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Normal value of cephalic index and craniotypes: a pilot sonographic cephalometric survey of pregnant women of Yoruba ethnic origin in Lagos, southwest Nigeria

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Abstract

Background: Sonographic cephalometry is used to identify ethnic differences. Biparietal diameter (BPD) and occipito-frontal diameter (OFD) may be used to compute cephalic index (CI).

Methods: A sonographer measured the BPD and OFD in 200 pregnant women of Yoruba ethnic origin. The formula BPD/OFD x 100 was used to compute the CI. Mean CI was used to determine craniotypes. Coefficient of correlation, line graph, and the Bland-Altman plot, were used to determine the relationship between CI, BPD and OFD.

Results: Mean CI was 77.24 ± 3.88 mm. There was a statistically significant difference ($p < 0.05$) in mean CI between fetuses of Yoruba, Igbo and Indian ethnic origin. Correlation was significant between CI and BPD ($r = 0.163$; $p = 0.02$) and between CI and OFD ($r = -0.02$; $p = 0.000$); 68.0% of fetuses had mesocephaly. The formula CI = 0.0371(BPD) + 74.656 and CI = 0.0035 (OFD) + 77.559 may be used to calculate CI on the basis of respective sonographically measured BPD and OFD.

Conclusion: While the skull appeared to have grown to its full length and breadth in the first trimester of pregnancy, a typical fetus of Yoruba ethnic origin in Lagos metropolis most likely would have a long and flat skull at birth. Even as ethnic differences appear to be a major factor in the development of cranial development in the population studied, a simple regression equation can be used to compute cephalic index and to correct atypical craniotypes among fetuses without craniofacial anomalies.

Keywords Fetus, simple regression, Bland-Altman plot, craniometry

INTRODUCTION

Morphological features in different ethnic groups are usually not randomly distributed. Instead, they appear in geographical clusters.[1] Cephalometry may literally be defined as the study and measurement of the head. Anthropologists were among the earliest to use cephalometric values to describe and generalise facial appearances to specific populations. It is believed that cephalometry is arguably the most useful technique in the investigation of craniofacial morphology because of its validity and practicality.[2] Craniometry is useful in the diagnosis of craniosynostosis (also known as synostosis) which is early fusion of two or more bones of the calvarium that results in an abnormal head shape.[3] Although sporadic cases have been reported, syndromic craniosynostosis is inherited and is often associated with genetic disorders such as Apert, Baller-Gerold, Pfeiffer and Muenke syndromes.[4] Lemon-shaped head is associated with spina bifida in 31.6% of fetuses; strawberry-shape is associated with aneuploidy in 18.4% of fetuses.[5] Trisomy-13, on the other hand, is associated with facial defects and urogenital malformations while trisomy-21 is characterised by facial dysmorphism.[6-7]

Standardised cephalometric values are useful when comparing patients with the normal population and also useful in pediatrics, forensic medicine, and plastic as well as orodental surgery.[1-2] In fact, knowledge of the normal cephalic index (CI) range is important in determining atypical fetal head shapes.[8] CI has been described as the relationship between the long and short axes of the foetal calvarium used to distinguish a normal fetal head shape from an abnormal one. It is the ratio of the maximum width (i.e. BPD) of the head multiplied by 100 divided by its maximum length (i.e. OFD) and a quantitative and objective method of determining skull shape.[9-11] To neurosurgeons, knowledge of the normal range of CI is useful in a pre-operative work-up as well as in a post-operative assessment of correction of skull deformities.[8,12] Craniometry is also useful in studies pertaining to primate phylogeny.[1]

There are significant variations in cranial shape and size in different ethnic groups. Chinese heads, for instance, have been reported to be more round than their Caucasian counterparts.[13-15] Among the Idoma and Igede ethnic nationalities in northcentral Nigeria, mesocephaly was reported as the predominant head shape; dolichocephaly was reported as predominant craniotype in a population of Yoruba people of southwest Nigeria.[16-17] Since geographic, ethnic and dietary differences exist amongst different population groups, information about morphometric characteristics becomes important for purposes of comparison. Due to ethnic differences, age and population-specific data on cranial morphometry are not only useful in clinical practice as indicators of growth and development, but are also important in determining changes in size and shape or abnormalities of the crania.[18] With the existence of ethnic differences in cranial size well known, it is little wonder that postnatal cephalometric normal values of cephalic length, cephalic breath and cephalic index (CI) have been reported for different ethnic groups.[17,19-20]

Early diagnosis of congenital fetal anomalies helps a physician to choose between the non-aggressive obstetric management and termination of pregnancy.[21] In spite of the role of postnatal craniometry in differentiating craniotypes, it is imperative to note that cranial anomalies are mostly congenital with cranial vault shape reported to be more dependent on genetic factors than on cerebral development.[8] Imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography may be used for prenatal metric evaluation of craniofacial form.[1] Sonography does not involve ionising radiation, it is less expensive than CT or MRI, and is commonly available in developing countries like Nigeria. It therefore is preferred in the intra-uterine evaluation of the fetus.

In sonographic cephalometry, standardised measurement of fetal biparietal diameter (BPD), head circumference (HC), as well as occipito-frontal diameter (OFD), may be used to estimate fetal age as well to diagnose congenital anomalies. Studies have demonstrated the effective use of sonographic CI in the diagnosis of closure of sutures in the third trimester of pregnancy, strawberry-shaped cranial vault and narrow flattened front-occipital region in trisomy 18 while sonography has equally been used to determine normal CI values in early cyesis using the transvaginal approach in various ethnic populations.[8,22-25] Data on CI obtained from fetal sonographic craniometry is sparse in Nigeria that has many distinct ethnic groups. To the best of our knowledge, there is no data on sonographic fetal craniometry in any population of Yoruba people who make up one of the largest ethnic groups in Nigeria. The purpose of this study was to perform fetal craniometry in a Nigerian population of fetuses of Yoruba ethnic extraction in Lagos, southwest Nigeria using ultrasonography technique in order to provide baseline cephalometric data, cephalic indices and craniotypes for clinical use and future reference.

METHODS

A prospective longitudinal study was carried out at a private hospital in Lagos metropolis between November 2016 and August 2017. Ethics approval was obtained from the Human Research Ethics Committee at the hospital located in Ketu, Lagos. Informed written consent was obtained from women before they were recruited. In line with the standards for reporting diagnostic accuracy studies (STARD), potentially eligible participants were identified. They were pregnant women who were referred to the ultrasound centre at the hospital for routine antenatal examination. From potentially eligible participants, a convenience sample of 200 healthy Nigerian women of Yoruba ethnic origin with singleton pregnancy was selected. Participants were recruited on first-to-come first-to-be recruited basis. Only Yoruba women who were married to Yoruba men were included in the study to ensure that fetuses were of Yoruba ethnic origin. Women who were sure of the date of onset of their last menstrual period (LMP) who agreed to undergo first trimester ultrasound examination for pregnancy dating as well as 2nd and 3rd trimester follow-up examinations were recruited. Sonographic measurement of crown-rump length (CRL) was done within 7-13 weeks of cyesis. In line with recommendations,[26] each participant was included in the present study only when the difference between fetal age calculated from LMP and ultrasound estimation was ≤7 days. Socio-demographic and anthropometric data were collected. Trans-abdominal ultrasonography was performed using Mindray DC-N3 ultrasound machine with a 3.5MHz convex probe. All sonographic measurements were performed by one sonographer who has >8 years of experience in obstetric sonography. Each participant was examined while lying supine. In line with recommended protocols for performing obstetric sonography,[27] the probe was placed perpendicular to the central axis of the fetal head on a plane that traversed the thalami and cavum septum pellucidium and care was taken to ensure that

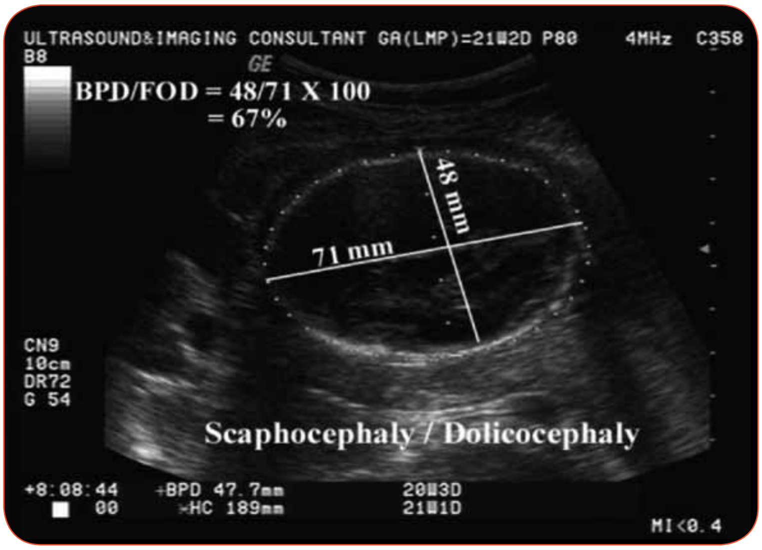

Figure 1. Sonogram of fetal head showing BPD and OFD measurement

Table 1. Mean Cephalic Index for the population, 2nd trimester and 3rd trimester

	MEAN ± STANDARD DEVIATION			*P* VALUE
	POPULATION n = 200	2nd TRIMESTER n = 200	3rd TRIMESTER n = 200	
Cephalic index	77.24 ± 3.88	76.77 ± 3.25	77.58 ± 4.26	0.147§
Range	69.33 - 114.87	69.33 - 84.62	71.80 - 114.87	

§ *Independent samples t-test for 2nd and 3rd trimester only*

Table 2. Comparison of mean CI in the present study with Igbo population in Nigeria

	MEAN ± STANDARD DEVIATION		*P* VALUE	MEAN DIFFERENCE
	PRESENT STUDY	UGWU *ET AL.* (2007)		
Cephalic index	76.77 ± 3.25	85.92 ± 4.88	0.000‡	-8.677445
Range	69.33 - 84.62	71.80 - 114.87		

‡ *One sample t-test*

cerebellar structures were avoided. Both BPD and occipito-frontal diameter (OFD) were measured at the level of the thalami and septum pellucidium. For BPD (width of the skull) measurement, the cursor was placed at the outer edge of the proximal and then taken to the inner edge of the distal calvarial wall. For OFD (the longitudinal diameter of the calvarium) measurement, the cursor was placed at the proximal outer and drawn to the distal outer calvarial wall (Figure 1). As was previously done in several similar studies[13,19] the cephalic index (CI) was thereafter computed using the formula: CI = BPD/OFD x 100. Craniotyping was thereafter performed using Mishra et al's method[19] as follows:

Ultra-dolichocephalic:
cephalic index = 55.0 - 59.9

Hyper-dolichocephalic:
cephalic index = 60.0 - 64.9

Dolichocephalic:
cephalic index = 65.0 - 74.9

Mesocephalic:
cephalic index = 75.0 - 79.9

Brachycephalic:
cephalic index = 80.0 - 84.9

Hyper-brachycephalic:
cephalic index = 85.0 - 89.9

Ultra-brachycephalic:
cephalic index = 90.0 - 94.9

Mean CI ± standard deviation (SD) was computed for the population and for 2nd and 3rd trimester. Paired t-test was used to compare mean CI in the present study with previously published means in different populations. Pearson's product moment correlation analysis and line graphs were used to determine correlation between CI, BPD and OFD. Bland-Altman plot was used to determine 95% confidence interval of CI (mean CI ± 2 SD) in the population. Thereafter, the proportion for each head shape (craniotype) was computed. Simple logistic regression analysis was used to produce equations (nomograms) that could be used to compute CI in the population. Data were analysed using SPSS software version 17 (SPSS Inc., Chicago, Illinois, USA). Results were tested for statistical significance at $p \leq 0.05$.

Table 3. Comparison of mean CI in the present study with an Indian population

CEPHALIC INDEX	MEAN ± STANDARD DEVIATION		*P* VALUE‡	MEAN DIFFERENCE
	PRESENT STUDY	RAJLAKSHMI *ET AL.*		
16 - 20	76.4 ± 3.2	79.2 ± 3.6	0.0001	-2.793000
21 - 25	76.9 ± 3.6	80.6 ± 3.7	0.0001	-3.743375
26 - 30	76.9 ± 2.4	82.6 ± 6.5	0.0001	-5.719432
31 - 35	77.2 ± 2.4	82.5 ± 1.7	0.0001	-5.284127
36 - 40	78.4 ± 6.4	88.7 ± 2.3	0.0001	-6.09926

‡ One sample t-test

Table 4. Comparison of mean CI in the present study with Manipuri Indian population

CEPHALIC INDEX	MEAN ± STANDARD DEVIATION		*P* VALUE‡	MEAN DIFFERENCE
	PRESENT STUDY	LOKESH *ET AL.*		
16 - 20	76.41 ± 3.16	80.36	0.0001	–3.953000
21 - 25	76.86 ± 3.59	77.00	0.802	–0.143375
26 - 30	76.89 ± 2.44	80.59	0.0001	–4.52447
31 - 35	77.22 ± 2.39	79.77	0.0001	–2.554127
36 - 40	78.42 ± 6.40	80.41	0.054	–1.988171

‡ One sample t-test

Table 5. Classification of fetal head shapes in the population studied

TYPE OF HEAD SHAPE	N (%)
Dolichocephaly	10 (5.0)
Mesocephaly	136 (68.0) *
Brachycephaly	48 (24.0)
Hyperbrachycephaly	6 (3.0)
Total	**(100.0)**

**Mesocephaly was the commonest head shape in the population*

Table 6. Correlation of CI with BPD and OFD

		CI	BPD	OFD
Cephalic Index (CI)	Pearson Correlation	1	.163*	-.020
	Sig. (2-tailed)		.021	.782
	N	200	200	200
Biparietal Diameter (BPD)	Pearson Correlation	.163*	1	.983**
	Sig. (2-tailed)	.021		.000
	N	200	200	200
Occipito-frontal Diameter (OFD)	Pearson Correlation	-.020	.983**	1
	Sig. (2-tailed)	.782	.000	
	N	200	200	200

** Correlation is significant at the 0.05 level (2-tailed).*
*** Correlation is significant at the 0.01 level (2-tailed).*

RESULTS

The mean age of the population was 33.4 ± 2 years. The mean CI in the population was 77.24 ± 3.88 mm; mean CI for the 2nd and 3rd trimester was 76.77 ± 3.25 mm and 77.58 ± 4.26 mm, respectively. Mean CI for 2nd and 3rd trimesters was not statistically different from each other (p=0.147; Table 1). Mean CI in the population was statistically different (p=0.000) from mean CI previously reported in an Igbo population (Table 2). There was a statistically significant difference ($p<0.05$) in the mean CI obtained in the present study compared with means reported in different Indian populations (Tables 3 and 4). Most fetuses (68.0%) had mesocephalic head shape whereas the head was hyper brachycephalic in 3.0% of fetuses (Table 5).

There was significant correlation between CI and BPD (r=0.163; p=0.02) (Table 6) and between CI and OFD (r=-0.02;

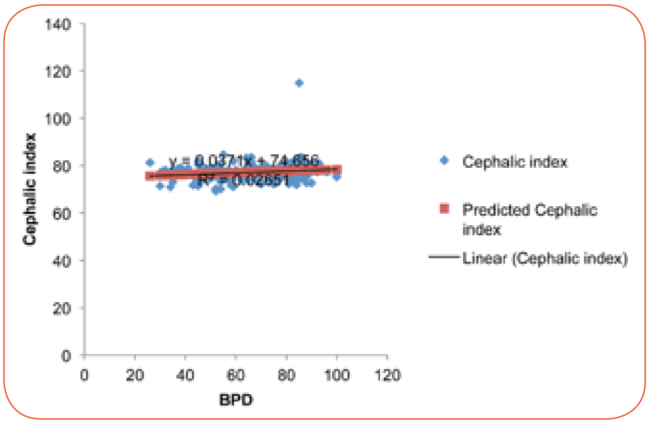

Figure 2. Line graph showing goodness-of-fit HCI/BPD plot.

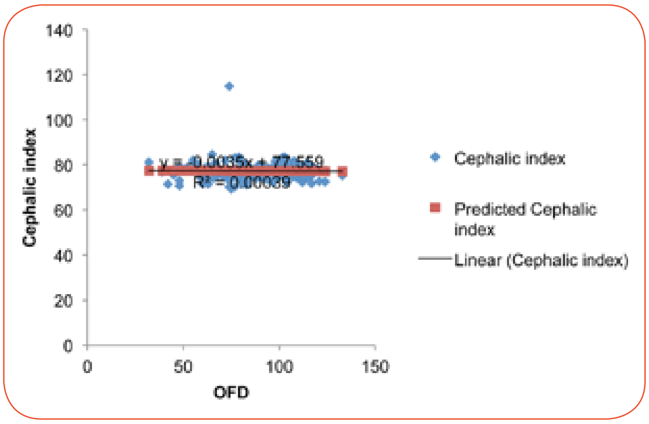

Figure 3. Line graph showing goodness-of-fit HCI/OFD plot.

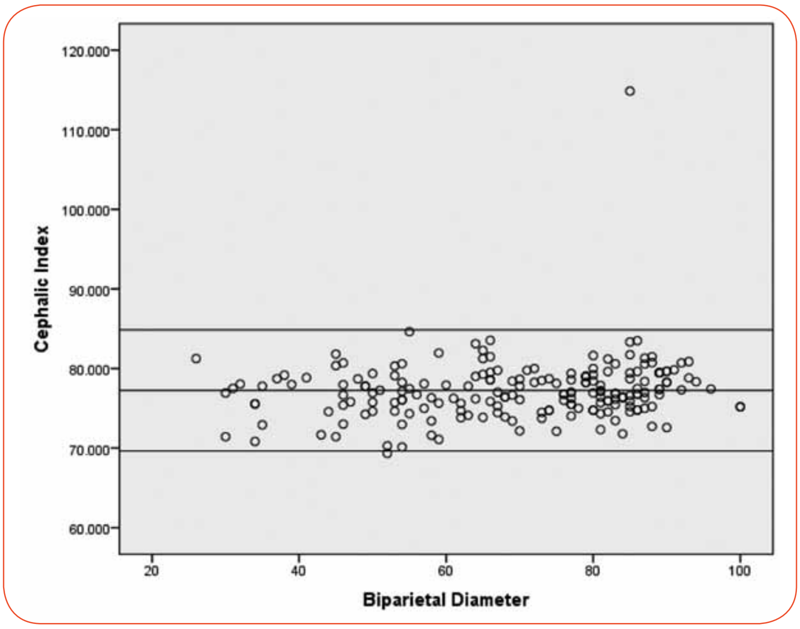

Figure 4. Bland-Altman plots of horizontal cephalic index and biparietal diameter.

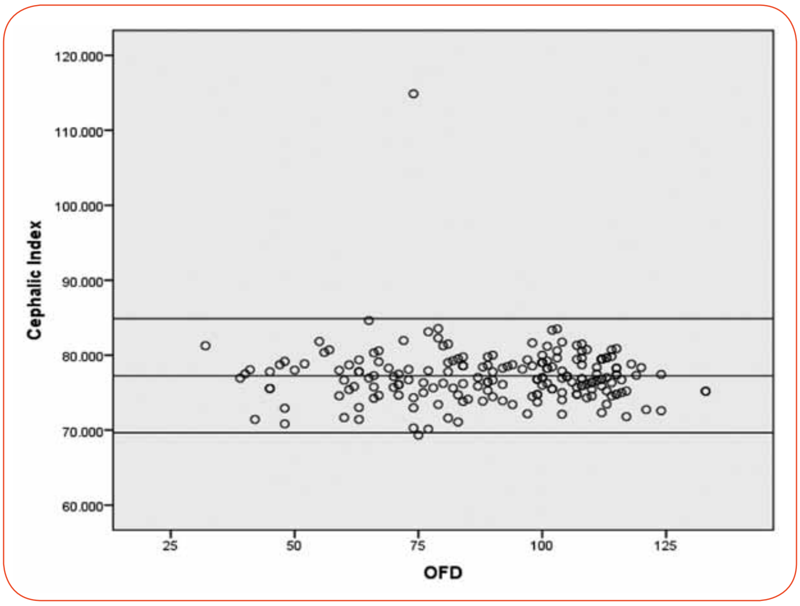

Figure 5. Bland-Altman plots of horizontal cephalic index and OFD.

p=0. 000) (Table 6). Figures 2 and 3 are line graphs depicting significant correlation between CI and BPD as well as between CI and OFD. Figures 4 and 5 are Bland-Altman graphs showing CI ± 2 standard deviations (SD) for CI against BPD and for CI against OFD, respectively. Simple regression equation for calculating CI on the basis of BPD and OFD are CI = 0.0371 (BPD) + 74.656 and CI = 0.0035 (OFD) + 77.559, respectively.

DISCUSSION

It is well known that ethnic characteristics of a population are expressed in phenotype skeletal morphology. The view of Williams et al[28] is that their best and most obvious expression is in the skull. They also opine that cranial morphometry (CI in particular) establishes the most significant characteristic for defining the ethnic difference. It is an established fact that a comparison of CI between parents, offspring and their siblings has the potential to give a reliable clue towards genetic transmission of inherited characteristics. Craniometry is also important for facial reconstruction in cases of disputed identity. Cephalometry is a simple and accurate method for investigating craniofacial skeletal morphology hence its continued popularity in the assessment of such characteristics.[30] This study appears to be the first to undertake prenatal sonographic measurement of CI. It provides data that could be useful regarding cephalic indices and craniotypes in a population of fetuses of Yoruba origin in Lagos, southwest Nigeria.

There was a statistically significant difference (p<0.05) in mean CI (77.24 ± 3.88 mm; range = 69.33 - 114.87 mm) in the present study. In accordance with the classification of Mishra et al,[19] mesocephaly was the dominant craniotype in the population studied. This craniotype suggests that a fetus from the Yoruba ethnic nationality, in Lagos Nigeria, with no craniofacial anomaly will almost certainly have a long and flat head at birth. We noted a significant difference when the mean CI in our study was compared with the mean CI that was reported by Ugwu et al[8] in an Igbo population in southeast Nigeria. There was also statistically significant difference between mean CI observed in the present study compared to mean CI reported in different Indian populations.[31-32] These differences support the view that ethnicity/genetic makeup plays a role in the development of craniotypes.[18]

With respect to fetuses in the 16-20 weeks gestational age range, we observed a statistically significant difference in mean CI (76.4 ± 3.2 mm) compared to 79.2 ± 3.6 mm reported by Rajlakshmi et al[31] in Manipuri, Indian fetuses between the ages of 16 and 20 weeks. While we cannot rule out that the sonographic technique and the quality of ultrasound machines used could have contributed to differences in CI, we are inclined to believe that our study appears to reaffirm the opinion that ethnic differences exist in CI. We observed a marginal increase in CI mostly within the 2nd trimester which strongly suggests that fetal head/brain development was probably more rapid within the first trimester of pregnancy. Although we did not compute the rate of cranial growth, our observation somewhat agrees with Rajlakshmi et al's[31] earlier submission to the effect that CI increased with advance in fetal age.

A mixed pattern of craniotypes was observed in the present study; mesocephaly was the commonest fetal head shape in the population. This suggests that most fetuses of Yoruba extraction in the population studied would most likely have medium sized heads. It also points to the fact that other factors, other than genetic makeup, play appreciable roles in cranial development. The proportion of fetuses with mesocephaly in our study (68.5%) is more than 33.6% reported in an India population.[32] In the same Indian population, 54% of fetuses had brachycephaly whereas 48% of fetuses had brachycephaly in the present study. This suggests that a typical Indian fetus in the Manipuri region would most likely be born with a relatively broader and shorter skull than its Yoruba counterpart in Lagos metropolis. The 5% of fetuses with dolichocephaly and 3% with hyper brachycephaly observed in the population studied suggest that it would not be totally unusual for a typical Yoruba couple in Lagos metropolis to have a baby with a relatively long skull or an extremely short skull in spite of their genetic makeup. More Indian fetuses in the Manipuri region[32] had dolichocephaly and hyper brachycephaly (4% and 8.4%, respectively). This appears to reaffirm that fetuses in the Manipuri region would mostly have shorter and broader skull at birth than their Yoruba counterparts in Lagos metropolis. While we concede that errors in measurement could have contributed to differences in craniotypes reported, we are inclined to suggest that ethnic/dietary differences most certainly played dominant roles in cranial development in those populations. It is therefore, not implausible to submit that fetuses of Yoruba origin are likely to be born with flatter/longer skull than their Indian counterparts from the Manipuri region.

Within the 2nd and 3rd trimester of cyesis, we observed that fetal skull was generally mesocephalic; no significant difference in mean CI was observed between 2nd and 3rd trimesters. This suggests that the fetal skull was more or less fully developed in the 1st and probably early 2nd trimester in the population studied. This supports Tuli et al[33] who earlier reported no significant change in CI between the 2nd and 3rd trimester of gestation with fetal heads generally mesocephalic in the 2nd and 3rd trimester of cyesis. This study thus reiterates the importance of performing 1st and early 2nd trimester sonographic evaluation in a patient with high risk for congenital anomaly. Our study, however, does not support Bharati et al's opinion[34] which states that the head is usually flat and long (dolichocephalic) in tropical regions but generally round (mesocephalic/brachycephalic) in temperate regions.

We observed a significant correlation between BPD and CI, and between OFD and CI in the population studied. While this might not be totally unexpected as pregnancy advanced, we believe that it underscores the need for sonographic measurement of OFD and subsequent computation of CI in obstetric evaluation of women at high risk of congenital anomalies. It also highlights the superiority of sonographic cephalometry in the evaluation of atypical craniotypes instead of visual inspection and measurement of BPD that is usually done by a few sonographers in Lagos metropolis. In the present study, simple regression analysis showed that atypical craniotypes can be corrected using an equation while Bland-Altman graphs showed that within 2-SD of the mean, CI could be used to categorise fetal head shape thereby reaffirming that computation of CI should be considered when the fetus presents with atypical craniotype.

Mesocephaly had earlier been reported by Obaje et al[16] as the dominant head shape among the Idoma and Igede ethnic nationalities in northcentral Nigeria. Oladipo et al[17] also reported dolichocephaly as the dominant craniotype in a cohort of Yoruba people in the southwest of the country. Neither studies[16,17] carried out prenatal cephalometric studies which made their results unsuitable for comparison with ours. Another limitation of our study was the small sample size in terms of the population of people of Yoruba ethnic origin in Nigeria. Although it can be argued that data obtained in the present study were reliable since only one sonographer performed sonographic measurements, we think that without further validation, reference values of CI, craniotypes and the nomogram developed in the present study might be valid only among fetuses in the population studied.

CONCLUSION

While the skull may appear to have grown to its full length and breadth in the first trimester of pregnancy, a typical fetus of Yoruba ethnic origin in Lagos metropolis would most likely have a long and flat skull at birth. Even as ethnic differences appear to be a major factor in cranial development in the population studied, a simple regression equation can be used to compute cephalic index and to correct atypical craniotypes among fetuses without craniofacial anomalies.

CONFLICT OF INTEREST

We have none to declare.

CONTRIBUTIONS OF AUTHORS

CUE (University of Lagos) was the main researcher; DCE (Hospital Support Diagnostic Center, Ketu, Lagos) was responsible for data collection; LCA (University of Lagos) assisted with data analysis and interpretation of the results. DOO (University of Lagos) drafted the manuscript.

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