

## Cranio-metric Indices of Nigeria Skulls

Research Article

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## Abstract

**Introduction:** Craniometric indices show the percentage relationship between different dimensions. It is an important parameter for classification of race and sex of individuals of unknown identity. This study was undertaken to determine the craniometric indices of gnathic, palatal, orbital, cranial and nasal indices of Nigerian skulls.

**Materials and Methods:** One hundred adult dry skulls, (78 males, and 22 females) free from damage and deformities from eleven Departments of Anatomy in Nigerian Universities were used. Automatic digital and spreading callipers were used for the measurement. Data was analyzed with Graph Pad Prism 5.03. The mean, coefficient of variation, correlation, linear regression, percentiles, the male/female ratio were calculated.

**Results:** The male/female ratios for the mean measurements were greater than unity. The mean value of all cranial parameters showed high level of sexual dimorphism. The male gnathic, palatal, orbital, cranial and nasal indices were found to be 99.50, 79.22, 89.59, 76.03, 53.67 respectively while female gnathic, palatal, orbital, cranial and nasal indices were 98.78, 87.66, 87.04, 76.12, 59.11 respectively. Male basion-nasion versus basion-prosthion length had positive correlation and the fit line sloped upward. There was no correlation between female basion-nasion versus basion-prosthion and the fit line was straight. Percentiles of indices showed a progressive increase from 10<sup>th</sup> - 90<sup>th</sup>.

**Conclusion:** The findings from this study will be handy tools in anatomical modelling, in addition to providing information for both cosmetic surgery and medico-legal guide in forensic science.

**Keywords:** Gnathic Index; Palatal Index; Skull; Anthropometry; Forensic Medicine.

## Introduction

Cranio-metry is the scientific measurement of skull. It plays an important role in forensic practise. Skull is the skeleton of the head and consists of cranium and facial skeleton. The cranium is made up of occipital, temporal, parietal, frontal, sphenoid and ethmoid bones while the facial skeleton comprises of maxillae, palatine, nasal, zygomatic, inferior nasal conchae, lacrimal, mandible and vomer bones. Measurement of cranial bones play an important role in analysis of skeletal variation in determining population history and classification.

Indices show the relationship between different dimensions (length and breadth) which can also be expressed as ratios or percentages of comparison of two measurements. The general formula of index is the ratio of numerator (smaller measurement) to denominator (larger measurement) multiplied by hundred [22]. They are vital tools for forensic experts with respect to identification and classification of races and sexes. Indices can demonstrate the degree of disproportions in various parts of human body caused by hormonal and other disorders, congenital anomalies or trauma [12]. Also variations between and within population have been attributed to a complex interaction between genetic and en-

vironmental factors [17].

Gnathic index is the ratio of basion – prosthion to basion – nasion multiplied by hundred. Gnathic index has been classified into three namely, orthognathous which is 98 and below, mesognathous which ranges between 98-103, prognathous which is above 103. Palatal index is ratio of palatal breadth to palatal length multiplied by hundred and is also classified into three: leptosthylin or narrow palate which is less than 79.9, mesosthylin or medium palate which ranges from 80-84.9 and brachysthylin or broad palate which is 80 and above.

Orbital index is ratio of greatest height of the orbital cavity to its greatest breadth multiplied by hundred [22]. Three classes of orbit index have been described: Megaseme (large) with orbital index of 89 and above usually seen in yellow races [5]. Mesoseme (intermediate): The orbital index range between 89 and 83. This type is seen in the white races [24]. Microseme (small): Orbital index 83 or less. This type is characteristic of the black races where the orbital opening is rectangular [5]. Nasal index is ratio of the greatest width of the nasal aperture to the length or height multiplied by hundred [22]. There are three main nasal types; leptorrhine, (narrow) which ranges from 54.9 to 69.9. Mesorrhine

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**Received:** December 01, 2015

**Accepted:** December 30, 2015

**Published:** January 04, 2016

**Citation:** Orish CN, Ibeachu PC (2016) Craniometric indices of Nigeria skulls. *Int J Anat Appl Physiol.* 2(1), 6-13. doi: <http://dx.doi.org/10.19070/2572-7451-160001>

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(medium) which ranges from 70.0 to 84.9 and platyrrhine with a range from 85.0 to 99.9.

Cranial index is ratio of the maximum breadth of the bare skull to its maximum length multiplied by hundred [22]. Cranial index is classified into, four main types namely dolicocephalic which is less than 74.9, mesocephalic with cranial index between 75 to 79.9, brachycephalic with cranial index between 80 to 84.9 hyper-brachycephalic with cranial index from 85 to 89.9 [22].

Several researches have worked on various craniometric indices [35, 6]. Such measurements are also useful in the analysis and classification of fossil remains as well as study of living population [4]. Information on craniometric indices especially palatal and gnathic indices is sparse in Nigerian population. The present study is aimed at adding some fund of knowledge to address the information gap in craniometric indices of Nigerian skulls.

## Materials And Methods

A total of 100 adult dry skulls (78 males and 22 females), free from damage and deformity, fully ossified collected from Departments of Anatomy in Nigerian Universities were used for this study. A digital caliper with a precision of 0.01mm (Mitutoyo®), spreading calliper, marker was used to measure the following length parameters basion-prosthion, basion-nasion, palatal length and breadth, orbital length and breadth, nasal height and breadth, cranial length and breadth.

### Basion - Prosthion, Basion - Nasion

It measures the straight distance between basion – prosthion. Basion, the most anterior point of the great foramen magnum in the sagittal plane [3]. Prosthion, the lowest, most anterior point on the alveolar portion of the premaxilla in the median plane, between the upper central incisors [3]. Nasion: This is the midpoint of the sutures of the frontal and nasal bones [3].

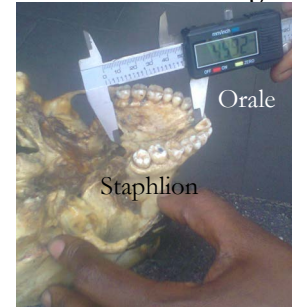


### Palatal Length (Orale –Staphyilion)

It measures the straight distance between orale and staphyilion. The skull was held with the norma basalis facing upward [3]. Staphyilion: This is a single point on the posterior hard palate

where the palatal suture is crossed by a line drawn tangent to the curves of the posterior margin of the palatal bones [3]. Orale: This is the most anterior point on the hard palate where a line drawn lingual to the central incisors intersects the palatal suture [3].

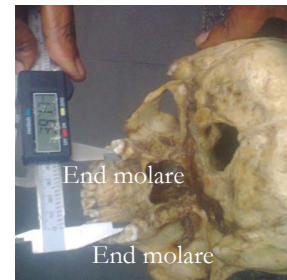
**Photo 3: Palatal length**



### Palatal Breadth

It measures the straight distance between the middle of the inner margin of the alveolar on the second molar i.e. end molar to end molar. End molar: This is the most medial point on the inner margin (lingual surface) of the socket of the second upper molar. It is used to measure palatal width. The skull was held in the norma basalis facing upward [3].

**Photo 4: Palatal breadth**



### Orbital length and breadth

**Orbital breadth (maxillofrontale-ectoconchion):** This measures the straight distance between maxillofrontale-ectoconchion. Maxillofrontale is the point where anterior lacrimal crest meet the frontomaxillary suture. Ectoconchion is the point where a line running parallel to the the upper orbital border cuts lateral orbital margin. The skull was held in the norma frontalis facing upward [3].

**Orbital length:** The length of the orbit was measured from supraorbital margin to the optical canal i.e., the maximum distance between the upper and lower margin of the orbital cavity taken perpendicular to the orbital breadth.

**Photo 5: Orbital height**



**Photo 6: Orbital breadth**



**Maximum Cranial Length (Glabella - Opisthocranium)**

The straight distance from the glabella to the opisthocranium. Glabella is the most prominent point between the two supra-orbital ridges above the fronto-nasal suture in the mid-sagittal plane. Opisthocranium is the most posterior point from the glabella in the mid-sagittal plane, excluding the inion.

**Photo 7: Cranial length**



**Maximum Cranial Breadth**

The straight distance between the two euryon points. Euryon is the most lateral point on the skull, which can only be determined by measuring the maximum cranial breadth, as it is variable.

**Photo 8: Cranial breadth**



**Nasal Breadth:** The maximum breadth between the two lateral margins of the nasal apertures. **Nasal Height (nasion to nasospinale):** The straight distance from the nasion to nasospinale. Nasospinale is the point where a line touching the lower margin of the nasal aperture crosses the mid-sagittal plane.

Data was analyzed with Graph Pad Prism 5.03. The mean, standard deviation, correlation, linear regression, percentiles, sexual dimorphism ratio and cranial indices were calculated. Student's *T*-test was used to compare male-female and right-left measurements.

**Photo 9: Nasal height**



**Photo 10: Nasal breadth**



$$\text{Gnathic index} = \frac{\text{Basion - prosthion} \times 100 \%}{\text{Basion-nasion}}$$

$$\text{Palatal index} = \frac{\text{Palatal breadth} \times 100 \%}{\text{Palatal length}}$$

$$\text{Nasal index} = \frac{\text{Nasal breadth} \times 100 \%}{\text{Nasal height}}$$

$$\text{Orbital index} = \frac{\text{Orbital height} \times 100 \%}{\text{Orbital width (breadth)}}$$

$$\text{Cranial index} = \frac{\text{Cranial breadth} \times 100 \%}{\text{Cranial length}}$$

Effect of sex on the following cranial parameters namely basion–prosthion, basion-nasion, palatal length and breadth, orbital length and breadth, nasal height and breadth, cranial length and breadth are shown on Table 1. Male parameters were significantly higher than female parameters except basion–prosthion, basion-nasion.

Table 2 shows sexual dimorphism ratio of the basion–prosthion, basion-nasion, palatal length and breadth, orbital length and breadth, nasal height and breadth, cranial length and breadth. The male/female ratios for the mean measurements were greater than unity in all. The percentiles of palatal length, breadth and index and basion-nasion versus Basion–prosthion and gnathic index are shown on Tables 3 and 4. There was progressive increase in these parameters from 10<sup>th</sup> to 90<sup>th</sup> percentiles. Table 5 shows cranial indices. The palatal, nasal and cranial indices were higher in female while gnathic and orbital indices were higher in male.

The incidence and classification of male and female gnathic indices are shown in Figure 1. Mesognathous and orthognathous showed higher incidence in males and females respectively. Figure 2 shows incidence and classification of male palatal and female palatal indices with leptostphylin and brachystphylin having the higher incidence respectively.

Figure 3 shows a scatter plot of the linear relationship between male basion-nasion versus basion- prosthion length. There was positive correlation between the left and right hence the fit line sloped upward. The scatter plot of the linear relationship between female basion-nasion versus basion-prosthion length (Figure 4). There was no correlation between them hence the fit line was straight (Figure 4).

Table 1. Effect of sex on the cranial parameters.

Parameters	Sex	Mean $\pm$ SD	Max	Min	Significant level
Basion-prosthion	M	100.5 $\pm$ 5.95	115	85	p > 0.05
	F	96.80 $\pm$ 2.66	100	92	
Basion-nasion	M	101 $\pm$ 5.53	110	90	p > 0.05
	F	98.00 $\pm$ 4.22	105	90	
Palatal length	M	54.04 $\pm$ 5.66	66.3	26.31	*p, < 0.05
	F	45.46 $\pm$ 6.50	51.56	34.28	
Palatal breadth	M	42.81 $\pm$ 3.78	54.40	24.72	*p, < 0.05
	F	39.85 $\pm$ 4.66	45.88	31.05	
Orbital breadth	M (left)	40.50 $\pm$ 3.20	48.51	26.67	*p, < 0.05
	F (left)	37.80 $\pm$ 2.29	40.37	33.93	
	M (Right)	40.01 $\pm$ 3.20	52.14	29.29	*p, < 0.05
	F (Right)	37.65 $\pm$ 3.18	41.30	33.35	
Orbital length	M (left)	36.59 $\pm$ 5.72	46.01	30.20	*p, < 0.05
	F (left)	32.75 $\pm$ 2.23	35.22	28.70	
	M (Right)	36.45 $\pm$ 3.00	36.30	29.26	*p, < 0.05
	F (Right)	32.94 $\pm$ 2.21	36.30	29.26	
Nasal breadth	M	29.69 $\pm$ 1.33	66.30	26.31	*p, < 0.05
	F	28.42 $\pm$ 1.02	51.56	34.28	
Nasal length (Height)	M	55.56 $\pm$ 3.52	54.40	24.72	*p, < 0.05
	F	48.48 $\pm$ 0.78	45.88	31.05	
Cranial breadth	M	137.2 $\pm$ 7.95	160	120	*p, < 0.05
	F	127.5 $\pm$ 3.53	150	125	
Cranial length	M	180.4 $\pm$ 8.12	195	155	*p, < 0.05
	F	167.5 $\pm$ 7.88	185	160	

Table 2. Sexual dimorphism ratio.

Parameters	Male mean (mm)	Female mean (mm)	Sexual dimorphism ratio*
Basion-nasion	101	98	1.03
Basion-prosthion	100.5	96.8	1.04
Palatal length	54.04	45.46	1.19
Palatal breadth	42.81	39.85	1.07
Nasal breadth	29.82	28.42	1.05
Nasal height	55.56	48.42	1.15
Cranial breadth	137.20	127.50	1.08
Cranial length	180.40	167.50	1.08
Average Orbital breadth	40.76	37.73	1.08
Average Orbital height	36.52	32.85	1.11

Sexual dimorphism ratio\* = Male mean/Female Mean

## Discussion

This study has shown that the cranial parameters are higher in male than females. Our findings show that the basion-prosthion were 100.5  $\pm$  0.67 and 96.80  $\pm$  0.84mm, basion-nasion 101  $\pm$  5.53 and 98.00  $\pm$  4.22 for male and female respectively. Kajanjola 1966 reported basion-prosthion as 9.85  $\pm$  0.07cm and 9.45  $\pm$  0.76cm and basion nasion as 9.98  $\pm$  0.43cm and 9.66  $\pm$  0.47cm for male and female respectively. Deshmukh and Devershi (2006) reported Basion-Prosthion length 90  $\pm$  4.21 and 89  $\pm$  5.08 and basion

nasion length as 99  $\pm$  4.19 and 96  $\pm$  4.61 for male and female respectively and was found to be significant by univariate analysis with p < 0.05. Steyna and Yasar (1998) found basion-prosthion length to be 95.4  $\pm$  5.39 and 90.0  $\pm$  5.03 and basion-nasion as 102.4  $\pm$  4.40 and 96.2  $\pm$  4.10mm for male and female respectively. Kraniotia et al 2008 in their work titled Craniometric analysis of the modern Cretan population found Basion-prosthion length to be 93.11  $\pm$  5.05 and 88.76  $\pm$  5.70 and Basion-nasion length to be 102.01  $\pm$  3.85 and 96.25  $\pm$  6.54mm for male and female respectively. Rooppakhun et al (2011) showed that the mean of



**Table 3. Percentiles of Palatal length, breadth and index.**

Parameters	Sex	10 <sup>th</sup>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	90 <sup>th</sup>	Normality test
Palatal length	Male	49.31	52.53	54.38	56.38	59.44	0.0001**
	Female	34.29	40.82	47.53	50.73	51.54	0.3021
Palatal breadth	Male	39.27	41.25	42.95	43.90	46.76	0.0001**
	Female	31.43	37.05	41.00	43.09	45.74	0.4900
Palatal index	Male	67.85	75.36	79.44	82.38	88.37	0.0001**
	Female	78.32	80.70	85.02	90.27	129.1	0.0001**

**Table 4. Percentiles of Basion-nasion, Basion – prosthion and gnathic index.**

Parameters	Sex	10 <sup>th</sup>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	90 <sup>th</sup>	Normality test
Basion-prosthion length	Male	90.00	98.75	100	105	105.5	0.6774
	Female	92.30	95	97	100	100	0.9197
Basion-nasion breadth	Male	95	95	100	105	110	0.0120*
	Female	90.50	95	100	105	110	0.7514
Gnathic index	Male	94.74	95.41	100	104.8	105.3	0.1263
	Female	95	96.38	98.50	105.9	108.2	0.3697

**Table 5. Craniometric indices of Nigerian skulls.**

Indices	Sex	Values	Categories
Gnathic	M	99.50	Mesognathous
	F	98.78	Mesognathous
Palatal	M	79.22	Leptostaphylin (Narrow palate)
	F	87.66	Brachystaphylin (Broad palate)
Cranial	M	76.03	Mesocephalic
	F	76.12	Mesocephalic
Orbital	M	89.59	Megaseme
	F	87.04	Mesoseme
Nasal	M	53.67	Hyerleptorrhine
	F	59.11	Leptorrhine

**Figure 1. The incidence and classification of male and female gnathic indices.**

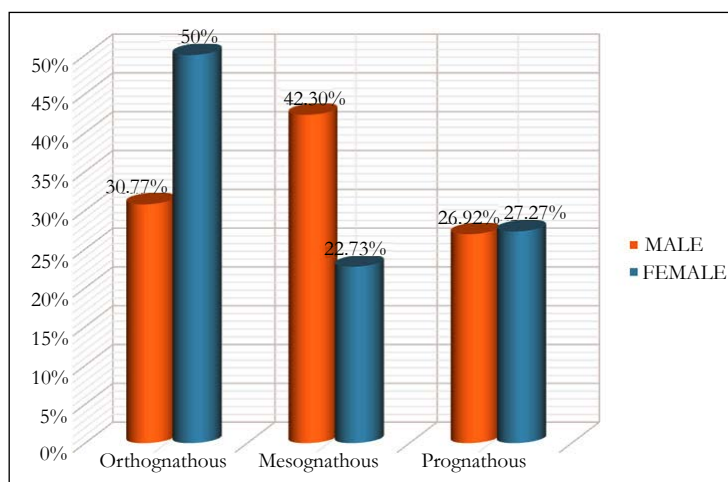


Figure 2. Incidence and classification of male palatal and female palatal indices.

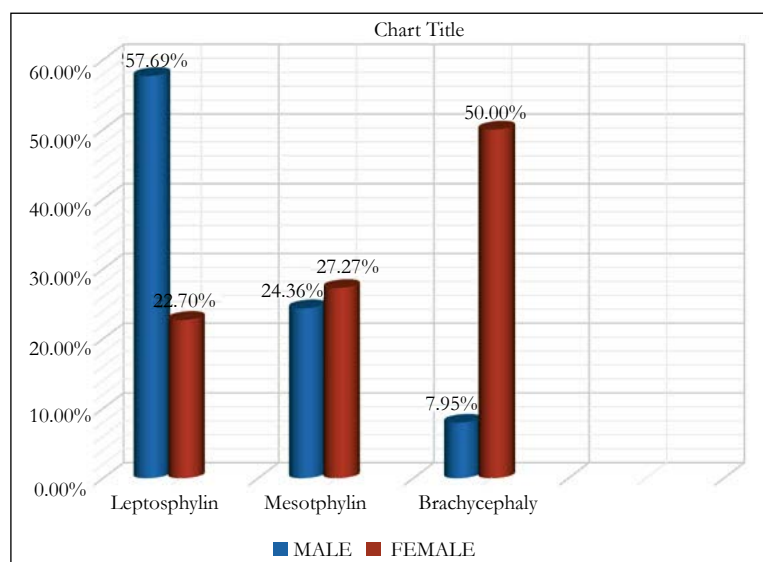


Figure 3. Linear regression graph of male basion-nasion versus basion-prosthion length.

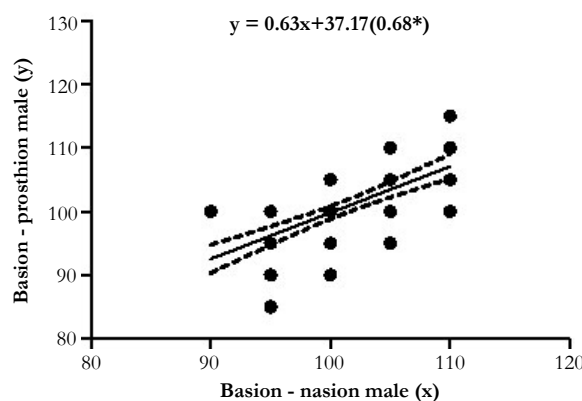
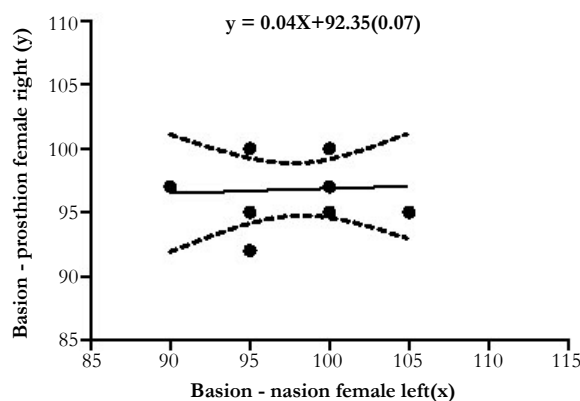


Figure 4. Linear regression graph of female basion-nasion versus basion-prosthion length.



Basion-prosthion to be  $96.1 \pm 5.4$  and  $92.9 \pm 5.5$ mm for male and female respectively. Ahmed et al 2011 in Northern Sudanese using crania (69 males, 41 females) found Basion-prosthion to be  $98.39 \pm 4.89$  and  $93.12 \pm 4.98$  and Basion-nasion  $100.62 \pm 4.09$  and  $94.41 \pm 3.38$ mm for male and female respectively.

Deshmukh and Devershi (2006) reported palatal length of  $45 \pm 3.08$  and  $44 \pm 3.37$ , palatal breadth  $35 \pm 1.50$  and  $34 \pm 2.73$ mm for male and female respectively and was found to be significant ( $p < 0.05$ ) by univariate analysis. Rooppakhun (2011) study on advanced medical imaging and reverse engineering technologies in craniometric studies using 104 skulls (63 males and 41 females) reported palatal length of  $42.6 \pm 4.2$  and  $42.6 \pm 4.4$ mm and

palatal breadth of  $39.1 \pm 3.1$ mm and  $37.6 \pm 2.4$ mm for male and female respectively. The above findings differ from our own research which reported higher values for male and female to be  $54.04 \pm 0.64$  and  $45.46 \pm 2.06$ mm respectively.

Dave et al, 2013 reported incidence of palatal index of 63% as narrow (leptostaphylin), 24% had intermediate (mesostaphylin), and 13% had wide (brachystaphylin). This agrees well with male palatal index of the present study which showed that majority of the skulls 57.69% had narrow (leptostaphylin), 24.36% had intermediate (mesostaphylin), 17.95% had wide (brachystaphylin). It contradicts however with female palatal index which

reported majority of the skulls to be 50% brachystaphylin, 30% mesostaphylin and 20% leptostaphylin.

In this study orbital breadth and height have higher values which can be attributed to racial differences. In a study by Gosavi et al., (2014) from central India, the mean height of the orbit was observed as  $32.31 \pm 2.52$ mm. Kaur et al., 2012 recorded orbital height it as  $32.05 \pm 2.0$ mm in North Indian skulls. The orbital width was observed as  $36.5 \pm 1.92$  and  $36.41 \pm 1.78$ mm on right and left sides respectively by Narasinga and Pramila 2015 whereas it was reported to be  $39.25 \pm 2.3$ mm by Kaur et al., (2001). Ebeye and Otiipo 2013 in Nigerian subjects observed orbital height as 32.46mm and mean orbital width as 41.43mm. Weaver et al., 2010 in their computer tomography scan based study in Caucasian population observed orbital height as  $32.09 \pm 2.2$ mm and orbital width as  $37.01 \pm 2.0$ mm. Also Ebeye and Otiipo 2013 in their study observed orbital index as 78.15 which is different from our reported orbital indices of 89.59 and 87.04 for male and female respectively. The orbital index which determines the shape of the face differs in different population groups. This means that the orbit with larger width than height will have smaller orbital indices while those with larger orbital index will have narrow faces. Kaur et al., 2012 observed orbital index as 81.65 while Narasinga and Pramila 2015 recorded right and left orbital indices as 86.13 and 90.69 respectively.

The Indian population according to Kaur et al 2012 that reported an orbital index of 81.65 belongs to the microseme category. Kaplanoglu et al 2013 in Turkey reported the average orbital index in females to be 85 in males 84.6 belonging to mesoseme category. The orbital indices for male and female from the present study are 89.59 and 87.04 suggesting that Nigerian skulls can be classified as megaseme and mesoseme for male and female respectively. This is in agreement with earlier study by Ukoha et al 2011 in Nigerian skulls with orbital index of 89.21. In Malawians, the skulls have been categorized as megaseme with the orbital indices in males and females as 94.35 and 96.03 respectively [37]. In an old study conducted by Casidy, the black race was categorized as microseme [27].

Kranioti and Iscan 2008 reported nasal breadth and height to be higher in male higher than female which is similar to our findings. In another skull study, Vidya et al 2012 reported nasal breadth as  $2.36 \pm 0.26$  and  $2.23 \pm 0.24$ cm, nasal height  $4.79 \pm 0.57$  and  $4.54 \pm 0.35$ cm for males and females respectively and the differences were found to be significant ( $p = 0.026$ ). Nasal indices of 49.38 and 49.24 for male and female respectively have been reported by Vidya et al 2012, whereas the nasal indices from the present study are 58.6 and 53.4 for male and female respectively.

Kranioti et al 2008 reported cranial length as  $181 \pm 6.63$  and  $172.89 \pm 6.48$ mm in males and females respectively. These data tend to agree with the present study that has cranial length of  $180.4 \pm 8.12$ ,  $167.5 \pm 7.28$ mm for male and female respectively. Vidya et al 2012 also reported cranial length of  $16.81 \pm 1.61$ ,  $16.67 \pm 1.73$  and breadth of  $13.29 \pm 1.93$  and  $13.28 \pm 1.45$ mm and cranial indices of 78.40 and 79.13 for male and female respectively. Strouhal 1992 reported that the cranial index in ancient Egyptians skulls ranged from 71.80-76.10 while the present recorded cranial indices of 76.03 and 76.12 for male and female respectively.

In a study of 62 skulls, Seema and Gandhi 2011 reported that the cranial indices for male were 72.54 and female 72.06. Adejuwon

et al 2011 reported cranial indices of 72.97 and 71.72 for males and females respectively. Jaysingh et al 1979 in their study of 300 human skulls reported a cranial index of 74.35.

In a Tibetan skull study by Morant, the cranial index was 75.25 [25]. Chaturvedi et al 1963 reported a cranial index of 70.75. In Mongoloid race dolicocephaly is rare while brachycephaly is rare in Negroid race [30]. The present study also showed the rarity of brachycephaly. Human knowledge of paleontology and available data suggest that early man was generally dolicocephalic. Brachycephaly developed later as a result of repeated mutation and various other factors [30]. The present study shows that the majority of the skull are dolicocephalic which is in agreement with the work of Vishal and Pradeep 2012 study on in South India skulls. However the mean of the cranial indices from the present study suggest mesocephalic for both sexes.

Taken together there was a progressive increase in the 10<sup>th</sup> percentiles to 90<sup>th</sup> percentiles of palatal length, breadth and index, basion-nasion, basion-prosthion and gnathic index. To the best of our knowledge, this is the only study that has reported the percentiles of palatal length, breadth and index, basion-nasion, basion-prosthion and gnathic index.

In a bid to model the relationship between two anthropometric parameters, this study has employed linear regression and correlation tools as aforementioned using the equation  $y = ax + b$ . With this equation the value  $y$  can be predicted when  $x$  is known. Hitherto information is scanty on the mathematical models of these craniometric parameters [28]. A positive regression coefficient indicates a positive relationship between two variables and from the graph the fit line sloped upward as in male Basion-nasion v Basion-prosthion while a negative regression coefficient indicates a negative relationship between two variables and from the graph the fit line sloped downward as in male Basion-bregma v Nasion bregma. Ahmed et al, 2011 reported that sexual dimorphism ratio (male/female ratios) for the mean measurements were greater than unity, indicating that the male crania were larger in all linear dimensions than female crania. This correlates well with the present study which reported that sexual dimorphism ratio for the mean measurements were greater than unity too, indicating that the male crania were larger in all linear dimensions than female crania. Knowledge of gnathic and palatal, orbital, cranial and nasal indices of Nigerians will be of immense help to forensic expert with respect to classification of races and sexes and also to surgeons in clinical practise.

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