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The Use of Foramen Magnum in The Determination of Sex Using Computed Tomography (CT) Scan Images of Sampled Population Attending National Ear Care Centre Kaduna State, Nigeria

قياس الثُّقبة العظمى لتقدير الجنس باستخدام صور التصوير المقطعي المحوسب لعينة من مراجعي المركز الوطني للعناية بالأذن بولاية كادونا، نيجيريا

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Abstract

Determination of sex is an important element of human identification which becomes challenging when only only fragments of body parts are available for investigation by forensic experts.

This study was aimed at assessing the utility of foramen magnum parameters in the determination of sex among the Nigerian population.

A retrospective study was conducted on patients attending National Ear Care Center Kaduna between the years 2017-2019. A total of 399 normal Multislice CT images of skulls (236 males and 163 females) of the age of 18 – 95 years were randomly picked from the archives of the Hospital in the computer database of the Radiology Department. The foramen magnum and occipital condyles parameters were measured by an experienced radiologist.

Males tend to have a significantly higher mean value of foramen magnum width, Foramen Magnum Index, the

Keywords: Forensic Science, Foramen Magnum, Sex Differences, Nigeria.

المستخلص

يُعتبر تقدير الجنس عنصرًا مهمًا في تحديد الهوية البشرية، ويصبح عملًا صعبًا للغاية عندما لا تتوافر سوى بقايا من أعضاء الجسم متاحة للتحقيق من قبل خبراء الطب الشرعي.

وقد هدفت هذه الدراسة إلى تقييم صحة تقدير الجنس لدى السكان النيجيريين بواسطة قياس الثُّقبة العظمى.

وتم إجراء دراسة استرجاعية على مرضى من مراجعي المركز الوطني للعناية بالأذن في كادونا بين عامي 2017-2019. وتم اختيار ما مجموعه 399 صورة مقطعية طبيعية متعددة الشرائح للجمجمة لدى 236 من الذكور و163 من الإناث تتراوح أعمارهم بين 18 و95 عامًا بشكل عشوائي من أرشيف قاعدة بيانات الحاسب في قسم الأشعة في المستشفى؛ حيث أجرى أخصائي أشعة ذو خبرة قياس أبعاد الثُّقبة العظمى واللقمة القذالية.

وتبين أن المتوسط لدى الذكور كان ذا قيمة أعلى بكثير منه لدى الإناث من ناحية عرض الثُّقبة العظمى، ومؤشر الثُّقبة العظمى، وطول اللقمة

الكلمات المفتاحية: علوم الأدلة الجنائية، الثُّقبة العظمى، الاختلافات بين الجنسين، نيجيريا.

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length of the right occipital condyle, and the length of left occipital condyles as well as the width of the right occipital condyle at a p-value ≤ 0.05. The width of right occipital condyles was the only variable that got a significant ($p \leq 0.05$) impact on our sex estimation following multiple logistic regression. However, by applying discriminate function analysis the length of the left occipital condyle and width of the right occipital condyle were the only discriminatory variables chosen for this study population.

In conclusion, this study indicated that five variables of foramen magnum out of ten were statistically significantly different with males having higher mean values than females. Moreover, the only significant discriminatory variables to determine sex in this study population were the length of the left occipital condyle and the width of the right occipital condyle respectively.

القذالية اليمنى، وطول اللقمة القذالية اليسرى بالإضافة إلى عرض اللقمة القذالية اليمنى بقيمة احتمالية ($p \leq 0.05$). فيما كان عرض اللقمة القذالية اليمنى هو المتغير الوحيد ذو التأثير الكبير على تقدير الجنس اعتمادًا على الانحدار اللوجستي المتعدد بقيمة احتمالية ($p \leq 0.05$). وعلى الرغم من ذلك، ومن خلال إجراء التحليل الوظيفي التمييزي، فقد كان طول اللقمة القذالية اليسرى وعرض اللقمة القذالية اليمنى هما المتغيران التمييزيان الوحيدان اللذان تم اختيارهما لمجتمع الدراسة.

وفي الختام، أشارت هذه الدراسة إلى وجود فروق ذات دلالة إحصائية في خمسة متغيرات من أصل عشرة، كما أن المتوسط كان ذا قيمة أعلى لدى الذكور منه لدى الإناث. بالإضافة إلى ذلك، فإن المتغيرات التمييزية المهمة الوحيدة لتقدير الجنس في مجتمع الدراسة كانت طول اللقمة القذالية اليسرى وعرض اللقمة القذالية اليمنى على التوالي.

1. Introduction

Sex determination is an essential component of human identification which becomes challenging when only fragments of body parts were available for investigation by forensic scientists [1–3]. The DNA analysis is known to be a reliable way of estimating sex, but due to cost and time exhaustion as well as the effect of local conditions [4], the human skeletal remains are used instead as reliable determinants of sex [5]. especially in situations where DNA analysis is not achievable, and often, the anthropological examination of occipital bone which forms part of the skull's base is used in sex estimation since it has the propensity to withstand physical insults caused by fire or entombment better than many other regions of the cranium [5,6].

The morphological and metric methods are the two methods used commonly for the determination-determinationof sex in the human cranium. The former involves the use of anatomical impressions of the cranium such as crudeness of the nuchal lines or the external occipital protuberance which are sites for muscular attachment [7–10] while the latter involves the method of measurements by discriminant functions [11,12].

The foramen magnum is an important landmark located at the occipital bone in the base of the cranium [13]. It is bounded anteriorly by the basilar part and posteriorly by the squamous part of the occiput. On each side of the anterior half of the foramen magnum is the occipital condyles which are joint surfaces that articulate with the atlas vertebra to form the Antlanto-occipital joints. Several authors reported the use of dimensions of occipital condyles and the foramen magnum for quantitative diagnosis of sex [14–17].

The skull is an effective bone used precisely to estimate the sex of an individual by using Radiological modalities such as computed tomography (CT), magnetic resonance imaging (MRI), as well as X-ray, and that provides suitable data which is similar to measurements calculated through the use of callipers in the dry skulls [18] since some studies [19,20]. revealed that measurements obtained using Come Beam Computer Tomography were not different statistically from those obtained in the solid skeleton.

Although previous studies conducted in different populations for morphometric cranial analyses using CT scan images showed different accuracy rates, for example, the overall predictive accuracy rate in the Indian population was given as 74% [5] and 90.9% [21], Nigerian population as 65.5% [22], Turkish population as 91.5% [23], Swiss population as 66% and Bulgarian population as 60.7% - 69.3% [24] among others, while the anatomic overall predictive accuracy among Indian population was given as 64.5% [25].

The foramen magnum is an important land mark located at the occipital bone in the base of the cranium [13]. The anatomic and radiologic values of the foramen magnum have been the purpose of several studies. However, the anatomic values which are obtained by direct measurements of the skull are nearly the same but differ slightly from radiologic values which are obtained through the imaging modality [26].

Even though foramen magnum has the forensic potential to identify unknown skeletal stiff, few studies have been reported in the Nigerian population using both the anatomic metric method [27] as well as the radiologic method [22,28]. Therefore this study aims to evaluate the potential accuracy of foramen magnum dimensions to differentiate sex using a discriminant function analysis when a broken piece of skull's base is available for identification among the adult Nigerian population by Computed Tomography imaging.

2. Materials and Methods

2.1 Study population

The study was conducted retrospectively in the unit of Radiology of the National Ear Care center Kaduna, in Kaduna State North-Western Nigeria.

A total of 399 subjects (comprising 236 males and 163 females) cranial computed tomography scans of known sex available at the archive of the National Ear Care center Kaduna were randomly collected from the database from 2017 through 2019 by systematic random sampling method. The unequal numbers of male and female subjects were obtained due the randomization effect or drop-out of samples as per the exclusion criteria, and data were collected based on its availability on the archives. Highly reconstructed CT images with normal scans of human skulls between the ages of (18 – 95 years of male and female sexes) that came for computed tomography on account of medical or surgical indications were included in the study. Fuzzy or images with low-quality, cut images, artifacts, or subjects with a history of traumatic injuries, surgical disease anomalies such as congenital defects of the head, and focal brain lesions that may lead to deformities in the skull region were excluded. Ethical approval was obtained from National Ear Care Center, Kaduna Health Research Ethics Committee (NECC/ADM/197/1/95).

Table 1- *The standard acquisition protocol used in obtaining the head computed tomography (CT) scans.*

Acquisition parameter	Value
Tube current (kVp)	120 - 140
Tube current modulation	Helical and sure exposure + 3D reconstruction
Pitch	0.652
Rotation time (s)	3.0
Detector configuration	32 × 0.5
Scan range	Base of skull to vertex
Slice thickness (mm)	5.0

2.2 Image acquisition and measurement procedure

Images were gotten by Toshiba Acquilion 16 Slices CT Scanner (Toshiba Medical systems Corporation, Otawara, Japan) using a standard acquisition protocol as presented in Table 1.

Table 1 indicates standard acquisition protocol used to perform the head computed tomography (CT) scans.

Measurements of the skull were performed on workstation software (Vitrea CT Software Version 6.9.2) on transaxial image of the skull based on the previous report by Chovalopoulou and Bertsatos as well as Uysal [5,29] as shown in Table 2.

2.3 Statistical analysis

The data were expressed as mean ± standard deviation (SD). The mean differences of the studied variables in males and females were obtained using a student's t-test while paired t-tests were employed to determine the bilateral asymmetry between measurements involving the right and left sides.

Table 2 - *Procedure for the measurement of the craniometric parameters*

S/No	Parameter	Methodology
1.	Maximum internal length of the foramen magnum (FML)	Measured in an anteroposterior direction along the principal axis of the FM in mid-sagittal plane (the basion–opisthion distance).
2.	Maximum internal width of the foramen magnum (FMW)	Measured approximately perpendicular to the FML and recorded at the widest transverse diameter of the FM (the greatest distance between the lateral borders of the foramen magnum; perpendicular to the midsagittal plane).
3.	The measured length and width will be inserted into two different reported formulae to estimate: a. The foramen magnum index (FMI), b. The foramen magnum area (FMA),	It is the quotient of the anteroposterior and transverse diameters; FMI =WFM/LFM X 100. according to Routal (1) : Area=¼ Xπ X FML X FMW.
4.	The maximum length of the right occipital condyle (LROC)	Measured along the long axis from the edges of the articular surface.
5.	The maximum length of the left occipital condyle (LLOC):	Measured along the long axis from the edges of the articular surface.
6.	.The maximum width of the right occipital condyle (WROC):	Measured from the articular edges along a line perpendicular to the long axis.
7.	The maximum width of the left occipital condyle (WLOC):	Measured from the articular edges along a line perpendicular to the long axis.
8.	Maximum bicondylar distance (MBD):	The distance between the lateral edges of the articular surfaces of the condyles
9.	Minimum intercondylar distance (MnICD):	Direct distance from the most medial point on the margin of the left occipital condyle to the most medial point on the margin of the right occipital condyle.

Correlations between the measured variables were investigated using Pearson's correlation coefficient.

The receiver operating characteristic curve (ROC) was performed to test for sensitivity and specificity using different cut-off points. The univariate and multivariate logistic regressions were performed with the significant parameters to predict better significant determinants of sex by moderating the confounding factors.

The discriminant functions analysis was used to determine the variables that best predict sex. The discriminant equation was developed by using a coefficient and constant and a sectioning point was obtained by taking the average of the males and females group centroids respectively. Fisher's linear discriminant analysis is a linear combination of measured parameters that best describe the separation between known groups of the observation, and it classifies or predicts problems where the dependent variable appears in quantitative form. The canonical discriminant function is a linear combination of variables that best separates the mean vectors of two more groups of multivariate observation. The value higher than the sectioning point indicates the male sex while the values lower than the sectioning point indicate the female sex. The cross-validated accuracy rates of the significant variables were obtained, and a p-value ≤ 0.05 was deemed statistically significant. All statistical analysis was performed using Statistical Package for the Social Sciences software (IBM SPSS Statistic 20 Ink).

Table 3 - *Mean, standard deviation of the studied Nigerian population (n =399) with Mean differences in males (n = 236) and females (n =162).*

Parameters	TOTAL (n = 399)		MALES n = 236) 95% CI)			FEMALES n = 162) 95% CI)		
	Min-Max	Mean ± SD	Lower Bound	Upper Bound	Std. Error	Lower Bound	Upper Bound	Std. Error
FML (cm)	2.82-5.08	3.73±0.35	3.69	3.78	0.02	3.66	3.77	0.03
FMW (cm)	2.05-4.53	3.02±0.35	3.01	3.10	0.02	2.92	3.04	0.03
FMI	54.00-119.72	81.36±7.80	81.12	82.98	0.47	79.10	81.73	0.66
FMA (cm^2)	4.66-16.20	8.91±1.67	8.80	9.21	0.10	8.50	9.04	0.14
LROC (cm)	1.15-3.25	2.01±0.20	2.00	2.05	0.01	1.95	2.01	0.01
LLOC (cm)	1.23-3.51	2.01±0.22	2.00	2.06	0.02	1.95	2.01	0.01
WROC (cm)	0.84-2.36	1.23±0.12	1.23	1.26	0.01	1.20	1.23	0.01
WLOC (cm)	0.83-2.00	1.24±0.12	1.24	1.27	0.01	1.21	1.25	0.01
MBD (cm)	2.02-3.84	2.93±0.30	2.90	2.97	0.02	2.86	2.96	0.02
MnID (cm)	0.89-1.99	1.42±0.21	1.40	1.46	0.01	1.37	1.43	0.02

SD: Standard deviation, cm: centimeter, Std: Standard, CI: Confidence Interval, FML: Foramen magnum length, FMW: Foramen magnum width, FMI: Foramen magnum index, FMA: Foramen magnum area, LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle, WROC: width of Right occipital condyle WLOC: width of Left occipital condyle, MBD: Maximum intercondylar distance, MnID: Minimum intercondylar distance.

3. Results

Table 3 indicates the mean and standard deviation of the studied Nigerian population (n=399) with mean differences in males and females respectively.

Table 4 indicates the mean and standard deviation of the foramen magnum and occipital condyles parameters in a studied Nigerian population. The result showed significant sexual dimorphism in the width of the foramen magnum, foramen magnum index, and length of right and left occipital condyles, as well as the width of the right occipital condyle respectively. The males scored higher mean values than females in all the aforementioned variables. However, the result of paired t-test showed no significant bilateral asymmetry on the left and right occipital condyle dimensions in males and females.

Tables (5 and 6) indicate a correlation of the craniometric parameters in the studied population from Nigeria across sexes: the result indicates the strength of the relationship between the studied craniometric variables. The strongest relationship was seen between foramen magnum width with foramen magnum area (r = 0.909) and foramen magnum length with foramen magnum area (r = 0.872) among males. A similar trend was also noted among females.

Fig. 1 indicates the receiver operating characteristic curve: among the significant univariate variables, the length of the left occipital condyle (LLOC) indicates a better possibility of sex prediction (having the higher area under the curve value i.e AUC = 0.571) followed by foramen magnum width (AUC = 0.569), length of right occipital condyle (AUC = 0.563) and width of right occipital condyle (AUC = 0.562) respectively.

Table 7: indicates the binary logistic regression

Table 4 - *Mean and standard deviation of foramen magnum and occipital condyles parameters among the studied Nigerian population in males (n= 236) and females (n = 163)*

Parameters	MALES (n = 236)		FEMALES (n = 163)			
	Min-Max	Mean ± S.D	Min-Max	Mean ± SD	t-value	P
FML (cm)	2.82-5.08	3.73 ±0.35	2.87-4.81	3.72±0.37	.379	0.705
FMW(cm)	2.16-4.53	3.05 ±0.33	2.05-4.37	2.98±0.37	2.027	0.043
FMI	57.58-106.41	82.05 ± 7.26	54.00-119.72	80.37±8.44	2.062	0.040
FMA$(cm)^2$	5.35-16.20	9.00 ± 1.61	4.66-15.53	8.77±1.74	1.378	0.169
LROC (cm)	1.15-3.25	2.02 ± 0.21	1.62-2.48	1.98±0.18	2.148	0.032
LLOC(cm)	1.23-3.51	2.03 ±0.24	1.58-3.00	1.98±0.19	2.257	0.025
Paired t ¥	t = -0.69	P = 0.36	t = -0.28	P = 0.78		
WROC(cm)	0.95-2.36	1.25 ± 0.13	0.84-1.57	1.22±0.11	2.349	0.019
WLOC(cm)	1.01-1.49	1.25 ± 0.11	0.83-2.00	1.23±0.13	1.873	0.062
Paired t ¥	t = - 0.92	p = 0.09	t = -1.58	p = 0.12		
MBD(cm)	2.23-3.84	2.94 ± 0.29	2.02-3.74	2.91±0.30	.840	0.401
MnID(cm)	0.90-1.99	1.43 ±0.22	0.89-1.99	1.40±0.20	1.534	0.126

S.D: Standard deviation, cm: centimeter, Min: minimum, Max: maximum, FML: Foramen magnum length, FMW: Foramen magnum width, , FMI: Foramen magnum index, FMA: Foramen magnum area, , LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle, WROC: width of Right occipital condyle WLOC: width of Left occipital condyle,MBD: Maximum intercondylar distance, MnID: Minimum intercondylar distance., ¥ Paired-t comparing right to left, *significant p <0.05.

Table 5 - *Correlations between craniometric parameters in males group (n = 236)*

Variable	FML (cm)	FMW (cm)	FMI	FMA (cm^2)	LROC (cm)	LLOC (cm)	WROC (cm)	WLOC (cm)	MBD (cm)	MnID (cm)
FML (cm)	1	0.596**	-0.303**	0.872**	0.202**	0.246**	0.007	0.082	0.289**	0.045
FMW (cm)		1	0.579**	0.909**	0.275**	0.303**	0.097	0.210**	0.529**	-0.002
FMI			1	0.193**	0.119	0.107	0.115	0.160*	0.342**	-0.039
FMA (cm^2)				1	0.266**	0.310**	0.064	0.174**	0.465**	0.022
LROC (cm)					1	0.533**	0.164*	0.209**	0.291**	-0.069
LLOC (cm)						1	0.123	0.254**	0.250**	-0.011
WROC (cm)							1	0.471**	0.104	0.001
WLOC(cm)								1	0.144*	-0.067
MBD (cm)									1	0.102
MnID (cm)										1

FML: Foramen magnum length, FMW: Foramen magnum width, FMI: Foramen magnum index, FMA: Foramen magnum area, LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle, WROC: width of Right occipital condyle WLOC: width of Left occipital condyle, MBD: Maximum intercondylar distance, MnID: Minimum intercondylar distance. * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level.

Table 6 - *Correlations between craniometric parameters in females group (n = 163)*

Variables	FML (cm)	FMW (cm)	FMI	FMA $(cm)^2$	LROC (cm)	LLOC (cm)	WROC (cm)	WLOC (cm)	MBD (cm)	MnID (cm)
FML (cm)	1	0.562**	-0.243**	0.849**	0.285**	0.212**	0.016	0.081	0.362**	0.039
FMW (cm)		1	0.660**	0.910**	0.266**	0.261**	0.008	0.069	0.537**	-0.085
FMI			1	0.292**	0.053	0.123	-0.010	0.011	0.292**	-0.120
FMA (cm^2)				1	0.306**	0.255**	0.014	0.078	0.518**	-0.042
LROC (cm)					1	0.630**	0.096	0.140	0.341**	-0.115
LLOC (cm)						1	-0.008	0.089	0.300**	-0.046
WROC (cm)							1	0.540**	-0.037	-0.050
WLOC (cm)								1	0.079	-0.025
MBD (cm)									1	0.058
MnID (cm)										1

FML: Foramen magnum length, FMW: Foramen magnum width, FMI: Foramen magnum index, FMA: Foramen magnum area, LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle, WROC: width of Right occipital condyle WLOC: width of Left occipital condyle, MBD: Maximum intercondylar distance, MnID: Minimum intercondylar distance. * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level.

of the significant univariate parameters. Firstly the WROC with an odd ratio (OR) of 8.309 was the best predictor model followed by LLOC (OR = 2.997) and LROC (OR = 2.997) respectively. However, following multivariate logistic regression using the stepwise discriminant function, only WROC with an adjusted odd ratio (AOR) of 6.134 was chosen as a significant independent predictor of sex, and the equation for prediction of sex using the model is given as Sex = WROC*1.814 – 5.932. Where

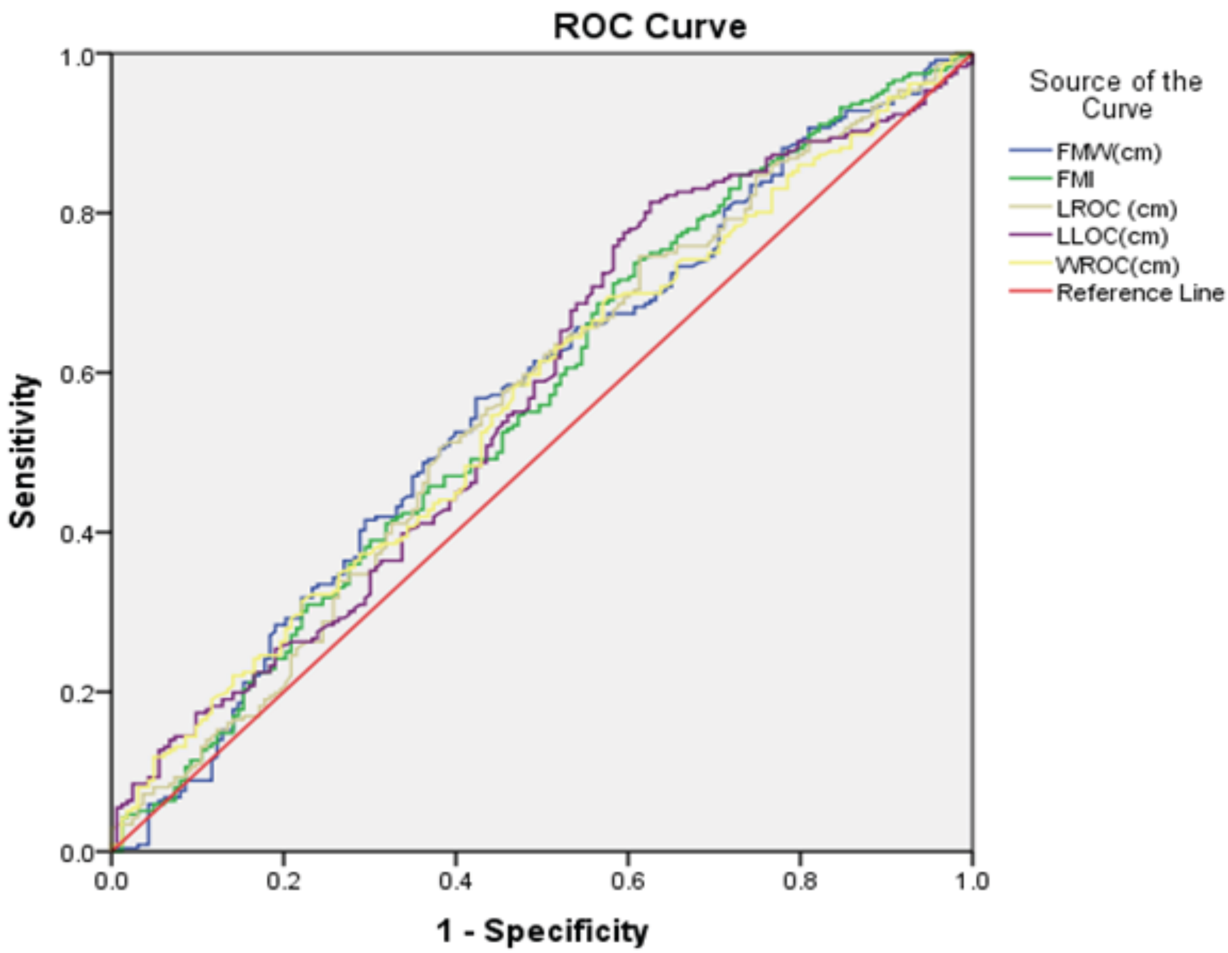

Fig 1- *Receiver operating characteristic curve (ROC) for the significant univariate parameter (FMW -= 0.569, LROC = 0.563, LLOC = 0.571, WROC = 0.562) among the studied parameters in the Nigerian population (n = 399). FMW: Foramen magnum width, FMI: Foramen magnum index, LROC: Length of right occipital condyle, WROC: width of right occipital condyle.*

Table 7 - *Binary Logic regression analysis for Nigerian population (n = 399)*

Independent Predictors	Univariate Logistic Regression Analysis				Multivariate Logistic Regression Analysis			
	Constant	B	P-value	OR (95% CI)	Constant	B	P-value	AOR (95% CI)
FMW(cm)	-1.46	0.608	0.043	1.84 (1.018-3.314)		0.103	0.80	1.109(0.503-2.442)
FMI	-1.92	0.028	0.036	1.029 (1.002-1.056)		0.020	0.23	1.021(0.987-1.056)
LROC (cm)	-1.826	1.098	0.039	2.997 (1.055-8.510)		0.429	0.51	1.536(0.426-5.537)
LLOC (cm)	-1.781	1.098	0.039	2.997 (1.098-7.768)		0.617	0.31	1.854(0.569-6.043)
WROC (cm)	-2.235	2.117	0.021	8.309 (1.376-50.177)	-5.932	1.814	0.05	6.134(0.981-38.346)

FMW: Foramen magnum width, FMI: Foramen magnum index, , LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle, WROC: width of Right occipital condyle. OR: Odds ratio, AOR: Adjusted odds ratio, CI: Confidence interval, *significant p<0.05.

1.814 is the beta coefficient (B) and -5.932 is the regression constant in the equation.

Table 8: indicates the canonical discriminant coefficients for various parameters.

The contributions of a particular parameter to the classification were seen with the standardized coefficients.

- 0.029 was the calculated sectioning point and sex will be determined by comparing the discriminant equation (discriminant score =D) with the sectioning point. If the calculated discriminant score is greater than the sectioning point, then the individual will be classified as male, and if the score is less than the sectioning point, then the individual will be classified as female.

The equation for prediction of sex in this studied population has been put as Y = - 2.953 LLOC + 5.754 WROC + (-13.040).

Table 9: indicates the percentage of correct group membership. The overall predictive accuracy after cross-validation is given as 54.4%, which could correctly identify individuals in 54.6% and 54.2% of the cases as males and females respectively as indicated by the multivariate analysis.

4. Discussion

The base of the cranium is known to withstand both physical insults caused by fire or following the changes caused by the environment and time [2,11,17]. Also in situations where DNA examination is not possible as a result of mortification or damage of the sample material following extensive heat damage [30–32] the base of the cranium can be used to estimate sex by metric measurements. Its ability to remain intact due to the robustness of the bone of the occiput and the protective anatomical position of its feature [17,21,33–35] has made it the area of choice for many researchers across the globe. Despite that sex determination may pose a great challenge in catastrophic conditions especially

Table 8 - *Canonical discriminate coefficients, of craniometric Measurements of Nigerian population (n = 399)*

Variable	Cononical df Male Female		Fisher's Ldf				Group Centroid	
	Constant	Coefficient	Constant	Coefficient	Constant	Coefficient	Male	Female
			Univaraite Analysis					
FMW(cm	-8.727	2.885	-39.345	25.424	-37.908	24.825	0.085	-0.123
WROC (cm)	-10.040	8.139	-51.908	82.510	-49.890	80.571	0.097	-0.141
FMI	-10.040	8.139	-51.908	82.510	-49.890	80.571	0.097	-0.141
LROC (cm)	-9.965	4.969	-51.050	49.953	-49.304	48.896	0.087	-0.126
LLOC (cm)	-9.109	4.526	-42.842	41.636	-41.190	40.629	0.091	-0.132
			Multivariate Analysis					
LLOC (cm)		2.953		38.174		37.248	0.128	-0.186
WROC (cm)		5.754		76.956		75.151		
Constant	-13.040		-87.247		-83.536			

LDF: Linear Discriminate function, WROC: width of Right occipital condyle, LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle.

Table 9 - *Percentages of correct group membership and cross validation of craniometric measurements in Nigerian population (n = 399)*

Variable	(%) Corrected Prediction Rate			Corrected Prediction Rate (%) After Cross Validation		
	Male	Female	Mean	Male	Female	Mean
			Univaraite Analysis			
FMW(cm)	98.7	4.3	60.2	98.3	3.7	59.6
WROC(cm)	97.5	3.7	59.1	96.2	3.7	58.4
FMI	97.5	4.9	59.6	97.5	4.9	59.6
LROC (cm)	99.2	1.2	59.1	99.2	0.6	58.9
LLOC(cm)	98.3	1.2	58.6	98.3	0.6	58.4
			Multivariate Analysis			
LLOC(cm)	54.2	55.2	54.6	54.6	54.2	54.4
WROC(cm)						
Constant						

Mean = Mean Correct Prediction rate, WROC: width of Right occipital condyle, LROC: Length of Right occipital condyle, LLOC: Length of Left occipital condyle.

if a fragment of the human skeleton are the only evidence available for identification [36].

Few studies have been reported on the Nigerian population using the anatomic metric method [27] as well as the radiologic method of sex determination using cranial dimensions [22,28,37], despite the miscegenation nature caused by diverse ethnic groups. This study provides a discriminant measurement for foramen magnum and occipital condyles which can be used when CT scan images of a broken piece of the skull are available for evaluation of sex among the adult Nigerian population.

The significant difference in sex of foramen magnum width, width of right occipital condyle, foramen magnum index as well as left and right occipital condyles in this study corroborate the previous report of Bello and Zirahei [22,37] in Nigeria, and is in partial agreement with the report of Abo-El-Atta and Ibrahim [1,38] from the Egyptian population, as well as Gargi [21] from Indian population. The values of foramen magnum dimensions are slightly higher in this study than in the previous studies of Abo-El-Atta, Murshed, Uthman and Tambawala [1,2,26,39] from Egypt, turkey, Iraq and Indian population respectively, but lower than the studies of Barrany and Madadin [40,41] from Sudan and Saudi Arabian population respectively, this could be partly due to genetic and or environmental conditions resulting from different geographic locations emphasizing the population specificity in anthropological variables.

Several studies involving measurements of the Foramen magnum (FM) using different metric means like direct anatomical measurement of the skull base, X-ray radiographs, or CT scans indicated sexual dimorphism of the foramen magnum [29,39,42]. However, in partial agreement with the present study, some studies have argued that sexual differentiation in the foramen magnum does not exist [32,43].

The foramen magnum index (FMI) in the present study indicated differences in males and females, which contradicts the findings of Gargi [21] in the Indian population

Statistically significant relationships were observed in the present study between LLOC/LROC, WLOC/WROC, FML/FMW, FML/FMI, FML/FMA, FMW/FMI, and FMW/FMA between males and females, pointing to a uniform growth across males and females in the Nigerian population. This is in line with the study of the Egyptian population [1]. Moreover, the strongest relationships were observed between FMW/FMA and FML/FMA among males and females which agrees with the previous findings [1,26,39,40]. However, the weakest correlations were those of WLOC/MBD among males and FML/LLOC among females respectively. These findings are in partial agreement with the report of Abo-El-Atta et al [1] from the Egyptian population.

Receiver Operating Characteristic (ROC) curves for the significant univariate variables (FMW, FMI, LROC, LLOC, and WROC) were applied (AUC= 0.569, 0.566, 0.563, 0.571, and 0.562 respectively) indicating that LLOC is the best variable for determination of sex. This finding is contrary to the report of Babu et al from the Indian population and Toneva et al from the Bulgarian population [24,25] who independently reported that ROC analysis in their study reveals foramen magnum length to be the best parameter for determination of sex followed by foramen magnum area. The foramen magnum width has the lowest predicting- ability in sex determination in comparison with the length and area of the foramen magnum but is in partial agreement with that of Abo-El-Atta et al [1] from the Egyptian population emphasizing that ethnic variation and sample sizes can affect.

The present study highlighted the possible application of binary logistic regression of the univariate predictors such as that of WROC, LLOC and LROC, as the independent parameters for the determination of male sex among Nigerian population, although, following multivariate regression only WROC with an adjusted odd ratio (AOR) of 6.134 was picked-out as the significant independent predictor of sex, this is in partial agreement with the report from Egyptian population [1,38] but contradict reports from Turkey, Sudanese and Swiss population respectively [29,40,44].

The result of the univariate discriminant function in this study showed FMW and FMI to predict sex better independently (both having an accuracy of 59.6%). This contradicts the findings of Madadin and Tellioglu [36,41].

The present results confirm that the foramen magnum is a sexually dimorphic structure with significantly different dimensions in male and female sexes. However, the accuracy rates of the produced discriminant functions and regression models do not indicate that the foramen magnum dimensions are very useful in sex assessment as indicated by the low accuracy predictive rate of this study. However, the generated formulae can be used with other complementary parameters of the cranium to estimate the sex of an unknown victim found and brought for a CT scan from a scene. Similar findings by Lopez-Capp [45] were also seen in the Brazilian population but Abo El-Atta [1] in Egypt, [26], Aljarrah in Saudi Arabia [46], Wani from Indian population [47], as well as Toneva [24] from Bulgarian Population reported higher accuracy following the summation of all the foramen magnum parameters to a discriminant model.

5. Conclusion

The present study has shown that some parameters involving the foramen magnum and occipital condyle measurements among the

Nigerian population demonstrated significant sexual differences. However, caution should be applied while using foramen magnum and or occipital condyles in sex determination for forensic examination purposes when a fragment of craniums is found since the result indicated a limited accuracy rate. It is recommended that the application of these parameters should be complemented with other parts of the skull to increase the percentage of correct classifications. But where the whole cranium is available, the parameters with higher accuracy rates are recommended.

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Conflict of interest

The authors declare no conflicts of interest.

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