

Sonographic Assessment of the Fetal Heart Circumference as a Predictor of the Gestational Age

Original scientific paper



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Results: There is a strong positive linear correlation between the FHC and the GA ($r^2 = 0.964$, $p < 0.001$). The equation of GA prediction is $Y = 0.246X + 5.06$ (where $y = GA$, $X = FHC$). FHC weekly growth rate is 3.81mm. FHC is more accurate between 12-20 weeks GA and its accuracy decreases as the pregnancy progresses. There is a strong correlation between FHC and biparietal diameter (BPD) ($r^2 = 0.959$), HC ($r^2 = 0.946$) and FL ($r^2 = 0.962$).

Conclusion: The study has derived a nomogram of FHC as a predictor of the GA in Nigerian population and has shown that the FHC is a good predictor of GA especially in the early second trimester. Also, there was a statistically significant difference between the FHC in our study population (blacks) and those of the Caucasian population.

Abstract

Introduction: Ultrasound is a non-invasive imaging modality, safe for both the mother and the fetus, which uses a high frequency sound to generate images of body tissues and organs. It has been widely used for fetal evaluation and dating.

Purpose: To determine normative values of fetal heart circumference (FHC) as a predictor of the gestational age (GA) in black population and compare it to those of the Caucasian population.

Material and Methods: A prospective cross-sectional study was carried at the University of Maiduguri Teaching Hospital (UMTH), Nigeria. 324 women with a singleton pregnancy between 12 -40 weeks, who conceived naturally, were scanned using a 2D ultrasound machine with a 3.5 MHz curvilinear probe. Two fetal heart diameters at right angle to each other were taken at the level of the four-heart chamber view, during diastole.

Keywords: Fetal Heart circumference (FHC), Gestational age (GA), Ultrasound scan, nomogram

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Introduction

Ultrasound has proved to be a useful and accurate method of determining the GA of the fetus [1, 2]. It has advanced the assessment of fetus in utero, including accurate estimation of the GA when performed in the first half of the pregnancy [3]. Accurate assessment of GA is the most useful contribution sonogram has made to obstetric practice [4]. It is important to find new parameters to measure fetal growth that correlate with fetal age so that fetuses that are not growing well can be identified and treated [5]. Studies have supported that the use of multiple parameters improves the accuracy of fetal age and weight estimation [6]. The combination of more than one parameter should be used to increase the reliability, sensitivity and accuracy of fetal biometry [7]. Several sonographic fetal measurements are used nowadays to determine the GA: Crown rump length (CRL) [8, 9], the BPD [10, 11], the femur length (FL) [5, 12], the fetal kidney length (FKL) [13], head circumference (HC) [14], fetal foot length (FFL) [7] and FHC [15].

In placental vertebrates, the heart is the earliest major organ to function [16]. However, the FHC is seldom used to predict the GA in our locality. There are very few literature sources/articles that demonstrate the relationship and correlation between GA and FHC using sonogram/echocardiogram which is mostly used for assessing various fetal cardiac anomalies (congenital heart disease). Sonogram is useful in fetal heart assessment and can be an early predictor of fetal heart anomaly [17]. Also, there is little previous information about the FHC growth pattern; and the normal values at our disposal are those of Caucasians which are likely to be different due to racial differences.

Material and Methods

A prospective cross-sectional study conducted at UMTH with participants selected mainly from the antenatal clinic; from April 2015 to March 2016. Approval was obtained for the research committee of the UMTH and ethical standard in accordance with the Helsinki dec-

laration of 1975 as revised in 2000 was adopted [18]. The participants' consent was requested with regard to using their fetuses' parameters for research purpose. Measurements were taken only on those who accepted.

324 women underwent obstetric ultrasound scans using a two-dimensional ultrasound machine with good resolution (Aloka Prosound SSD-3500 PLUS) and with a 3.5MHz curvilinear probe. The age, tribe and parity of the women were also taken. The inclusion criteria were: singleton fetus, pregnancy from 12 weeks and above, no history of prolonged maternal illness, no fetal abnormality or deformity. Exclusion criteria were: multiple gestation, any fetal deformity, fetal growth restriction, maternal diabetes and/or hypertension, uterine and/or placental anomalies, maternal substance abuse, smoking and alcohol.

Scanning technique: Ultrasound scans were carried out by a sonographer with more than 17 years of experience. The patient lied either supine or in semi-Fowler position with her legs extended on the examination bed. Using a 3.5MHz curvilinear transducer, the patient was scanned. A general survey (sweep) was initially performed to ensure that the fetus, the placenta and the uterus are all normal. The four-heart chamber view was used as landmark for measurement of the FHC. The FHC was measured during diastole, using the method described by Jeanty et al, [19] and Jordaan et al [16].

The FHC was derived using these two formulas: $HTC = \pi(D_1 + D_2)/2$ and $HTC = \pi\sqrt{\{(D_1^2 + D_2^2)/2\}}$; assuming that the cross section of the heart at the four-heart chamber view is oval in shape. A two-tailed student T test showed that there was no significant difference between the values obtained from the two formulas used to derive the FHC ($p \leq 0.995 > 0.05$).

The BPD was measured from the proximal edge to the proximal edge of the deep border [20]. The transducer was placed perpendicular to the central axis of the head, such that the hemispheres and calvaria appeared symmetrical, with the midline falx, the thalami symmetrically positioned on either side of the falx and visualization of the septum pellucidum at one of the fronto-occipital distance. The cerebellar hemispheres should not be in the plane of the image. [21, 22]

The HC was obtained at the same plane with the BPD using the measurement of an ellipse around the outer calvaria.

The FL was measured using the fetal thigh closer to the transducer, from the major trochanter to the lateral femoral condyle along the longest axis of the central shaft exclusive of the epiphyses. [10]

Due to some factors such as faulty memory, bleeding in early pregnancy and the use of contraceptives, the last menstrual period (LMP) as a gold standard has several potentials of inaccuracy [23]. For those reasons the LMP was not used. Rather our measurements were correlated to the average GA obtained from the BPD, HC and FL. This is because the combination of more than one parameter increases the reliability, sensitivity and accuracy of fetal biometry [7] and allows the fetuses that are not growing well to be identified and treated [5].

Statistical analysis: Data were analysed using Microsoft Excel software (from Microsoft Office 365). Both descriptive and inferential statistics were used to analyse the data. The frequency, standard deviation, percentage, means, growth rate, tables and charts were used to describe the data. The correlation analysis was carried out and the Pearson's moment correlation coefficient was calculated. Regression analysis was also carried out and the equation of the line of best fit was determined using the method of least square. A two-tailed student T test was used to compare the mean FHC in black population to that of Caucasian population.

Results

The data were collected from 324 pregnant women. Their ages range from 12 and 40 years (mean age 25.95 ± 6.48).

Table 1 shows the distribution of participants according to their tribes. Kanuris (125=38.58%) were the majority, followed by Igbo (49=15.12%), Fulani (24=7.4%), Hausa (23=7.098%) and other minorities.

Figure 1 shows the age distribution of the participants. The majority of them were between 20 and 29 years old while very few were between 40 and 42 years old.

Figure 2 shows the distribution of the participants according to their presenting pregnancy ages. The majority (151=46.6%) had a presenting pregnancy age between 30 and 40 weeks while the minority had a pregnancy age between 12 and 20 weeks.

Table 2 shows the mean, the standard deviation and the number of measurements made for each week ranging from 12 to 40 weeks.

Figure 3 shows a scatter diagram used to assess the correlation between the GA and the FHC. The coefficient of determination was $r^2=0.964$. Moreover, the equation of the line of best fit was computed and it is $Y=0.246X+5.056$, where Y is the average GA and X is the FHC. The calculated average growth rate per week was 3.81mm.

Table 3 compares the mean FHC in this study (black population) to that of Hill et al (Caucasians).

Table 4 shows the GA groups and their respective coefficient of determination. The coefficients of determination were 0.812, 0.7864 and 0.7247 for 12-20 weeks, 21-30 weeks and 31-40 weeks respectively.

Figure 4, Figure 5 and Figure 6 show the correlation between the FHC and the BPD, the FHC and the HC, and FHC and the FL respectively. They all show linear, highly positive and statistically significant correlations ($R^2=0.9595, p<0.001$; $R^2=0.9465, p<0.001$; $R^2=0.9628, p<0.001$ respectively).

A two-tailed student T test showed there was a statistically significant difference between the mean of the measured FHC in the black population and those of Caucasian population ($p \leq 0.036 < 0.05$).

Discussion

In this study we try to establish the possibility of using FHC in assessing the gestational age of the fetus using an ultrasound scan. For decades, ultrasound scanning of pregnant mothers has been evolving in resolution and routes of usage in obstetrics and gynaecology with better precision and accuracy in modern medicine. It is mostly used in assessing GA using a non-cardiac parameter (mean sac diameter, crown rump length, biparietal diameter and femur length), heart rate, fetal and placenta anomalies and fetal heart anomalies [24].

The majority of our participants are less than 30 years of age, mostly between 20-29 years of age (50.61%), presenting mostly after 30 weeks gestational age (fig:1-2). At this period of time, the fetus is well developed and has already grown to some extent, reducing the probability of detecting fetal anomalies, as optimal fetal information is obtained when the scan is carried out

Table 1. Distribution of participants according to their tribes

Tribe	Number of subjects
Kanuri	125 (38.58%)
Igbo	49 (15.12%)
Fulani	24 (7.40%)
Kuteb	2 (0.61%)
Idoma	6 (1.85%)
Marghi	19 (5.86%)
Calabar	1 (0.30%)
Hausa	23 (7.1%)
Bura	4 (1.23%)
Yoruba	14 (4.32%)
Chibok	1 (0.30%)
Shuwa	15 (4.63%)
Kanakura	1 (0.30%)
Dowaldi	1 (0.30%)
Tiv	2 (0.61%)
Edo	4 (1.23%)
Babur	1 (0.30%)
Mandara	2 (0.61%)
Michika	1 (0.30%)
Baseyap	1 (0.30%)
Bayelsa	1 (0.30%)
Hidi	1 (0.30%)
Delta	1 (0.30%)
Bago	1 (0.30%)
Cross-river	1 (0.30%)
Igala	1 (0.30%)
Okoja	1 (0.30%)
No tribe info.	20 (6.17%)

Table 2. Means, standard deviations and number of measurements made for each week ranging from the 12th to the 40th week

Gestational age (Weeks)	Frequency	Mean FHC (mm)	SD (mm)
12	10	29.93	1.05
13	9	33	1.18
14	5	36.96	1.53
15	6	42.45	3.41
16	9	45.25	5.10
17	10	51.93	10.07
18	9	54.58	5.91
19	10	59.80	3.56
20	7	62.22	6.93
21	9	66.54	6.48
22	8	71.008	7.70
23	9	73.15	4.01
24	9	81.26	6.61
25	9	85.81	9.24
26	17	86.83	5.23
27	15	92.11	7.60
28	15	97.21	6.97
29	7	100.57	5.05
30	17	105.47	6.98
31	10	108.52	8.84
32	20	111.28	6.19
33	21	114.72	7.17
34	10	121.31	5.77
35	11	123.71	7.23
36	20	125	2.90
37	17	127.54	3.11
38	4	130.03	3.23
39	8	133.76	1.31
40	13	136.77	1.65

Table 3. Comparison between the mean FHC in this study of the black population and Caucasian population

GA	Caucasians	Blacks
12		29.93
13		33
14		36.96
15	39	42.45
16	48	45.25
16	49	51.93
18	58	54.58
19	60	59.8
20	65	62.22
21	73	66.54
22	79	71.008
23	80	73.15
24	80	81.26
25	96	85.81
26	106	86.83
27	109	92.11
28	112	97.21
29	107	100.57
30	118	105.47
31	119	108.52
32	126	111.28
33	127	114.72
34	135	121.31
35	138	123.71
36	145	125
37	150	127.54
38	150	130.03
39	145	133.76
40	154	136.77
41	161	
42	164	

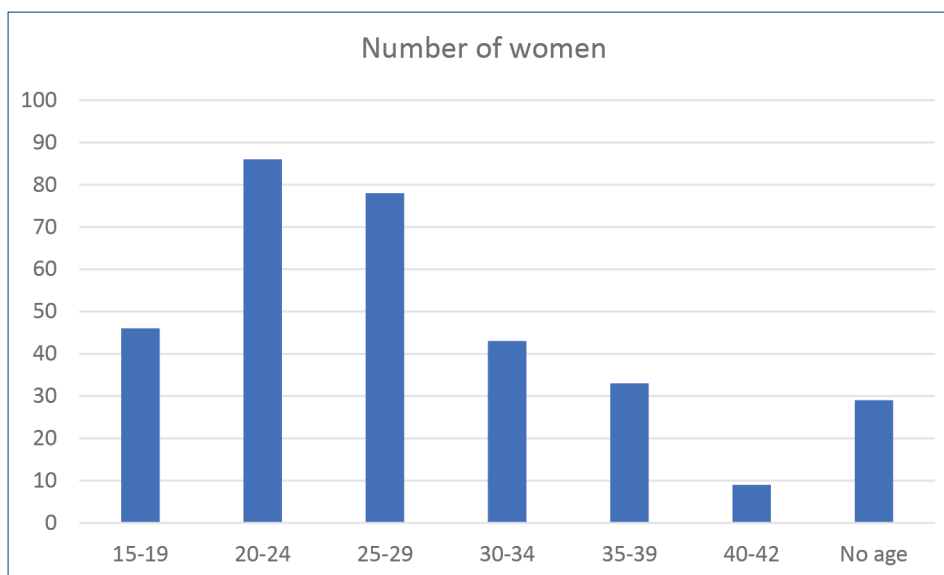


Figure 1. Age distribution of the participants

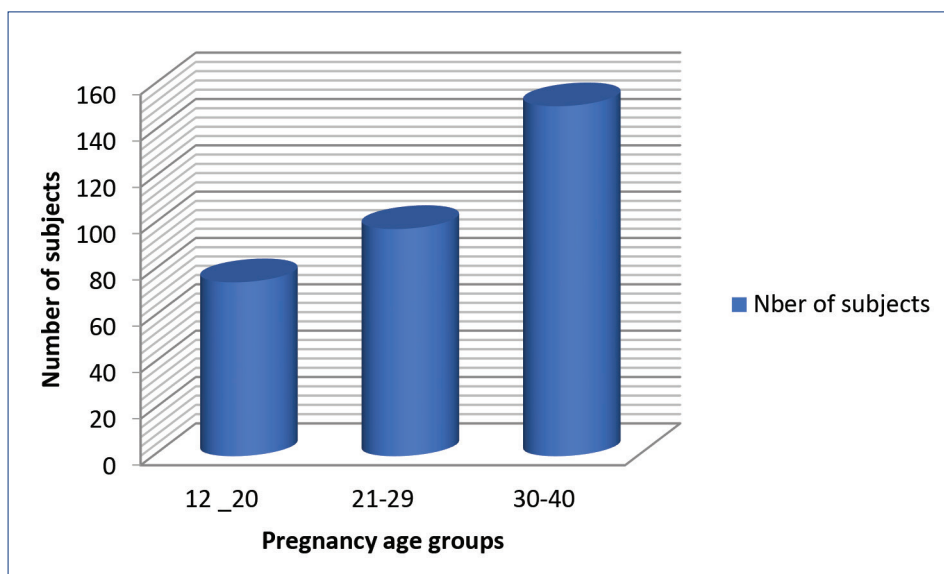


Figure 2. Distribution of participants according to their presenting pregnancy ages

Table 4. Gestational age groups and their respective coefficient of determination.	
Gestational age group	Coefficient of determination
12 – 20	0.812
21 – 30	0.7864
31 – 40	0.7247

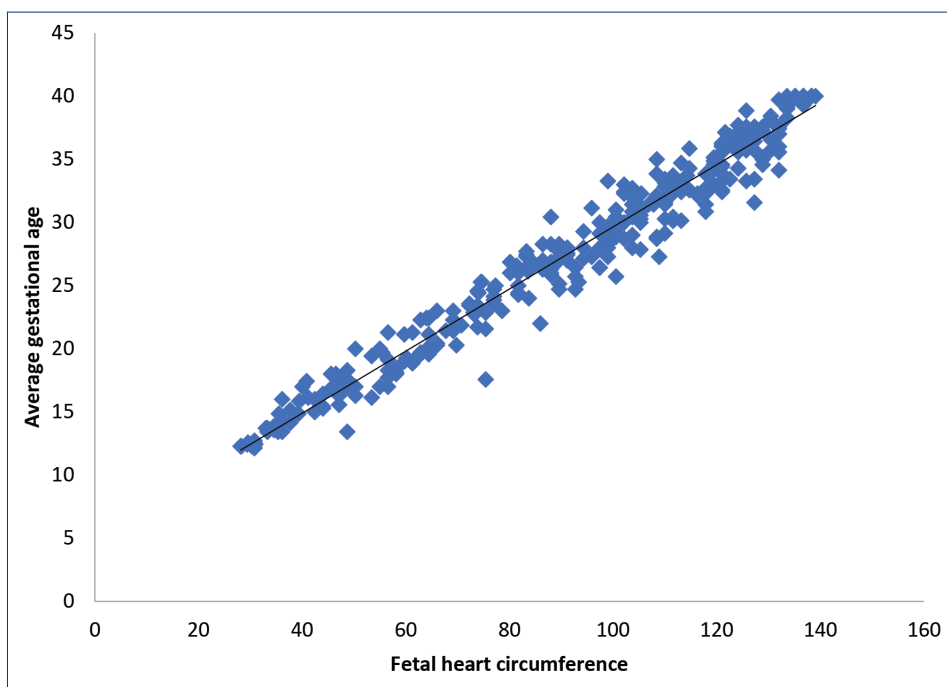


Figure 3. **Distribution of observed FHC values at various points in gestation ($r^2 = 0.964$, $p \leq 0.001$)**

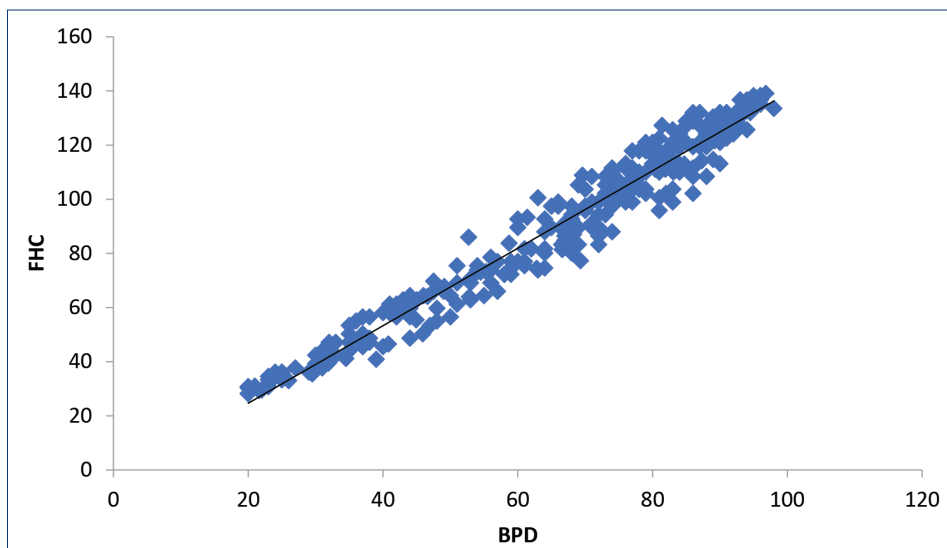


Figure 4. **Scatter diagram of the FHC against the BPD ($r^2 = 0.9595$, $p \leq 0.001$)**

between the 14th and the 18th week of gestation.[25]. Furthermore, in a review of 11 studies, it was shown that the second trimester ultrasound has an overall greater sensitivity (41.3%) compared to the third trimester ultrasound (15.6%).[26]. Therefore, women in this study locality should be sensitized more on the importance of early and anatomy ultrasound scans. They should also be informed about other benefits of ultrasound scan, e.g. detection of fetal anomalies. Dalinga et

al, in a study conducted at the same institution (UMTH), also reported that the highest attendants at the antenatal clinic were women between 20-29 years and very few patients are above the age of 40. In that study, it was also concluded that most of the women above 40 did not find the necessity for prenatal ultrasound scan as many had previous uneventful pregnancies without having an ultrasound done.[27]. It could also be justified by the decrease in fertility in that age group. There

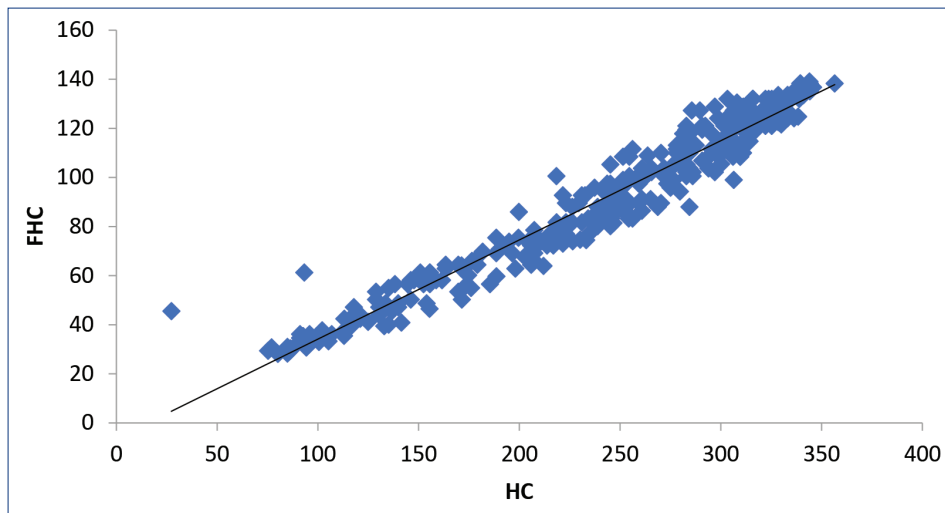


Figure 5. **Scatter diagram of the heart circumference against the HC ($r^2 = 0.9465$, $p \leq 0.001$)**

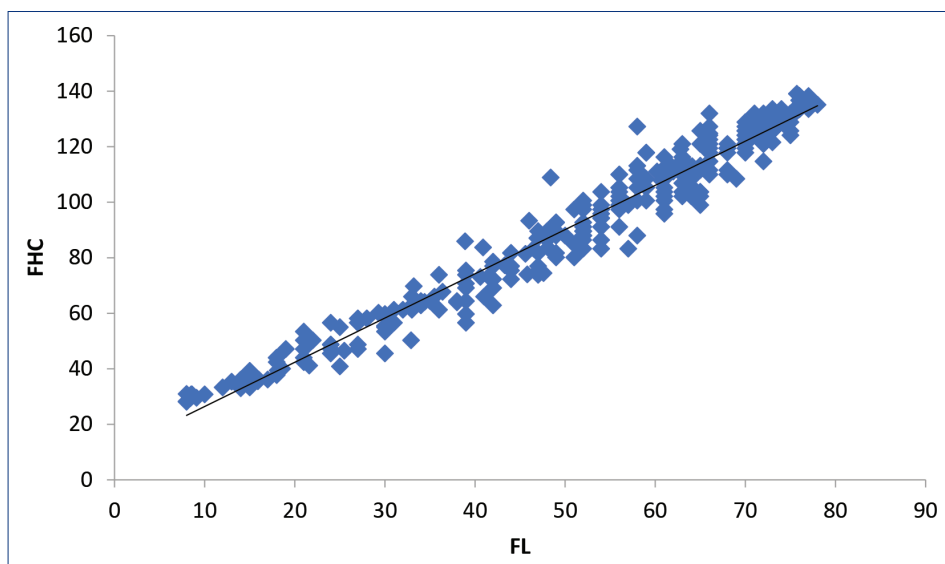


Figure 6. **Scatter diagram of the heart circumference against the FL ($r^2 = 0.9628$, $p \leq 0.001$)**

is need to create further awareness on the benefits of ultrasound scans.

In this study, the FHC appears to increase at a rate of 3.81mm per week. This study shows a strong positive linear correlation ($r^2 = 0.96$, $P < 0.001$). These findings are similar with those obtained by Hill *et al* [15] and Jordaan [16]. In their studies, there was a strong correlation ($r^2 = 0.94$ and $r^2 = 0.86$ respectively) between the FHC and the GA in normally growing fetuses. However, Jordaan [16] did not tabulate his data in a way that would permit GA assessment as the purpose of his research was to use FHC as an index for anomalous cardiac development.

In this study, there is a statistically significant difference between our values (blacks) and those of Hill *et al* (Caucasians) ($p \leq 0.036 < 0.05$). This is possibly due to racial differences. This could also be due to the difference in the study design and methods of data collection (FHC measurement methods), as Hill *et al* used the free hand tracing technique rather than two diameters at right angle to each other as we did.

This study further corroborates other studies that show a linear and statistically significant correlation between the FHC and other parameters (BPD, HC and FL) (shown in Figure 4, 5 and 6). In Jordan *et al*. [18] and Gembruch *et al*. [28] studies however showed a strong linear cor-

relation with between the FHC and the BPD, abdominal circumference (AC), GA and estimated fetal weight.

The present study also shows that FHC is more accurate in determining the GA when the ultrasound is done between 12 and 20 weeks of pregnancy age; and that accuracy reduces as the pregnancy progresses. This aligns with Verburg *et al* [29] who found that the earlier the ultrasound assessment the more accurate the prediction of the date of delivery.

Major limitations of this study are the small sample size and the uneven representation of the different ethnic groups which may make the result not generally applicable to the whole country, and to the black population. Likewise, modern scans now using high resolution transducers and 3D and 4D scans are way better than 2D scans in appreciation of fetal cardiac geometry for optimal analysis because of the changes as the pregnancy advances [30]. Other possible limitations to the use of FHC to determine the GA will probably be the changes in fetal heart morphology as the pregnancy advances. Data obtained in this study does not categorically demonstrate superior acceptability of FHC over conventional parameters like BPD, FL, CRP etc. in assessing GA, but shows a potential use in conditions where those parameters cannot be used or properly assessed.

Ethics approval and consent to participate: Approval was obtained for the research committee of the UMTH. The participants' consent was requested with regard to using their fetuses' parameters for research purpose. Measurements were taken only on those who accepted.

Conflict of Interest: Authors declare they have no competing interest.

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ULTRAZVUČNA PROCJENA CIRKUMFERENCIJE FETALNOG SRCA KAO PREDIKTOR GESTACIJSKE DOBI

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Sažetak

Uvod: Ultrazvuk je neinvazivni način snimanja, siguran za majku i fetus, koji upotrebljava visokofrekventne zvučne valove za stvaranje slika tjelesnih tkiva i organa. Uvelike se primjenjuje za fetalnu procjenu i datiranje.

Svrha: Utvrditi normativne vrijednosti cirkumferencije fetalnog srca (FHC) kao prediktora gestacijske dobi (GA) u populaciji crnaca i usporediti je s onom kod bijelaca.

Materijali i metode: Prospektivna presječna studija provedena je u Sveučilišnoj bolnici Maiduguri u Nigeriji. 324 žene s jednoplodnom trudnoćom između 12 i 40 tjedna trudnoće, koje su začele prirodnim putem, pregledane su s pomoću 2D ultrazvučnog aparata sa zakrivljenom sondom od 3,5 MHz. Snimljena su dva promjera fetalnog srca pod desnim kutom na razini prikaza četiriju srčanih komora tijekom dijasole.

Rezultati: Postoji snažna pozitivna linearna korelacija između cirkumferencije fetalnog srca (engl. *fetal heart*

circumference – FHC) i gestacijske dobi (engl. *gestational age* – GA) ($r^2 = 0,964$, $p < 0,001$). Jednadžba za predviđanje gestacijske dobi jest $Y = 0,246X + 5,06$ (gdje je $y = GA$, $X = FHC$). Tjedna stopa rasta FHC-a iznosi 3,81 mm. FHC je točniji između 12 i 20 tjedna gestacije i njegova se točnost smanjuje kako trudnoća odmiče. Postoji jaka korelacija između FHC-a i biparijetalnog promjera (engl. *biparietal diameter* – BPD) ($r^2 = 0,959$), HC ($r^2 = 0,946$) i duljine bedrene kosti (engl. *femoral length* – FL) ($r^2 = 0,962$).

Zaključak: Studija je rezultirala izradom nomograma FHC-a kao prediktora gestacijske dobi u nigerijskoj populaciji i pokazala je da je FHC dobar prediktor gestacijske dobi, posebno u ranom drugom tromjesečju. Također, postojala je statistički značajna razlika između FHC-a u našoj istraživanoj populaciji (crnci) i populaciji bijelaca.

Ključne riječi: cirkumferencija fetalnog srca (FHC), gestacijska dob (GA), ultrazvučno skeniranje, nomogram