Original Article

NORMATIVE REFERENCES OF FETAL CHEST CIRCUMFERENCE IN A NIGERIAN POPULATION

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Abstract

Background: A linear relationship between gestational age and fetal thoracic size has been observed, with growth occurring at a regular rate from 16 to 40 weeks.

Objective: To determine the fetal chest circumference in normal late second and third-trimester pregnancies in a Nigerian population.

Materials and Methods: This was a descriptive cross-sectional study carried out on gravid women with normal singleton pregnancies at 22 – 38 weeks gestational age. We recruited 440 eligible gravid women. The fetal gestational age was estimated from the last menstrual period and an early first trimester ultrasound report (< 10 weeks). The fetal chest circumference was measured on an axial view of the fetal chest after ensuring adequate visualisation of the four cardiac chambers, both fetal lungs and ribs. The other fetal biometric parameters were determined using the previously established guidelines. Descriptive statistics, Pearson's correlation, and regression analysis were used as appropriate. Statistical tests were considered significant at $P \leq 0.05$.

Results: The mean age of the subjects was 29.8 ± 4.6 years (range = 18-45 years). The chest circumference of the fetuses ranged from 16.56 ± 0.29 cm to 30.87 ± 6.88 cm. The fetal chest circumferences increased with advancing gestational age (16.56 ± 0.29 cm at 22 weeks to 30.87 ± 6.88 cm at 37 weeks gestational age). There was strong positive correlation between chest circumference and menstrual gestational age (r=0.85, p=<0.0001), biparietal diameter (r=0.88, p<0.0001), abdominal circumference (r=0.90, p<0.0001) and fetal length (r=0.88, p<0.0001).

Conclusion: The fetal chest circumference grew as the pregnancy progressed. There was a positive linear correlation between fetal chest circumference and menstrual gestational age as well as the other fetal biometric parameters.

Keywords: Normative references, Fetal Chest Circumference, Sonography, Gestational Age, Fetal Biometry.

Cite this article Akindeju FF, Ademola Adeyekun AA, Ogunsemoyin AO, Idowu BM. Normative references of fetal chest circumference in a Nigerian population. Yen Med J. 2022;4(3):43–53.

INTRODUCTION

The chest is an integral and vital part of the developing fetus. Although the fetal lungs are not involved in gas exchange in-utero (as this function is carried out through the placenta via the umbilical cord),[1] a well-developed lung is essential for normal extra-uterine survival.[2] Fetuses younger than 24 weeks of gestation are often deemed non-viable due to pulmonary immaturity.[2]

By 16 – 20 weeks gestation, the normal number of bronchi has formed.[3] It has also been established that the fetal thorax grows at a regular rate from 16 to 40 weeks, resulting in a linear correlation between gestational age and thoracic size.[4] In a normal pregnancy, the ratio between the chest circumference, abdominal circumference, head circumference and femur length also remains constant, with a high correlation coefficient.[5] Hence, alteration of fetal thoracic dimensions, including chest circumference, may suggest intrathoracic pathologies which may affect the survival of the fetus postpartum.

Along with anomalies of the central nervous and skeletal systems, anomalies of the thorax constitute a major group of fetal abnormalities that are detectable prenatally.[2] Many of these abnormalities are potentially life threatening, either at the time they are observed, or by virtue of their potential to progress in severity. These intrathoracic abnormalities include congenital diaphragmatic hernia, congenital pulmonary airway malformation (formerly known as cystic adenomatoid malformation), fetal hydrothorax, congenital pulmonary sequestration, neurenteric and bronchogenic cysts, and pulmonary hypoplasia/agenesis.[6–11] Prior to the advent of non-ionizing imaging modalities such as ultrasound and magnetic resonance imaging (MRI), pathologies of the fetal thorax were diagnosed postnatally using radiography with its attendant ionizing irradiation and sometimes misguided management and fatal outcome.[12]

Although MRI is superior to ultrasound in making diagnosis and planning management of fetal chest pathologies,[13,14] the two modalities are complimentary. Overall, ultrasound remains the predominant modality for evaluating disorders related to the fetus and pregnancy largely due to its real-time nature and ready availability compared to MRI which is expensive and not readily available, especially in developing countries.[15–20]

Early in gestation, the pulmonary parenchymal appears similar to or slightly less echogenic than the liver. As gestation progresses, there is a trend towards increased homogenous pulmonary echogenicity compared to the liver.[2] The heart is usually no larger than one-third of the area of the chest and is normally deviated by about 45±20° towards the left side of the fetus.[21]

The degree of lung development is the prime determinant of fetal viability.[2] Adequate size and shape of fetal thorax, amongst other factors such as adequate amniotic fluid and fetal breathing, have also been noted to influence normal fetal lung growth. Pulmonary hypoplasia can occur when any of these factors are abnormal.[22]

Studies on the sonographic evaluation of the fetal thorax/chest in Nigerians are sparse. The aim of this study was to generate normative references of the fetal chest circumference (CC) in normal late second and third trimester pregnancies in a Nigerian population.

MATERIALS AND METHODS

Study Design: This was a descriptive cross-sectional study carried out from March 2012 to April 2013 on pregnant women with normal singleton fetuses (at 22 – 38 weeks gestation).

Study Setting: The study was conducted at the radiology department of the University of Benin Teaching Hospital, Benin City, Edo state, South-south. Nigeria.

Study Population: These were pregnant women at 22 – 38 weeks gestation referred to the radiology department of the institution. Four hundred and forty pregnant women at fetal gestational age of 22 – 38 weeks were consecutively enrolled having met the following eligibility criteria.

Eligibility Criteria: Inclusion criteria were regular menstrual cycle; known last menstrual period (LMP); and an early dating scan in the first trimester (< 10 weeks), normal live singleton gestation, and intact fetal membranes. The exclusion criteria were unsure LMP, multiple gestation, polyhydramnios or oligohydramnios, premature rupture of membranes, presence of congenital anomalies, maternal medical conditions (gestational diabetes, hypertensive disease of pregnancy, diabetes mellitus, systemic hypertension), and suspected fetal cardiac deviation from the left hemithorax (which may be due to an intrathoracic mass).

Data Collection: After a concise explanation of the study objectives and an assurance of strict confidentiality, written informed consent was obtained from each participant. A detailed medical history was obtained from each subject and documented. The fetal gestational age was determined by calculation from the last normal menstrual period and validation with an early first trimester ultrasound scan (< 10 weeks).

All the participants were scanned on a Medison Sonoace X4 scanner (Medison Co. Ltd, Gangdong-gu, Seoul, South Korea) with a 3.5 MHz frequency curvilinear transducer. Each participant laid supine on the examination couch with adequate exposure of the abdomen from the level of the xiphisternum to the public symphysis. The ultrasound coupling gel was applied on the abdomen. The transducer was then placed on the abdomen and scanning done in different planes with minimal transducer force. At the level of the four-chamber view of the fetal heart, the transducer was orientated transversely. After ensuring adequate visualisation of the four chambers of the fetal heart, both fetal lungs and ribs on this axial plane, the image was frozen. Tracing around the fetal chest was drawn, with the aid of the electronic calliper, using the ellipse function in order to obtain the fetal chest circumference (**Fig. 1**). The biparietal diameter (BPD) measurement was obtained from a trans-axial plane of the fetal head at the level of the thalami and cavum septum pellucidum as described by Kurtz et al.[23] The abdominal circumference was measured using the umbilical vein and the fetal stomach as landmarks.[24]

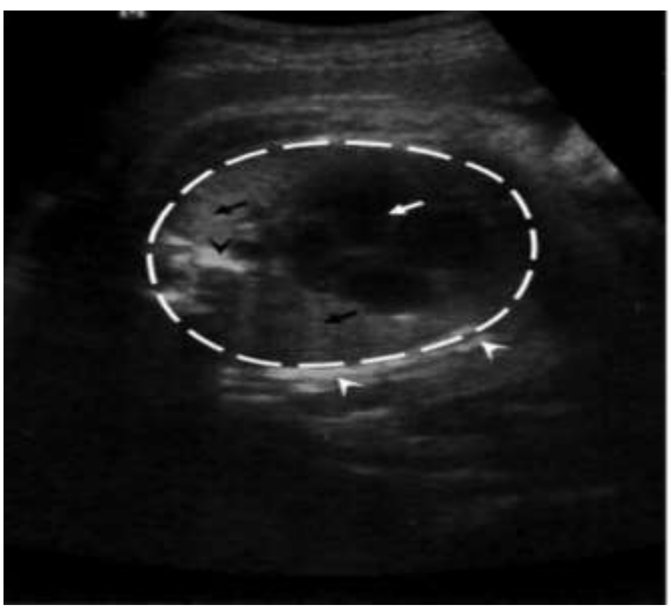

Figure 1. Sonogram of the foetal chest on a transverse view at the level of the 4-chamber view of the foetal heart. Foetal chest circumference (broken white line). Foetal heart (white arrow), foetal lungs (black arrow), foetal spine (black arrowhead) and thoracic cage (white arrowhead)

The femur length was measured from the greater trochanter to the distal metaphysis of the fetal femur.[25] Each measurement was taken three times and the average value was recorded to minimize intraobserver error. All the subjects were scanned by one sonologist so as to reduce interobserver variation.

Data Analysis: The data obtained were analysed using the Statistical Package for the Social Sciences (SPSS) version 17 (SPSS Inc, Chicago, IL, USA). Normality of data was determined using the Kolmogorov-Smirnov's test. Descriptive statistics and Pearson's correlation were used as appropriate. Linear regression analysis was used to assess the relationship between chest circumference and the other fetal biometric parameters. Statistical tests were considered significant at $P \leq 0.05$.

RESULTS

A total of four hundred and forty healthy women with singleton intrauterine pregnancy were recruited. The age range of subjects was 18 – 45 years with a mean of 29.8 ± 4.6 years. The modal age group was 26-30 years (n=172; 39.1%) (Table 1). The other general characteristics of the participants are shown in Table 1.

The chest circumference of the fetuses ranged between 16.56 ± 0.29 cm to 30.87 ± 6.88 cm (Table 2). With advancing gestational age, there was a corresponding increase in chest circumferences of the fetuses.

Table 3 shows the mean chest circumference in various gestational age groups. Expectedly, the mean chest circumference was least in the 22 - 27 weeks age group (19.39 ± 2.22cm) and most in the 33 - 38 weeks gestational age group (28.23 ± 3.91 cm).

There was strong positive correlation between chest circumference and menstrual gestational age (r=0.85, p=<0.0001). Also, chest circumference correlated positively with the other fetal biometric parameters of BPD (r=0.88, p<0.0001), AC (r=0.90, p<0.0001) and FL (r=0.88, p<0.0001) (Table 4).

Table 5 shows the predicted chest circumference from the menstrual gestational age at 25th, 50th, 75th and 90th percentiles. Table 6 shows the regression equations for the relationships between the chest circumference and the other fetal biometric parameters.

Table 1: Demographics of the study population

Variable	Frequency	Percentage	Cumulative Percentage
Age group (years)			
18 – 21	6	1.4	1.4
22 – 25	78	17.7	19.1
26 – 30	172	39.1	58.2
31 – 35	138	31.4	89.5
36 – 40	42	9.5	99.1
41 – 45	4	0.9	100.0
Mean Age ($\overline{X}$ ± SD) (years)	29.8 ± 4.6		
Parity			
0	167	38.0	38.0
1	112	25.5	63.4
2	96	21.8	85.2
3	45	10.2	95.5
4	10	2.3	97.7
5	8	1.8	99.5
9	2	0.5	100.0
Mean parity ($\overline{X}$ ± SD)	1.2 ± 1.3		
Menstrual Gestational age group (weeks)			
22 – 27	138	31.4	31.4
28 – 32	106	24.1	55.5
33 – 38	196	44.5	100.0
Mean Menstrual Gestational age ($\overline{X}$ ± SD) (weeks)	30.6 ± 5.5		
Educational Status			
Primary	21	4.8	4.8
Secondary	119	27.0	31.8
Tertiary	300	68.2	100.0
Ethnicity			
Bini	237	53.9	53.9
Esan	52	11.8	65.7
Etsako	36	8.2	73.9
Igbo	85	19.3	93.2
Owan	4	9	94.1
Yoruba	26	5.9	100.0

Table 2: Mean Chest circumference at specific gestational age

Menstrual Gestational age (weeks)	Chest circumference (cm) Mean ±SD	Frequency (N)	Percentage	Cumulative Percent
22	16.56 ± 0.29	23	5.2	5.2
23	17.07 ± 1.37	21	4.8	10.0
24	18.76 ± 1.62	24	5.5	15.5
25	19.40 ± 1.38	21	4.8	20.3
26	20.32 ± 1.96	21	4.8	25.1
27	21.49 ± 1.93	22	5.0	30.1
28	21.79 ± 1.89	21	4.8	34.9
29	23.03 ± 2.03	30	6.8	41.7
30	23.04 ± 2.22	21	4.8	46.5
31	24.99 ± 1.73	28	6.3	52.8
32	26.06 ± 2.40	21	4.8	57.6
33	26.41 ± 2.21	30	6.8	64.4
34	28.61 ± 2.49	34	7.7	72.1
35	27.32 ± 3.28	26	5.9	78.0
36	27.91 ± 1.97	44	10.0	88.0
37	30.87 ± 6.88	30	6.8	94.8
38	29.19 ± 3.56	23	5.2	100.0
Total		**440**	**100.0**	**100.0**

Table 3: Mean Chest Circumference for the menstrual gestational age groups

Grouped Menstrual Gestational age (weeks)	Chest circumference (cm) Mean ±SD	Frequency (N)	Percentage	Cumulative Percent
22 – 27	19.39 ± 2.22	138	31.4	31.4
28 – 32	23.82 ± 2.44	106	24.1	55.5
33 – 38	28.23 ± 3.91	196	44.5	100.0

Table 4: Correlation of CC, BPD, AC and FL with Menstrual Gestational Age

		Menstrual Gestational Age	CC	BPD	AC	FL
Menstrual Gestational Age	r	1	0.85^{**}	0.96^{**}	0.96^{**}	0.96^{**}
	P value		<0.0001	<0.0001	<0.0001	<0.0001
CC	r	0.85^{**}	1	0.88^{**}	0.90^{**}	0.88^{**}
	P value	<0.0001		<0.0001	<0.0001	<0.0001
BPD	r	0.96^{**}	0.88^{**}	1	0.97^{**}	0.97^{**}
	P value	<0.0001	<0.0001		<0.0001	<0.0001
AC	r	0.96^{**}	0.90^{**}	0.97^{**}	1	0.97^{**}
	P value	<0.0001	<0.0001	<0.0001		<0.0001
FL	r	0.96^{**}	0.88^{**}	0.97^{**}	0.97^{**}	1
	P value	<0.0001	<0.0001	<0.0001	<0.0001	

*****Significant correlation***
CC=Chest circumference; BPD = Biparietal diameter; AC=Abdominal circumference; FL= Femur length
r = Pearson's correlation coefficient

Table 5: Predicted Chest circumference from menstrual gestational age (25th, 50th, 75th and 90th percentile)

Menstrual Gestational age (weeks)	Percentiles						
	5th	10th	25th	50th	75th	90th	95th
22	16.28	16.28	16.28	16.48	16.91	17.91	18.82
23	14.21	14.39	16.48	16.90	18.53	18.82	18.84
24	15.64	15.84	17.96	19.09	20.12	20.66	21.14
25	17.88	17.89	18.43	18.92	20.86	21.55	21.55
26	17.02	17.02	18.50	20.87	22.21	22.36	22.44
27	17.83	18.17	20.57	21.65	23.21	24.01	24.09
28	19.38	19.38	19.73	21.68	23.89	24.14	24.46
29	19.86	20.50	21.80	22.66	24.10	24.84	28.19
30	18.46	18.46	21.78	23.32	25.13	25.47	28.60
31	22.57	22.78	23.49	25.29	25.84	26.75	29.07
32	21.27	21.27	24.65	26.26	28.27	29.07	29.32
33	22.23	23.88	24.49	26.57	28.41	28.96	29.45
34	23.45	24.78	27.58	28.92	30.42	31.80	32.01
35	22.30	22.40	24.14	27.85	29.92	31.82	32.29
36	24.70	25.50	26.83	27.36	28.46	31.51	31.92
37	25.13	25.76	26.74	29.46	31.96	33.07	54.24
38	25.11	25.11	26.43	28.99	31.20	36.50	56.10

Table 6: Coefficients of determination (R^2) and regression equations using natural logarithm of Chest Circumference (InCC)

Analysis	R^2	Regression equation
CC vs GA	0.86	$InCC = 1.2923 + 0.0843(GA) - 0.0007(GA)^2$
CC vs FL	0.80	$InCC = 1.868 + 0.2854(FL) - 0.0104(FL)^2$
CC vs BPD	0.82	$InCC = 1.6538 + 0.2505(BPD) - 0.007(BPD)^2$
CC vs AC	0.88	$InCC = 1.6401 + 0.0814(AC) - 0.0009(AC)^2$

CC=Chest circumference; GA=gestational age; FL=femur length; BPD=biparietal diameter; AC=abdominal circumference

DISCUSSION

Prenatal ultrasound is an integral part of routine antenatal care, which is one pillar of the safe motherhood initiative aimed at preventing adverse pregnancy outcomes. Ultrasound is an important screening and diagnostic tool. It is safe for both the pregnant mother and her unborn fetus, mainly due to its non-ionizing property.

The fetal chest circumference has been shown to correlate positively with other routinely measured fetal biometric parameters, such as biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL).[4]

Chest circumference (CC) measurements were taken between 22-38 weeks in this study. Fong et al.[4] measured the CC from 13 to 41 weeks, while Nwobi[26] enrolled pregnant women at 15-41 weeks gestational age. The chest circumference in the index study ranged from 16.56 ± 0.29 cm to 30.87 ± 6.88 cm, the upper limit of which is comparable to the 9.16 - 32.17 cm reported by Nwobi.[26] The chest circumference showed a positive linear correlation with the menstrual gestational age (r=0.85, p=0.0001). This corroborates the findings of Fong et al.[4] and Nimrod et al.[27]

The regression analysis of the association between chest circumference and other biometric parameters (gestational age, femur length, biparietal diameter, and abdominal circumference) also showed a linear relationship. This is similar to the findings of Nimrod et al.[27], Chitkara et al,[28] and Siddiqi et al.[29] However, this is contrary to the findings of Fong et al,[4] who reported that the relationship was quadratic. This disparity might be due to fewer subjects (100) in their study.[4]

The nomogram developed in this study showed an increase in variability of the normal CC range with increasing GA, BPD, AC, and FL. This is similar to the pattern seen in previous studies.[4,27,28] The predicted chest circumference values at various BPD, AC, FL, and GA are also similar to those of some previous studies.[27,28]

Although sonographic features ("small" lungs, echogenic lungs, and similar findings) in the fetal chest alone cannot solely predict pulmonary function, a correlation between pulmonary hypoplasia and a small chest circumference has been reported.[5,30] Studies have also shown the importance of fetal chest circumference in the prenatal diagnosis of pulmonary hypoplasia.[4,31,32] Working in Ontario, Canada, Ohlsson et al.[31] studied 58 singleton pregnancies at risk of pulmonary hypoplasia. Using autopsy report to prove pulmonary hypoplasia, chest circumference had sensitivity, specificity, positive and negative predictive values of 0.55–0.80, 0.90–1.00, 0.80–1.00, and 0.87–0.91, respectively. They concluded that prenatal ultrasound measurement of fetal chest circumference is valuable in managing pregnancies at risk of lethal pulmonary hypoplasia.[31]

In Washington, USA, Songster et al.[32] evaluated ultrasonic fetal chest circumference measurements as a predictor of pulmonary hypoplasia in a group of 26 fetuses at risk. They found a 42% prevalence of autopsy-proved pulmonary hypoplasia in this population. On a nomogram of chest circumference versus head circumference, femur length, and gestational age, they noted a progressive lag in chest circumference growth among fetuses who proved to have pulmonary hypoplasia, correlating with the earlier findings of Nimrod et al.[27] and Devore et al.[30] Songster et al.[32] also indicated that fetal chest circumference is a valuable adjuvant in the diagnosis of deadly pulmonary hypoplasia.

The precise incidence of pulmonary hypoplasia is not known. The current reported incidences are 0.9 to 1.1 per 1000 in all births and 1.4 per 1000 in live births. Estimates show, however, that these numbers are inaccurately low given that infants with less severe sickness survive the newborn period and are found to have respiratory issues later in life.[33]A more recent study in the United States recorded the incidence of pulmonary hypoplasia among pregnant women (15-28 weeks gestational age) with mid-trimester rupture of membranes at 12.9%.[34]

In conclusion, this study showed that the fetal chest circumference increased as the pregnancy progressed. There was a positive linear correlation between fetal chest circumference and menstrual gestational age and the other fetal biometric parameters (BPD, AC, and FL).

A limitation of this study was the difficulty sometimes encountered in obtaining the fetal chest circumference because of unclear margins of the thorax. However, the 4–chamber view of the fetal heart was used to enhance accuracy and reproducibility.

AUTHOR CONTRIBUTIONS

FFA was involved in conception, design, literature search, data acquisition, data analysis, statistical analysis, manuscript preparation, manuscript editing and manuscript review. AA was involved in manuscript editing and manuscript review. AOO was involved in manuscript editing and manuscript review. BMI was involved in literature search, manuscript preparation, manuscript editing, manuscript review. All authors approved the final draft of the manuscript.

CONFLICT OF INTEREST

The authors have nothing to disclose.

FUNDING

Funded by the authors

ETHICAL APPROVAL

The Ethics and Research Committee of University of Benin Teaching Hospital, Benin City, Edo state approved the study protocol (ADM/E 22/A/VOL. VII/779).

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