SL, Stitzel JD. Morphometric analysis of variation in the ribs with age and sex. J Anat 2014; 225: 246-261.

[26]. Ishwarkumar S, Pillay P, Haffajee MR, Rennie C. Sex determination using morphometric and morphological dimensions of the clavicle within the KwaZulu-Natal population. Int J Morphol 2016; 34(1): 244-251.

How to cite this article: Woroma I. Benwoke, Eric O. Aigbogun (Jr.), Emmanuel Bienonwu, Tamuno-Olobo Johnbull. THE CLAVICLE AS A FORENSIC TOOL: SEX-DISCRIMINATORY CHARACTERISTICS IN CADAVERIC SAMPLES OF NIGERIA ORIGIN. Int J Anat Res 2019;7(2.1):6336-6340b. **DOI:** 10.16965/ijar.2019.109