OPEN ACCESS
Saudi Journal of Biomedical Research
Abbreviated Key Title: Saudi J Biomed Res
ISSN 2518-3214 (Print) |ISSN 2518-3222 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Estimation of Sex and Stature Using Craniofacial Variables in the Yoruba Ethnic Group of Nigeria

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DOI: 10.36348/sjbr.2021.v06i05.003 | **Received:** 23.03.2021 | **Accepted:** 01.05.2021 | **Published:** 07.05.2021

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Abstract

The development of a biological profile involves the estimation of sex and stature of the deceased individual usually by the comparison of the antemortem and postmortem data. Due to inadequate studies on the development of a biological profile from the craniofacial region in the Nigerian population, this study aimed to determine sex and stature from craniofacial variables in the Yoruba ethnic group of southwest Nigeria. A prospective cross-sectional study was carried out on 368 students and staff (217 males and 151 females) of the Ekiti State University, Ado-Ekiti, Nigeria within the age range of 18 – 55 years. Twelve craniofacial variables and stature were taken using standard anthropometric procedures and equipment. Data were analyzed using IBM® SPSS version 25.0, Armonk, New York, USA. Student's t-test Correlation analysis (Karl Pearson's), multivariate regression and discriminant function analysis were carried out. The results revealed sex differences as the males have higher mean values compared to the females except for the bizygomatic breadth. Physiognomic facial height offers a significant model for stature estimation in both male and female subjects. However, the craniofacial variables produced weak correlations with stature and are not suitable for estimating stature in the ethnic group. Multivariate regression analysis provided better results. The discriminant function analysis sufficiently discriminated sex and after cross-validation, it produced an accuracy of 86.2% for males and 89.4% for females. Sex and stature can be reliably inferred from the craniofacial region but caution should be applied as it has proven to be sex and population specific.

Keywords: Sex, Stature Craniofacial, Variables, Yoruba, Nigeria.

INTRODUCTION

Personal identification is essential, in both the living and the deceased, in other to prevent issues of identity crisis in everyday life. Fingerprints, foot/shoe prints, bloodstains, hair, gait, speech recognition, and other trace evidence are often used by law enforcement authorities to identify criminals in living people [1]. The responsibility of identifying the deceased is important in cases such as terror attack, bombings, assassinations, as well as circumstances where a body is putrefied or otherwise mutilated to mask the identity of the victim [2]. The approximation of sex and stature is crucial in the constitution of the tentative identity of the deceased [3].

Sex determination is the first step involved in the development of any biological profile, it provides a better understanding of other elements such as the determination of stature and age at death [4, 5]. Stature is described as an individual's "natural standing height"[6] and it is explicitly proportional to various regions of the body, including the craniofacial complex [7]. An individual's stature is a significant aspect of individuation that contributes to the creation of a biological profile [8].

There is a growing body of literature proposing the use of metrical craniofacial analysis for the establishment of personal identity in forensic science [9-15]. This is because it is less prone to errors [28] and of the usual possibility that fragmentary body parts including the craniofacial region may be presented for forensic analysis [29]. Because of the insufficiency of studies on the estimation of sex and stature from the craniofacial region and its importance in forensic medicine in Nigeria, this study attempts to determine the sex and stature of Nigerians belonging to the Yoruba ethnic group using craniofacial variables.

MATERIAL AND METHODS

Sample

This prospective cross-sectional study was carried out on 368 students and staff (217 males and 151 females) of the Ekiti State University, Ado-Ekiti, Nigeria within the age range of 18 - 55 took part in the study. The study participants all belong to the Yoruba ethnic group, having both parents up to their grandparents belonging to the Yoruba ethnic group. Participants having any significant disease, orthopaedic deformity, metabolic or developmental disorders that could have affected the general or bony growth were not included in this study.

Anthropometric Data Collection

A semi-structured questionnaire was developed for the study and administered to the participants for the purpose of collecting socio-demographic data. Those who satisfied the inclusion criteria were invited to the study. Direct measurements were carried out on each participant after the reception of a signed informed consent letter.

Stature was measured as the vertical distance from the vertex of the head to the floor with the subject standing upright and barefooted; weight was taken with a digital weighing scale, participant stood erect on the scale without putting on anything that could affect the measurement. Twelve craniofacial variables were measured on each subject. Measurements were taken in accordance with the methods suggested by Martin and Saller (1957) and Singh and Bhasin [16, 17].

Maximum Head Length (MHL): The straight distance between glabella (g) and opisthocranion (op). Maximum Head Breadth (MHB): The straight distance between the two eurya (eu1-eu2). Bizygomatic breath (BZB): The lateral aspects of the bizygomatic arches (zy1-zy2) Bi-gonial breadth (BGB): The straight distance between the two gonia (go1-go2). Biocular breadth (BOB): The straight distance between the two external canthi (ectocanthion). Physiognomic Facial Height (PFH): The straight distance between trichion (tr) and gnathion. Morphological Facial Height (MFH): The straight distance between nasion (n) and gnathion (gn). Total Head Height (THH): The distance between the vertex and the gnathnion. Nasal height (NH): The distance between the nasion and the pronasale. Nasal width (NW): The distance between the two alares. Physiognomic Ear Height (PEH): the distance between the superaurale (sa) and the subaurale (sba). Physiognomic Ear Width (PEW): the distance between the tragion and the opposite lateral margin of the ear (helix). These variables were measured as subjects were made to sit comfortably on a stool, the caliper ends were placed on the craniofacial landmarks and read accordingly.

Equipment

These variables were measured with a stature meter, spreading caliper (Biotech Ltd., Agra, India) and digital vernier caliper (Microtech, Ukraine, precision, ± 0.01 mm).

DATA ANALYSIS

Data analysis was carried out using Microsoft excel 2019 and Statistical Package for the Social Sciences (IBM® SPSS version 25.0, Armonk, New York, USA). The significance criterion was set at 95%; hence $p < 0.05$ was significant. Continuous variables were expressed as Means±SD (standard deviation). Sex differences were established using the student's t-test. Correlation analysis (Karl Pearson's was done to correlate craniofacial variables with stature. Multivariate regression was done to predict stature using values of craniofacial variables that significantly contributed to the model. Discriminant function analysis (DFA) was used in sex determination.

RESULTS AND DISCUSSION

Table-1: Descriptive and inferential statistics of age among subjects

Variable	Sex	N	Min	Max	Mean±SD	T-test			
						df	t-value	p-value	Inference
Age (years)	Male	217	18.00	56.00	25.08±6.28	270.60	2.05	0.04	**Sig**
	Female	151	18.00	45.00	23.48±8.03				
	Total	368	18.00	56.00	24.42±7.08				

Note: N = amount, min = minimum, max = maximum, Sig = Significant, Not sig = Not significant, SD = Standard deviation

The mean age (Mean±SD) of the subjects was 24.42±7.08 [M=25.08±6.28; F=23.48±8.03]. The study population of 368 subjects comprise males and females of unequal proportion, there was a significant difference between the male and female ages (t=2.05, p=0.04), we present these results in Table 1.

Table-2: Descriptive statistics and sex differences in the height of subjects

Variables	Sex	N	Min	Max	Mean±SD	T-test			
						df	t-value	p-value	Inference
Height (m)	Male	217	1.63	1.87	1.74±0.06	335.36	15.86	0.00	**Sig**
	Female	151	1.44	1.82	1.64±0.06				
	Total	368	1.44	1.87	1.70±0.08				

Note: N = amount, min = minimum, max = maximum, Sig = Significant, Not sig = Not significant, SD = Standard deviation

Table-3: Descriptive statistics and sex differences in craniofacial variables of the subjects

Craniofacial variables (mm)	Sex	N	Min	Max	Mean±SD	T-test			
						df	t-value	p-value	Inference
MHL	Male	217	17.00	21.00	19.14±0.78	266.60	3.16	0.00	**Sig**
	Female	151	16.00	23.50	18.83±1.02				
	Total	368	16.00	23.50	19.01±0.90				
MHB	Male	217	10.00	13.00	10.95±0.57	366.00	5.04	0.00	**Sig**
	Female	151	7.50	12.00	10.63±0.64				
	Total	368	7.50	13.00	10.82±0.62				
BZB	Male	217	10.50	14.00	11.94±0.96	347.59	5.76	0.00	**Sig**
	Female	151	7.00	14.00	11.39±0.84				
	Total	368	7.00	14.00	11.71±0.95				
BGB	Male	217	7.00	11.50	9.15±0.94	366.00	-4.80	0.00	**Sig**
	Female	151	7.00	14.00	9.65±1.08				
	Total	368	7.00	14.00	9.35±1.03				
BOB	Male	217	10.00	24.00	12.27±1.48	346.07	2.60	0.01	**Sig**
	Female	151	9.50	14.00	11.96±0.79				
	Total	368	9.50	24.00	12.15±1.25				
THH	Male	217	20.00	26.00	22.89±1.46	362.95	1.15	0.25	Not sig
	Female	151	20.00	25.00	22.73±1.11				
	Total	368	20.00	26.00	22.82±1.32				
PFH	Male	217	16.00	23.50	18.59±1.16	366.00	5.49	0.00	**Sig**
	Female	151	15.00	21.50	17.90±1.24				
	Total	368	15.00	23.50	18.31±1.24				
MFH	Male	217	9.60	12.20	10.98±0.56	366.00	15.81	0.00	**Sig**
	Female	151	9.00	11.70	10.06±0.54				
	Total	368	9.00	12.20	10.60±0.71				
NH	Male	217	2.80	5.00	4.20±0.43	344.40	9.98	0.00	**Sig**
	Female	151	2.50	4.90	3.78±0.38				
	Total	368	2.50	5.00	4.03±0.46				
NW	Male	217	3.60	5.30	4.54±0.42	340.66	12.66	0.00	**Sig**
	Female	151	3.00	5.00	4.01±0.38				
	Total	368	3.00	5.30	4.32±0.48				
PEH	Male	217	3.70	6.40	5.75±0.41	289.64	9.49	0.00	**Sig**
	Female	151	3.80	6.80	5.30±0.48				
	Total	368	3.70	6.80	5.56±0.49				
PEW	Male	217	2.30	4.10	3.29±0.31	366.00	5.88	0.00	**Sig**
	Female	151	2.30	4.00	3.10±0.31				
	Total	368	2.30	4.10	3.22±0.32				

Note: N = amount, min = minimum, max = maximum, Sig = Significant, Not sig = Not significant, SD = Standard deviation MHL= maximum head length, MHB= maximum head breadth, BZB=bizygomatic breadth, BGB=bigonial breadth, BOB=bioccular breadth, THH= total head height, PFH= physiognomic facial height, MFH=morphological facial height, NH=nasal height, NW= nasal width, PEH= physiognomic ear height, PEW= physiognomic ear width.

The results obtained from the preliminary analysis of the craniofacial variables of the subjects are presented in Table 3. T-test statistics show significant differences in craniofacial variables between the male and female subjects. However, the THH did not yield a significant difference between the Yoruba males and females.

Table-4: Correlation between craniofacial variables and stature of subjects

Correlation		Height (m) Male[N=217]	Height (m) Female [N=151]
MHL	r	0.034	-0.065
	p-value	0.618	0.704
MHB	r	0.114	0.230**
	p-value	0.095	**0.004**
BZB	r	0.218**	0.363**
	p-value	**0.001**	**0.000**
BGB	r	0.040	0.354**
	p-value	0.555	**0.000**
BOB	r	-0.040	0.361**
	p-value	0.557	**0.000**
THH	r	0.122	0.275**
	p-value	0.074	**0.001**
PFH	r	0.271**	0.236**
	p-value	**0.000**	**0.004**
MFH	r	0.139*	0.285**
	p-value	**0.041**	**0.000**
NH	r	0.061	0.236**
	p-value	0.368	**0.004**
NW	r	0.076	0.355**
	p-value	0.263	**0.000**
PEH	r	0.038	0.260**
	p-value	0.573	**0.018**
PEW	r	-0.040	-0.055
	p-value	0.562	0.502

Note: r = Pearson correlation, N = number of subjects, * = Correlation is significant at the 0.05 level (2-tailed), ** = Correlation is significant at the 0.01 level (2-tailed) MHL= maximum head length, MHB= maximum head breadth, BZB=bizygomatic breadth, BGB=bigonial breadth, BOB=bioccular breadth, THH= total head height, PFH= physiognomic facial height, MFH=morphological facial height, NH=nasal height, NW= nasal width, PEH= physiognomic ear height, PEW= physiognomic ear width.

The results for Pearson's correlational analysis between craniofacial variables and stature among subjects are presented in Table 4. The craniofacial variables that correlated with stature are highlighted.

Table-5: Model summary for the regression analysis of height and craniofacial parameters among subjects

Model	R	R^2	Adjusted R^2	S.E of the Estimate	ANOVA		
					df	F-value	P-value
Height (m) Males	0.39	0.15	0.12	0.06	8	4.53	**0.00***
Height(m) Females	0.57	0.32	0.28	0.28	9	7.47	**0.00***

***** = Significant, **R** = Pearson correlation, $\mathbf{R^2}$ = Coefficient of determination, **BMI** = Body Mass Index
Predictors (H) males: (Constant), PFH, BZB, NFWI, BOB, FSI, THH, NH, NW
Predictors (H) females: (Constant), BZB, NW, PEH, BGB, MFH, THH, PEW, BOB, NH

Table-6: Stepwise multivariate regression analysis of height and craniofacial parameters of male subjects

Term	Unstandardized Coefficients		Standardized Coefficients	t-value	P-value
	B	S.E.	Beta		
Stature estimation model					
(Constant)	2.04	0.94		2.17	**0.03***
PFH	0.08	0.04	1.57	1.86	0.06
BZB	0.05	0.04	0.84	1.41	0.16
BOB	0.00	0.00	-0.10	-1.50	0.13
FSI	-0.02	0.01	-1.72	-1.55	0.12
THH	-0.05	0.04	-1.30	-1.46	0.14
NH	0.01	0.01	0.07	1.11	0.27
NW	-0.10	0.10	-0.68	-0.97	0.33

Regression equation: All craniofacial parameters that contributed to estimating height
Height (m) = 2.04 + 0.08 (PFH) + 0.05 (BZB) + 0.00 (BOB) - 0.02 (FSI) - 0.05 (THH) + 0.01 (NH) - 0.10 (NW)

Table-7: Stepwise multivariate regression analysis of height and craniofacial parameters of female subjects

Term	Unstandardized Coefficients		Standardized Coefficients	t-value	P-value
	B	S.E.	Beta		
Stature estimation model					
(Constant)	0.96	0.11		8.80	**0.00***
BZB	0.01	0.01	0.10	1.17	0.25
NW	0.03	0.01	0.21	2.74	**0.01***
PEH	0.02	0.01	0.16	2.18	**0.03***
BGB	0.01	0.00	0.17	2.05	**0.04***
MFH	0.02	0.01	0.15	1.86	0.06
THH	0.00	0.00	0.09	1.12	0.26
PEW	-0.02	0.01	-0.09	-1.25	0.21
BOB	0.00	0.01	0.07	0.77	0.44
NH	0.01	0.01	0.06	0.74	0.46

Regression equation: All craniofacial parameters that contributed to estimating height

Height (m) = 0.96 + 0.01 (BZB) + 0.03 (NW) + 0.02 (PEH) + 0.01 (BGB) + 0.02 (MFH) + 0.00 (THH) - 0.02 (PEW) + 0.00 (BOB) + 0.01 (NH)

Sex determination

Table-8: Tests of equality of group means

Craniofacial parameters	Wilks' Lambda	F	df1	df2	P-value	Inference
MFH	0.59	249.83	1	366.00	0.00	**Significant**
NW	0.50	184.01	2	365.00	0.00	**Significant**
PEW	0.47	134.62	3	364.00	0.00	**Significant**
PEH	0.46	106.57	4	363.00	0.00	**Significant**
BGB	0.45	89.97	5	362.00	0.00	**Significant**
NH	0.44	77.27	6	361.00	0.00	**Significant**
BOB	0.43	67.41	7	360.00	0.00	**Significant**

The result in Table 8 reveals that the predictors entered into the model were statistically significant

Table-9: Tests of Equality in population covariance matrices and canonical correlation

BOX's M EQUALITY IN COVARIANCE		EIGEN VALUES		
		Function	Eigen value	Canonical Correlation
Box's M	140.91	1	1.311	0.75
F				
Approximately	4.93			
df1	28			
df2	363753.71			
P-value	0.00			

The small Eigen value of 1.311 shows a limited discrepancy in the predictor variables and magnitude of the actual effect of the predictors.

Table-10: Wilks' Lambda test for predictability into group membership

Test of Function(s)	Wilks' Lambda	Chi-square	Df	P-value	Inference
1	0.43	303.61	7	**0.00**	**Significant**

The results shows that the data (craniofacial variables) is a good fit (X2 = 303.61, P = 0.00), Hence suitable for sex categorization (Male and Female).

Table-11: Canonical discriminant function coefficient structured, standardized and unstandardized for subjects

Box's M structure Matrix Coefficients		Standardized Canonical Discriminant Function Coefficients	Unstandardized canonical discriminant function coefficients
Craniofacial parameters	**Function [a]**	**Function**	**Function [b]**
CONSTANT			-22.01
MFH	0.72	0.58	1.05
NW	0.57	0.45	1.12
NH	0.45	0.18	0.44
PEH	0.45	0.25	0.57
PEW	0.27	0.22	0.70
BGB	-0.22	-0.28	-0.28
BOB	0.11	0.15	0.12

The unstandardized coefficients were used to generate the discriminant function (DF) equation, as presented below; Sex = -22.01 + 1.05 (MFH) + 1.12 (NW) + 0.44 (NH) + 0.57 (PEH) + 0.70 (PEW) - 0.28 (BGB) +0.12 (BOB).

Table-12: Functions at group centroids for subjects

Sex	Function
Male	0.95
Female	-1.37

Unstandardized canonical discriminant functions evaluated at group means the sex of an unknown individual can be estimated to belong to the Yoruba ethnic group any value obtained is compared to the canonical centroid (-1.37 to 0.95) in Table 12; if the value is close to -1.37 the unknown individual is said to belong to a female. However, if it is close to 0.95, it is likely a male.

Table-13: Percentage predictability for group membership for subjects

Sex			Predicted Group Membership		Total
			Male	**Female**	
Original	Count (%)	Male	190 (87.6)	27 (12.4)	217 (100)
		Female	16 (10.6)	135 (89.4)	151 (100)
Cross-validated[b]	Count (%)	Male	187 (86.2)	30 (13.8)	217 (100)
		Female	16 (10.6)	135 (89.4)	151 (100)

a. 88.3% of original grouped cases correctly classified.
b. 87.5% of cross-validated grouped cases correctly classified.

DISCUSSION

The mean values of the craniofacial variables of the subjects were comparatively lower in females than in male subjects. The only exemption is the mean value of the bi-zygomatic breadth of the female Yoruba subjects, which was slightly higher than that of the male subjects. The mean stature of the Yoruba subjects was 1.74m and 1.64m for the male and female subjects respectively (Table 2).

The highest correlation of craniofacial variables and stature was found with PFH, BZB also correlated with stature (p-value≤0.01) in male subjects. MFH shows positive significance in correlation (p-value≤0.05) with stature. For the female subjects, BZB gave the highest correlation with stature. BGB, BOB, THH, MFH, NW, NH and PEH exhibited positive significance in correlation with stature (p-value≤0.01). This suggests that these variables could be substituted in a linear regression equation for the estimation of stature. PFH gives a significant model for stature estimation in both Yoruba male and female subjects. The correlation coefficient values of physiognomic facial height in Yoruba male was R = 0.271 and in females R= 0.236. However, they all exhibited very weak correlations with stature and are not suitable for the estimation of stature for the Yoruba ethnic group.

The multivariate regression for stature estimation comprises the craniofacial variables of the subjects that are essential in stature estimation having filtered the craniofacial variables of insignificant contribution. This study generated the following equations for the estimation of stature.

For male subjects

Height (m) = 2.04 + 0.08 (PFH) + 0.05 (BZB) + 0.01 (NFWI) + 0.00 (BOB) - 0.02 (FSI) - 0.05 (THH) + 0.01 (NH) - 0.10 (NW).

Female subjects

Height (m) = 0.96 + 0.01 (BZB) + 0.03 (NW) + 0.02 (PEH) + 0.01 (BGB) + 0.02 (MFH) + 0.00 (THH) - 0.02 (PEW) + 0.00 (BOB) + 0.01 (NH).

Various authors have reported similar outcome on different populations. According to Lukpata and coworkers, nasal dimensions were not suitable estimators of stature in Ogoja teenagers of Cross River State, Nigeria [18], Agnihotri et al. reported that despite morphological facial height showing the highest correlation with stature, it failed to achieve significance and wasn't a suitable variable for the estimation of stature [9]. Shah and colleagues in a similar study found out that the correlation coefficients of all craniofacial dimensions were less than 0.5 and are not suitable for stature estimation in the Gujarati population of India [19]. Other authors have expressed this view [20, 21].

Krishan and coworkers found a strong correlation between the horizontal head circumference and stature and concluded that craniofacial dimensions offer good reliability and applicability for the estimation of stature in male Gujjars of North India [27]. Ukoha et al. also reported that horizontal head circumference and head breadth sufficiently predicted stature in the Igbo ethnic group of Nigeria [11]. Yadav et al. also found strong correlations between craniofacial dimensions and stature [22]. This different outcome brings to the fore population specificity of stature estimation models as findings ought to be interpreted with caution. This warrants further studies on populations to find out how the craniofacial region correlates with stature.

This study has found that craniofacial variables sufficiently discriminate sex and could be a viable forensic tool in estimating sex among Nigerians belonging to the Yoruba ethnic group.

A stepwise DFA was done using the craniofacial variables that significantly contributed to the sex estimation model for Yoruba subjects. The following discriminant canonical function equations was generated;

Sex = -22.01 + 1.05 (MFH) + 1.12 (NW) + 0.44 (NH) + 0.57 (PEH) + 0.70 (PEW) - 0.28 (BGB) +0.12 (BOB).

Using the above equation, a canonical vector score was obtained, which is compared to the canonical centroids -1.37 to 0.95 (Table 12). If a score tends towards -1.37 it's most likely female, else if it tends towards 0.95 it is likely a male. The model was tested for accuracy using the present data, after cross-validation it produced an accuracy of 86.2% for males and 89.4% for females. These values (86.2% - 89.4% > 50.0%) %) exceed the proportional chance criterion [23]. It can therefore be said to estimate sex; however, the predictive/ discriminating power of a canonical vector becomes more accurate when it tends towards 100%.

Sex estimations using DFA (stepwise approach) has achieved 68.5% [14], 70.3% [12], 81.7% [24], 85.7% accuracy [25], 79–84% [26], 92% males and 80.9% females [19]. We consider the model predictability for this study strong for the ethnic group, as it is statistically significant ($P < 0.01$).

CONCLUSION

Craniofacial variables are useful for the estimation of sex and stature in cases of limited resources and when incomplete skeleton or human remains are brought for forensic examinations. This study shows that using stepwise multivariate regression analysis and discriminant function analysis stature and sex can be reliably inferred from the craniofacial region respectively. However, these equations should be interpreted with caution as they are population-specific and revealed gender differences.

ACKNOWLEDGEMENT

We are grateful to the Head of Department of Anatomy, Ekiti State University, Ado-Ekiti, Nigeria, Dr. M.O. Alese for giving us an enabling environment to carry out this research. Special thanks go out to all those who took part in the study.

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