Original Communication

ESTIMATION OF STATURE FROM CEPHALIC DIMENSIONS IN A NIGERIAN POPULATION

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RESUMEN

Objetivos: El presente estudio trata de examinar la relación entre la estatura y dimensiones cefálicas en la etnia Igbo de Nigeria y proponer un modelo de regresión para estimar la estatura cuando las dimensiones cefálicas están disponibles. Materiales y Métodos: 500 sujetos (261 varones y 239 mujeres) de edades comprendidas entre 18 y 30 años, que vive en Nnewi, Nigeria, participaron en el estudio. La estatura y tres dimensiones cefálicas (longitud cabeza, amplitud cabeza y circunferencia de la cabeza horizontal) se tomaron de cada individuo. La estatura se tomó como la altura en posición de pie, y se midió (en centímetros) usando un metro de altura. La longitud de la cabeza fue tomada como la distancia occipito-frontal, y se midió (en centímetros) con un calibre deslizable Mitsutoyo. El tamaño de la cabeza fue tomada como la distancia máxima biparietal, y se midió (en centímetros) usando un calibre deslizante Mitsutoyo. Se midió la circunferencia horizontal de la cabeza (la distancia desde la glabela alrededor del cráneo de nuevo a la glabela) (en centímetros) usando una cinta métrica. Principales Resultados: Los resultados mostraron una correlación significativa de las dimensiones cefálicas con estatura en las mujeres ($p<0,01$). Para los varones, la circunferencia horizontal y la longitud de la cabezal tuvieron correlación significativa con la talla ($p<0,05$), mientras que la amplitud cabeza se correlacionó de manera insignificante ($p>0,05$). Las ecuaciones de regresión también se formularon para estimar la estatura de dimensiones cefálicas para sujetos masculinos y femeninos. Conclusión: El estudio mostró que la circunferencia horizontal y la amplitud de la cabeza es mejor predictor de la estatura que la longitud cefálica, y que las dimensiones cefálicas se puede utilizar para estimar la estatura.

***Palabras clave**: dimensiones cefálicas, antropología forense, la población de Nigeria, la estimación de estatura.*

ABSTRACT

Objectives: The present study sought to examine the relationship between stature and cephalic dimensions in the Igbo ethnic group of Nigeria, and to propose a regression model for stature estimation when the cephalic dimensions are available. Materials and Methods: 500 subjects (261 males and 239 females) between the ages of 18 and 30, living in Nnewi, Nigeria, participated in the study. Stature and three cephalic dimensions (head length, head breadth and horizontal head circumference) were taken on each individual. Stature was taken as standing height, and was measured (in centimeters) using a height meter. Head length was taken as the occipito-frontal distance, and was measured (in centimeters) with Mitsutoyo sliding calipers. Head breadth was taken as the maximum biparietal distance, and was measured (in centimeters) using Mitsutoyo sliding calipers. Horizontal head circumference (the distance from the glabella around the cranium back to the glabella) was measured (in centimeters) using a metric tape. Main Results: The results showed significant correlation of cephalic dimensions with stature in the females ($p<0.01$). For the male subjects, horizontal head circumference and head length had significant correlation with stature ($p<0.05$) while head breadth was insignificantly correlated ($p>0.05$). Regression equations were also formulated for estimating stature from cephalic dimensions for the male and female subjects. Conclusion: The study showed that horizontal head circumference and head breadth were better predictors of stature than head length, and that the cephalic dimensions can be used to estimate stature.

***Keywords:** Cephalic dimensions, Forensic Anthropology, Nigerian population, Stature estimation.*

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INTRODUCTION

Establishing the identity of an individual from mutilated, decomposed and amputated body fragments has become a necessity in recent times due to natural disasters like earthquakes, tsunamis, floods and man-made disasters like terrorist attacks, bomb blasts, car accidents, wars, plane crashes, etc. It is important both for legal and humanitarian reasons (Chikhalkar et al, 2010). In such situations as stated above, estimation of stature becomes equally important along with the other parameters which are age, gender and race (together referred to as the 'Big Four' of forensic anthropology) (Krishan, 2008a).

Stature means the natural standing height of an individual, and varies according to gender, age, ancestry, individual development, and hormonal influence (Black and Ferguson, 2011). It is considered important in anthropological research and forensics involving personal identification. Stature has a proportional biological relationship with every part of the human body, i.e. head, face, trunk, extremities. This relationship helps in calculating stature from dismembered and mutilated body parts in forensic examinations (Krishan, 2008a). For such a calculation, two methods, i.e. regression method and multiplication method have been used, and it has been universally agreed that the regression analysis provides best results for stature estimation (Krishan, 2002; Iscan, 2005). These regression equations are developed to estimate stature for a similar population. The estimated stature is then compared with both recorded and reported stature of missing individuals. If several of the identification factors, such as gender, ethnicity and age, as well as stature, concur with one individual, then he/she is generally considered identified.

Many studies have been conducted on the estimation of stature from various body parts like hands, trunk, scapula, intact vertebral column, upper and lower limbs, individual long and short bones, foot and footprints (Munoz et al, 2000; Bidmos, 2005; Hauser et al, 2005; Pelin et al, 2005 Bidmos, 2006; Ozer et al, 2007; Krishan, 2008b; Giroux and Wescott, 2008). Since all these parts of the body and bones are not always available for forensic examination, it becomes necessary to make use of other parts of the body like the head and face region.

Krishan and Kumar (2007) calculated regression formulae for stature estimation using 16 cephalofacial measurements in 252 Koli male adolescents of North India. Ryan and Bidmos (2007) took several skull measurements of 99 complete skeletons of South African origin, and successfully derived regression formulae for estimation of total skeletal height from these skull measurements. Krishan (2008) also reported that stature had strong positive correlation with cephalic dimensions, in a study using 996 adult male Gujjars of North India aged 18 to 30 years. Sahni et al. (2010) carried out an investigation to estimate stature from seven facial measurements of 300 (173 males and 127 females) healthy subjects from Northwest India, and derived a gender-specific regression equation. Ilayperuma (2010) studied the relationship between the cranial dimensions and height of adults in Sri Lanka and found a significant positive correlation; he also proposed a linear regression model for estimating height. Pelin et al (2010) also estimated stature from craniofacial dimensions in a Turkish population. Asha and Lakshmi (2011) examined the relationship between stature, head length and head breadth among 260 Indian subjects between the ages of 20–30. Kumar et al. (2011) also examined the relationship between stature and craniofacial dimensions in Indian males and females, and formulated a regression equation. Seema and Mahajan (2011) carried out a study on 400 (210 male and 190 female) Punjabi subjects of 18-23 years of age to determine the correlation between height and head length. The study showed that height had definite correlation with head length.

Despite its significance and potential practical utility, very little is known concerning the relationship between cephalic dimensions and stature among the Igbos, inhabitants of the South-Eastern region of Nigeria. Ewunonu and Anibeze (2013) carried out a study to estimate stature from cephalic parameters in the Igbos of South-Eastern Nigeria and proposed a regression equation.

This study is aimed at investigating the relationship between stature and cephalic dimensions of individuals belonging to the Igbo ethnic group in Nigeria, determining gender dimorphism, and proposing a regression model for the estimation of stature where the cephalic dimensions are available.

MATERIALS AND METHODS

Ethical approval was obtained from the Ethical Committee, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nigeria. The study was carried out in Nnewi, Anambra State between July and August, 2012. A total number of 500 (261 male and 239 female) subjects were used for the study after informed consent was obtained from them. The subjects were between the ages of 18 and 30 years. They had no

deformations of the skull and had both grandparents of Igbo origin. The measurements taken were:

a) ***Maximum head length:*** The maximum head length, called the *occipito-frontal distance,* is the distance between the glabella (the most prominent point on the frontal bone above the root of the nose, between the eyebrows) and the opisthocranion (the most prominent portion of the occiput). It was measured (in centi-meters) with sliding calipers made by Mitsutoyo (Japan). When taking the readings from the calipers, the main scale of the calipers was read off, as well as the Vernier scale, with the observer directly facing the calipers, to avoid errors due to parallax. The subject was either standing or sitting, but the head was stationary (Figure 1a). The reading was taken by one observer to avoid inter-observer bias, and was taken three times and the average calculated.

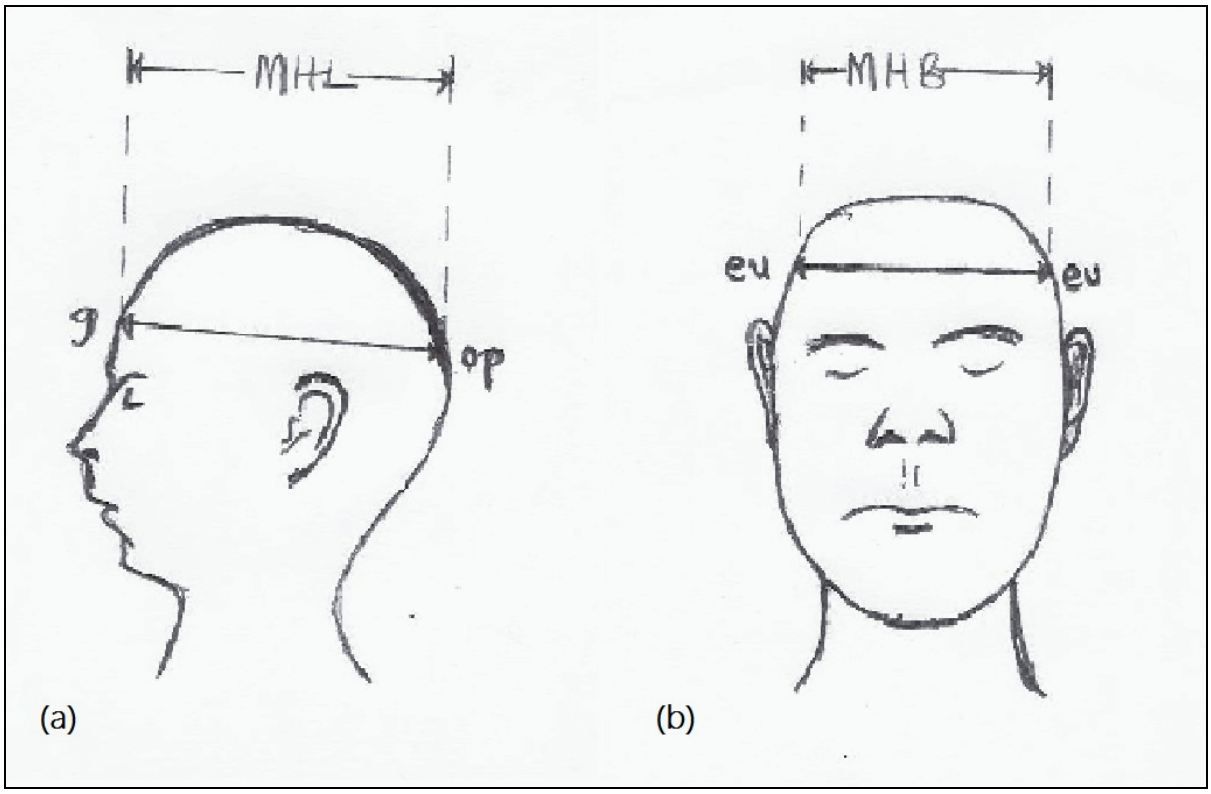


Figure 1(a): Landmarks on the head for measuring maximum head length. (MHL = maximum head length; g = glabella; op = opisthocranion)**. 1(b)**: Landmarks on the head for measuring maximum head breadth. (MHB = maximum head breadth; eu = euryon)

b) ***Maximum head breadth:*** The maximum head breadth, the *biparietal distance,* is the distance between the two eurya (singular-euryon), the most lateral points of the parietal bones. It was also measured (in centimeters) with a sliding caliper (Mitsutoyo, Japan). While taking the readings, the main scale was read off, as well as the Vernier scale, with the observer directly facing the calipers, to avoid errors due to parallax. The subject was either standing or sitting, but the head was stationary (Figure 1b). The reading was taken by one observer to avoid inter-observer bias, and was taken three times and the average calculated.

c) ***Horizontal head circumference***: It is the maximum circumference of the head (usually horizontal just above the eyebrow ridges), measured from just above the glabella area to the area near the top of the occipital bone (opisthocranion). It was measured (in centi-meters) with a soft metric tape. The reading was taken by one observer to avoid inter-observer bias, and was taken three times and the average calculated.

d) ***Stature:*** Stature is measured as vertical distance from the vertex to the floor, where vertex is the highest point on the head when the head is held in Frankfurt Horizontal plane. The stature was measured (in centimeters) with a height meter, where the subject stood erect on the horizontal resting plane of the, bare footed with back of the shoulders and buttocks touching the wall. The calibrated rod of the height meter was placed in straight vertical position behind the subject with head oriented in the Frankfort horizontal plane. A straight rod was brought in contact with the vertex in the mid-sagittal plane. The reading was taken by one observer to avoid inter-observer bias, and was taken three times and the average calculated.

The data collected was analyzed using Statistical Package for Social Services (SPSS) Version 16.0 on Windows 7. Mean, standard deviation and correlation coefficient between stature and the cephalic dimensions were determined for both male and female subjects. Finally, a regression equation for stature was derived from the individual cephalic dimensions to serve as a model for stature estimation. The level of significance was set at $p < 0.05$.

RESULTS

In Table 1, the mean and standard deviation of the cephalic dimensions and stature of the subjects are presented. Independent sample t-test was conducted to compare means between the male and female subjects, and indicated significant gender differences in all the parameters. The male subjects had significantly greater maximum head length ($P<0.001$), maximum head breadth ($P<0.05$), head circumference ($P<0.001$), and stature ($P<0.001$) when compared to the females.

CHARACTERISTICS	MALES (n = 261)	FEMALES (n = 239)	t-STAT	P-VALUE
Maximum Head Length (cm)	19.64 ± 0.70	19.29 ± 0.81	5.28	0.000[a]
Maximum Head Breadth (cm)	16.16 ± 0.63	16.02 ± 0.71	2.30	0.022[b]
Horizontal Head Circumference (cm)	57.82 ± 1.59	56.72 ± 1.82	7.14	0.000[a]
Stature (cm)	175.79 ±6.40	165.02 ±6.14	19.16	0.000[a]

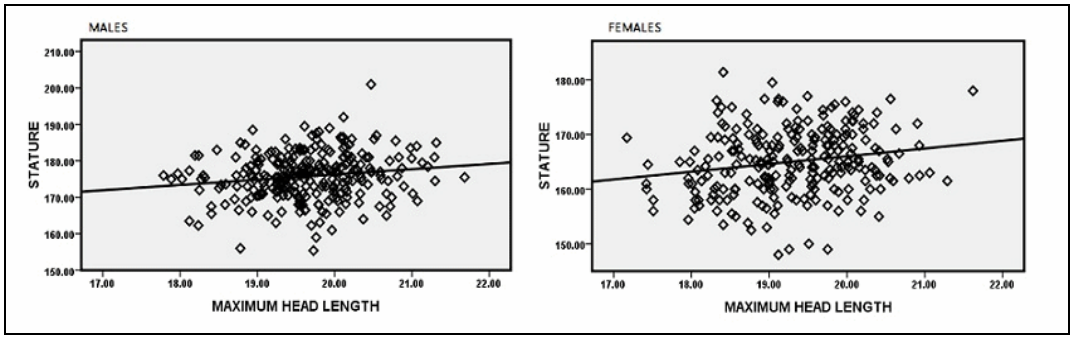
Table 1: Stature, cephalic dimensions and demographic characteristics of study subjects (n = 500)**.** (a = $p < 0.001$; b = $p < 0.05$)

MEASUREMENTS	MALES		FEMALES	
	Coefficient (r)	*P-Value*	*Coefficient (r)*	*P-Value*
Stature vs. Head Length	0.159	0.010[a]	0.186	0.004[c]
Stature vs. Head Breadth	0.101	0.103[b]	0.258	0.000[d]
Stature vs. Head Circumference	0.253	0.000[d]	0.203	0.002[c]

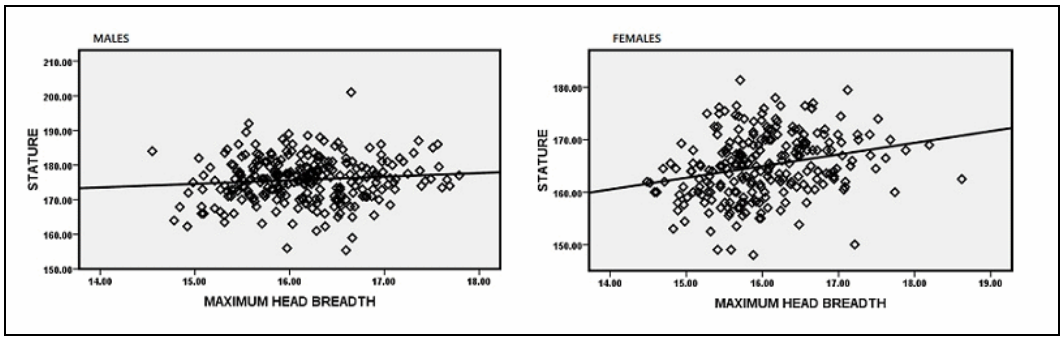
Table 2: **Correlation coefficients between stature and cephalic dimensions in study subjects (n = 500).** (a = $p < 0.05$; b = $p > 0.05$; c = $p < 0.01$; d = $p < 0.001$)

Table 2 presented Pearson's correlation test to determine the strength of relationship between stature and head length. The scatter plot was shown in Graphic 1. The results indicated low but significant association between stature and head length in males (R=0.159; P<0.05) and in females (R=0.186; P<0.01). Low but significant relationship was also observed between stature and head breadth in females (R=0.258; P<0.001) but not in males (R=0.101; P>0.05). The scatter plot was depicted in Graphics 2. Finally, stature was significantly associated with head circumference in males (R=0.253; P<0.001) and in females (R=0.203; P<0.01) respectively (scatter plot shown in Graphics 3).

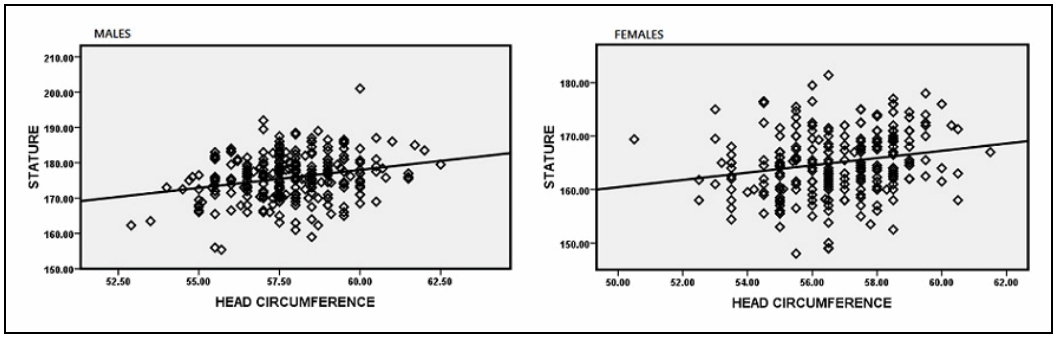
In Table 3, stature was estimated from individual cephalic measurements using the linear regression equation; *stature = a + bx,* where 'a' is the regression coefficient of the dependent variable, i.e. stature, and 'b' is the regression coefficient of the independent variables, i.e. the cranial dimensions; 'x' is any of the three cranial measurements – head length, head breadth, or horizontal head circumference.



Graphic 1: Scatter plot showing correlation of stature with maximum head length in males and females



Graphics 2: Scatter plot showing correlation of stature with maximum head breadth in males and females



Graphics 3: Scatter plot showing correlation of stature with horizontal head circumference in males and females

MEASUREMENTS	GENDER	REGRESSION EQUATION	± SEE
Maximum Head Length (cm)	M	147.383 + 1.445MHL	6.336
	F	137.732 + 1.415MHL	6.045
Maximum Head Breadth (cm)	M	159.014 + 1.037MHB	6.384
	F	129.395 + 2.224MHB	5.945
Horizontal Head Circumference (cm)	M	116.963 + 1.017HHC	6.208
	F	126.381 + 0.681HHC	6.025

Table 3: Regression equation for estimation of stature from cephalic dimensions in adult Igbo subjects (n = 500). MHL = maximum head length; MHB = maximum head breadth; HHC = horizontal head circumference; SEE = standard error of estimate

DISCUSSION

The results of the present study indicate that one can estimate stature from different cephalic dimensions in situations where cephalo-facial remains are available for forensic examinations. The stature estimation in these cases can complement the other personal identification data like estimation of age, gender, race, and identification from facial morphological characteristics as well as peculiar individualistic features. The estimated stature would then be compared with both recorded and reported stature of missing individuals. If various identification factors, such as gender, ethnicity and age, and of course stature, are same with one individual, the identity is considered established.

The findings of the study show that the three cephalic measurements (in females but two in males) are significantly correlated with stature. However, according to Krishan (2008a), it must be kept in mind that precise prediction of stature from cephalic dimensions may be unachievable and unnecessary because there would always be an estimation error of a few centimeters.

It is a known fact that gender difference is an important factor in the morphological variation of human populations. This is because the rate of skeletal maturity in males and females vary during the course of growth and development (Williams et al, 2011). In the present study, it was discovered that the male subjects had significantly greater stature and cephalic dimensions when compared to the females (Table 1). The gender dimorphism observed in the study supported previous observations by Ilayperuma (2010) who reported that the males had significantly greater stature and cranial dimensions than the females, and Asha and Lashkmi, 2011) who stated that the males had significantly higher height and cephalic dimensions. Kumar et al (2011) in their study also reported that the males had significantly higher stature and cephalic dimensions than their female counterparts. This is also in line with studies by Krishan and Kumar (2007). As a result of the gender dimorphism already established in the present study, the regression equation derived for estimating stature for the Igbos would be gender-specific.

Pearson's correlation test (Table 2) showed significant correlation between stature and head length, as well as between stature and head circumference in both genders. The highest correlation was found between stature and head breadth in females ($r=0.258$; $p<0.001$), and between stature and head circumference in males ($r=0.253$; $p<0.001$). Significant relationship was also observed between stature and head breadth in females but in males it was statistically insignificant ($P>0.05$). The result implied that horizontal head circumference was a better predictor of stature in males than the head breadth and head length, agreeing with research by Krishan (2008a) but contradicting the study done by Asha and Lashkmi (2011). The study further showed that the head breadth of females had better correlation with stature than other cephalic dimensions. The significant correlation coefficients of stature and cephalic dimensions seen in this study are in line with studies by Asha and Lashkmi (2011) where the highest correlation was 0.412. The present study however contradicted the study by Krishan (2008a) whose highest correlation was 0.781.

Table 3 showed the regression equations for estimating stature from cephalic dimensions in an Igbo population. The equations were specific for each gender. The standard error of estimate (SEE) was calculated for each independent variable and sought to show the reliability of the equation: the higher SEE, the lower accuracy of the equation and the lower SEE, the higher reliability of the regression formulae. In the present study, the horizontal head circumference had the lowest SEE in males (±6.208), while the head breadth had the lowest SEE in the females (±5.945). These data are lower than that reported by Ewunonu and Anibeze (2013) who reported their lowest SEE to be ±6.93 for the head circumference; and higher than the SEE reported by Krishan (2008) which was ±3.726 for the head circumference. The results showed that the horizontal head circumference was more reliable for estimating stature than the other cephalic dimensions in Igbo males, and the head breadth was the most reliable for Igbo females.

	Estimated Minimum Stature		**Estimated Maximum Stature**		**Estimated Mean Stature**	
	M	**F**	**M**	**F**	**M**	**F**
Head Length (cm)	173.09	162.03	178.71	168.32	175.76	165.03
Head Breadth (cm)	174.10	161.60	177.46	170.81	175.77	165.02
Horizontal Head Circumference (cm)	170.76	160.77	180.53	168.26	175.77	165.01
Actual Stature	155.40	148.00	201.00	181.40	175.77	165.02

Table 4: Comparison of actual stature with estimated stature from different cephalic dimensions

Author	**Population**	**Gender**	**Head Length**	**Head Breadth**	**Head Circumference**
Krishan and Kumar (2007)	North Indian	M	0.732	0.625	0.773
Krishan (2008)	North Indian	M	0.775	0.682	0.781
Ilayperuma (2010)	Sri Lankan	M	0.715	0.312	–
		F	0.470	0.454	–
Asha and Lashkmi (2011)	South Indian	M	0.412	0.219	–
		F	0.169	0.203	–
	North Indian	M	0.151	0.165	–
		F	0.202	0.293	–
Akhter et al (2012)	Bangladeshi	F	-0.029	–	0.278
Kumar and Gopichand (2013)	Haryanvi	M	0.174	0.321	0.122
		F	0.190	0.008	0.181
Present study (2012)	Nigerian	M	0.159	0.101	0.253
		F	0.186	0.258	0.203

Table 5: Correlation coefficients of various cephalic dimensions in relation to stature, compared with other studies

Table 4 showed a comparison between actual stature and stature estimated from the cephalic dimensions. Stature was calculated using minimum, maximum and mean values of the cephalic dimensions, and cross-validated with the actual stature. On comparison, the minimum and maximum stature differed from the actual stature, and only the mean stature was identical with the actual stature. The reason may be due to a high standard deviation in the stature, showing that both minimum and maximum stature greatly deviated from the mean stature.

Table 5 showed a comparison of the correlation coefficients of the present study with works by other authors. The present work had low values, almost identical to those of the North Indian and Haryanvi population, but differed from the Sri Lankan and South Indian population. Ironically, it was much lower than other North Indian groups as reported by Krishan and Kumar (2007), and Krishan (2008). Only the Bangladeshi population showed a negative correlation between head length and stature. The anthropological variation between populations is again depicted in this comparison.

The primary issue facing this method of stature estimation is that cephalic dimensions, like other body segments, vary between populations. As a result, the stature estimation equation for a particular population in a given region cannot be used for another population, unless they have similar variables. If the data required for stature estimation were collected from more populations, then more accurate equations could be developed and documented, and stature estimation would improve, resulting in a greater number of identified people (Shields, 2007).

Estimation of stature of an individual from the mutilated body parts plays an obvious role in enabling identification of persons in incidents of murder, accidents or natural disasters. In the present study it is concluded that cephalic dimensions (head length, head breadth and head circumference) can be used for the estimation of stature in forensic examinations and anthropological studies in Nigerians, the Igbo population to be exact. The results of this study are however applicable only when an intact skull is examined.

The results of the present study showed that the cephalic dimensions were significantly correlated with stature (three dimensions in females but two in males), and can be used to estimate stature when mutilated remains are brought for identification with the skull intact. In comparison, the horizontal head circumference showed to be more reliable for estimating stature in males, and the head breadth showed more correlation and reliability for the females.

Conflict of interests
None

Funding
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Ethical approval
Ethical approval was obtained from the Ethical Committee, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nnewi, Nigeria.

Informed consent
Informed consent of the subjects was obtained before the anthropometric measurements (stature and cephalic dimensions) were taken.

Limitations of the Study
The limitations include refusal of some persons to participate in the study due to their limited knowledge of research methodologies and the physical rigours of taking different anthropometric measurements on a single individual.

Contributorship
Ukoha U. Ukoha - Concept and design of the study. Drafting and revising the manuscript for important intellectual content. Final approval for the version which is going to be published.
Kosisochukwu E. Umeasalugo - Acquisition of data, analysis and interpretation of data. Drafting and revising the manuscript for important intellectual content. Final approval of the version which is going to be published.
Onochie O. Udemezue - Acquisition of data. Drafting and revising the manuscript for important intellectual content. Final approval of the version which is going to be published.
Lasbery A. Asomugha - Acquisition of data. Drafting and revising the manuscript for important intellectual content. Final approval of the version which is going to be published.

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