Ultrasound Biometry of Nigerian Fetuses: 2. Femur Length

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Abstract: Femur length studies are few in Nigeria and the population used for the studies have been too small to provide a meaningful statistically significant data for the relationship between it and gestational age. Femur length is a very useful parameter for gestational age assessment in the third trimester and therefore requires to be properly studied. Charts of fetal size are widely used in the follow-up of pregnant women, yet no charts have been constructed for the Nigerian population. This study was designed to construct a size chart for femur length in Nigerian fetuses using a large sample size which is evenly distributed from 12 to 42 weeks of pregnancy. A total of 13,740 pregnant women were scanned in a cross-sectional study at the Centre for Reproductive Health Research, Jos over a period of five years. The mean fetal femur length measurements of 13,740 fetuses from 12 to 42 weeks are presented here in a tabulated form together with the regression equation. Mathematical modeling of data demonstrated that the best-fitted regression model to describe the relationship between femur length and gestational age was the second order polynomial regression equation $y = -0.017x^2 + 3.2794x - 25.282$ with a correlation of determination $R^2 = 0.999$ ($p < 0.001$) where y is the femur length in millimeters and x is the gestational age in weeks. The mean weekly increase in the femur length in the 4th month of life was 2.6 mm/week, in the 6th month; it was 2.48 mm/week and 2.1 mm/week in the 9th week. A comparison of our chart with others showed significant difference. This chart can be used to provide assessment of gestational age in this country without reliance on Caucasian data as we had done in the past.

Key words: Anthropometry, Nigerian fetuses, femur length, reference values

INTRODUCTION

Femur length is one of the most frequently used fetal parameter for the estimation of gestational age. It grows linear throughout pregnancy and is best measured after 14 weeks of gestation (Marinho and Bamgboye, 1987; Deter et al., 1987; Chitty et al., 1994; Kurmanavicius et al., 1999). Several investigations have studied this parameter in normal pregnancy (Jung et al., 2007; Kankeow, 2007; Salomon et al., 2006; Paladini et al., 2005; Nasrat and Bondagji, 2005; Figueras et al., 2002; Jacquemyn et al., 2000; Kurmanavicius et al., 1999; Chitty et al., 1994) but there is nothing in the literature to show that the correlation involving femur length and other fetal parameters like abdominal circumference biparietal diameter and head circumference has been documented. In Nigeria, femur length studies are few in Nigeria and the sample size used for the studies have been too small to provide a meaningful statistically significant data for the relationship between femur length and gestational age. This study set out to determine the femur length mean values of Nigerian fetuses from 12 – 42 weeks and to

correlate this mean values biparietal diameter, head circumference, occipitofrontal diameter, abdominal circumference, estimated fetal weight, gestational age and symphysio-fundal height. The result of this study will be of benefit to obstetricians, embryologist, perinatologist, forensic pathologist, clinical anthropologist, scientific investigators and auxiologist

MATERIALS AND METHODS

This was a prospective cross-sectional study carried out at the centre for reproductive health research Jos between January 1998 and June 2002. The study was approved by the Ethics Committee of Jos University Teaching Hospital and before inclusion of the patients, informed consent was obtained.

A total of 13,740 pregnant women with only singleton pregnancies were included. Pregnant women with concomitant disease possibly affecting fetal growth (e.g., diabetes mellitus, asthma, hypertension, renal disease, thyroid disease) were not included as were those with complications of pregnancy known at the moment of

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the ultrasound scan (e.g., bleeding, pre-eclampsia). If a fetal malformation was detected during the examination the patient was excluded. Patients with a history of obstetric complications, intrauterine growth retardation or macrosomia were also excluded. The investigators did not take into account complications or diagnosis that occurred later in the pregnancy, after the ultrasound measurements were performed. Every fetus was measured and included only once so that a pure cross-sectional set of data was constructed. For each patient the gestational age was recorded, as were last menstrual period, maternal age and parity. Maternal age was calculated in completed years at the moment of the ultrasound. Symphysio-fundal height measurements were taken using a non-stretch tape measure in centimeter. Obstetric ultrasonography was carried out on the patients using Philips Real time ultrasound machine equipped with 3.5 MHz transducer and an electronic caliper system set at a velocity of 1540 m/s. Head circumference measurement was made at the fetal plane described by Campbell and Thoms (1977). Biparietal diameter measurement was made on the same frozen image for head circumference from outer to outer table of the skull (Campbell and Thoms, 1977). Abdominal circumference was made on the fetal plane described by Campbell and Wilkin (1975). Femur length measurements were made using the method described by

O'Brien *et al*. (1981). Estimated fetal weight was calculated in grams by the formulae described by Shepard (1982) as these are included in the software of most commercially available ultrasound scanners.

Data were analyzed using Number Cruncher Statistical System (NCSS/PASS 2006 Dawson Edition, USA). Values of abdominal circumference at various gestational ages were expressed as mean, standard deviation, standard error of mean together with percentiles. Statistical significance was considered at 0.001. Person's correlation and regression analysis was used to establish the relationship between femur length and gestational, symphysio-fundal height, biparietal diameter, head circumference, abdominal circumference, occipitofrontal diameter and estimated fetal weight

RESULTS

The distribution of mean femur length of fetuses by ultrasound gestational age grouping together with standard deviation, standard error of mean and percentiles is shown in Table 1. When mean femur length values were plotted against gestation age (Fig. 1), a positive correlation was found. Mathematical modeling of data demonstrated that the best-fitted regression model (Fig. 2)to describe the relationship between femur length

Table 1: Femur length mean values, standard deviation, standard error of mean and percentiles from 12 – 42 weeks gestation

| Gestational age (weeks)	Fetus number	Mean FL (mm)	SD	SE	3rd	5th	10th	50th	90th	95th	97th
12 to 12+6	49	12.2	2.1	0.3	9.0	9.5	10.0	12.0	14.0	17.0	19.0
13 to 13+6	384	14.6	8.0	0.4	10.0	10.0	11.0	14.0	16.0	18.0	20.5
14 to 14+6	371	16.3	4.8	0.2	12.0	12.0	13.0	16.0	19.0	21.0	21.0
15 to 15+6	351	19.0	3.1	0.2	13.6	14.0	16.0	19.0	22.0	23.4	24.0
16 to 16+6	505	22.9	6.3	0.3	17.0	18.0	19.0	22.0	26.0	27.0	28.0
17 to 17+6	427	25.0	2.9	0.1	20.0	20.0	21.0	25.0	27.0	30.0	31.0
18 to 18+6	446	29.0	5.2	0.2	22.0	23.0	25.0	29.0	31.0	33.0	37.0
19 to 19+6	282	31.6	4.3	0.3	26.0	27.0	28.0	31.0	36.0	37.8	42.6
20 to 20+6	553	33.5	3.8	0.2	26.6	27.0	29.0	34.0	38.0	39.0	40.0
21 to 21+6	400	36.7	3.9	0.2	29.0	30.0	32.0	37.0	40.0	41.0	42.0
22 to 22+6	398	38.7	3.5	0.2	30.0	32.0	34.0	39.0	42.0	43.0	44.0
23 to 23+6	478	41.1	2.9	0.1	35.0	36.0	37.0	42.0	44.0	46.0	46.0
24 to 24+6	520	43.8	3.0	0.1	38.0	39.0	40.0	44.0	47.0	48.0	49.0
25 to 25+6	388	46.2	3.8	0.2	39.7	41.0	42.9	46.0	49.0	52.0	53.0
26 to 26+6	511	49.1	3.6	0.1	42.0	44.0	46.0	49.0	52.8	55.0	56.0
27 to 27+6	432	50.9	2.3	0.1	46.0	47.0	48.3	51.0	54.0	54.4	55.0
28 to 28+6	548	53.6	3.4	0.1	48.0	49.0	50.0	54.0	57.0	58.0	59.0
29 to 29+6	484	55.4	3.8	0.2	50.0	51.0	52.5	55.0	59.0	61.0	62.0
30 to 30+6	625	58.3	3.5	0.1	52.0	53.3	56.0	58.0	61.0	63.0	65.0
31 to 31+6	523	60.3	3.4	0.1	55.0	55.0	57.0	60.0	62.0	64.0	66.0
32 to 32+6	583	62.1	3.3	0.1	56.0	57.0	59.0	62.0	64.0	65.0	66.0
33 to 33+6	516	64.1	2.4	0.1	59.0	60.0	62.0	64.0	65.0	66.0	67.0
34 to 34+6	744	66.2	3.4	0.1	60.0	62.0	64.0	66.5	68.0	69.0	70.0
35 to 35+6	739	68.5	2.4	0.0	63.0	65.0	66.0	69.0	70.0	70.0	72.0
36 to 36+6	599	70.6	3.3	0.1	65.0	66.0	68.0	71.0	72.0	72.0	73.0
37 to 37+6	532	71.7	5.5	0.2	64.0	65.0	69.0	73.0	74.0	74.0	75.0
38 to 38+6	481	73.9	4.7	0.2	66.0	69.0	71.0	75.0	76.0	76.0	77.0
39 to 39+6	525	76.7	3.0	0.1	70.0	71.3	73.0	77.0	79.0	80.0	81.0
40 to 40+6	252	78.8	3.7	0.2	69.7	72.0	74.0	80.0	83.0	83.4	84.4
41 to 41+6	72	79.9	5.4	0.6	73.0	73.0	74.3	79.0	88.0	92.0	96.9
42 to 42+6	22	84.9	12.0	2.6	71.0	71.0	71.6	81.0	99.0	99.0	99.0
Total	13,740										
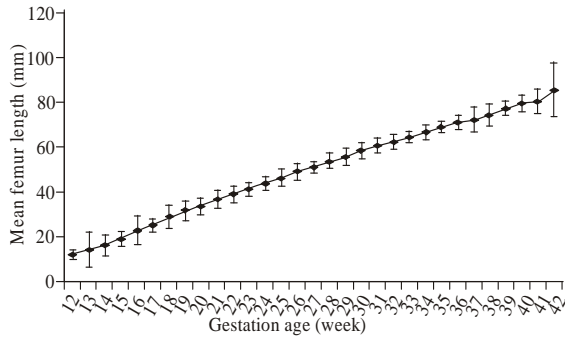
Fig. 1: Mean fetal femur length values in 13,740 fetuses of women at different gestational ages between 12-42 weeks. The vertical bars show the values of ±SD
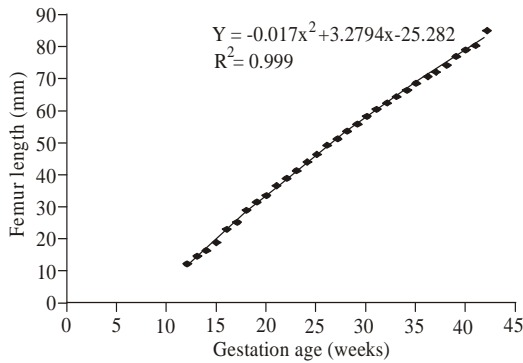

Fig. 2: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks

and gestational age was the second order polynomial regression equation $y = -0.017x^2 + 3.2794x - 25.282$ with a correlation of determination of $r^2 = 0.999$ (p < 0.001) where y is the femur length in millimeters and x is the gestational age in weeks.

When femur length mean values were correlated with biparietal diameter a positive polynomial correlation with a correlation of determination of $r^2 = 0.9993$ (p < 0.001) was found. The relationship is best described by the fourth order polynomial regression equation:

$$y = -4E\text{-}06x^4 + 0.0006x^3 - 0.0414x^2 + 2.3555x - 1.7905$$

where, y is the biparietal diameter in millimeters and x is the femur length in millimeters. Correlating femur length mean values with occipitofrontal diameter, gave a positive polynomial correlation which is best described by the quadratic regression equation of :

$$y = -0.007x^2 + 2.0251x + 4.2448$$

with a correlation of determination of $r^2 = 0.9973$ (p < 0.001) in Nigerian fetuses in Jos. From the graph correlating femur length with abdominal circumference it

was found that there is a positive linear correlation between femur length and abdominal circumference with a correlation of determination of $r^2 = 0.9952$ (p < 0.001) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation:

$$y = 4.179x + 22.077$$

where, y is the abdominal circumference in millimeters and x is the femur length in millimeters. The relationship between femur length and head circumference revealed that there is a positive polynomial correlation between femur length and head circumference with a correlation of determination of $r^2 = 0.9989$ (p < 0.001) in Nigerian fetuses in Jos. The relationship is best described by the third order regression equationL:

$$y = -0.0004x^3 + 0.0429x^2 + 3.1567x + 43.238$$

where, y is the head circumference in millimeters and x is the femur length in millimeters. The relationship between estimated fetal weight and femur length showed that there is a positive power correlation between estimated fetal weight and femur length with a correlation of determination of $r^2 = 0.9944$ (p < 0.001) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation:

$$y = 0.0575x^{2.534}$$

where, y is the fetal weight in grams and x is the femur length in millimeters.

When the relationship between femur length and symphysio-fundal height was determined, it was found that there is a positive polynomial correlation between symphysio-fundal height and femur length with a correlation of determination of $r^2 = 0.9941$ (p < 0.001) in Nigerian fetuses in Jos. The relationship is best described by the third order polynomial regression equation:

$$y = 0.0006x^3 - 0.064x^2 + 4.3915x - 32.499$$

where, y is the femur length in millimeters and x is the symphysio-fundal height in centimeters.

DISCUSSION

The mean values of femur length for fetuses of Nigerian women in Jos have been established and when they were compared with those of Saksiriwuttho *et al.* (2007) from Northeastern Thailand, the mean values of this study were significantly higher statistically. The result of this study have confirmed the findings of Jung *et al.* (2007), Nasrat and Bondagji (2005), Salomon *et al.* (2006), Drooger *et al.* (2005) and Jacquemyn *et al.* (2000) that fetal parameters differ form population to population. The differences of race, resolution and magnification of

the ultrasound machine might be the reasons why data differ from others. The strengths of the present study are a large sample size, the used of only one ultrasound machine and one abdominal transducer to avoid equipment variation.

By correlating these mean values with gestational age, a predictive formula was derived which can be used to predict the femur length at any given age. Apart from the predictive formula relating femur length with gestational, other predictive formulae were derived which can be used in this environment. When fetal femur length measurement is known, it can be used to predict the other parameters through the following formulae:

Biparietal diameter (BPD):

$$BPD = -4E\text{-}06FL^4 + 0.0006FL^3 - 0.0414FL^2 + 2.3555FL - 1.7905$$
$$r^2 = 0.9993$$

A fetus's biparietal diameter could be predicted using femur length. Femur length could explain the prediction of a fetus's biparietal diameter by 99.93 percent ($r^2 = 0.9993$) in the 13,740 fetuses scanned during this study.

Occipitofrontal diameter (OFD):

$$OFD = -0.007FL^2 + 2.0251FL + 4.2448$$
$$r^2 = 0.9973$$

A fetus's occipitofrontal diameter could be predicted using femur length. Femur length could explain the prediction of a fetus's occipitofrontal diameter by 99.73% ($r^2 = 99.73$) in the 13,740 fetuses scanned during this study.

Abdominal circumference (AC):

$$AC = 4.179FL + 22.077$$
$$r^2 = 0.9952$$

A fetus's abdominal circumference could be predicted using femur length. Femur length could explain the prediction of a fetus's abdominal circumference by 99.52% ($r^2 = 0.9952$) in the 13,740 fetuses scanned during this study

Head circumference (HC):

$$HC = -0.0004FL^3 + 0.0429FL^2 + 3.1567FL + 43.238$$
$$r^2 = 0.9989$$

A fetus's head circumference could be predicted using femur length. Femur length could explain the

prediction of a fetus's head circumference by 99.89% ($r^2 = 0.9989$) in the 13,740 fetuses scanned during this study.

Estimated fetal weight (EFW):

$$EFW = 0.0575FL^{2.534}$$
$$r^2 = 0.9944$$

A fetus's estimated weight could be predicted using femur length. Femur length could explain the prediction of a fetus's weight by 99.44% ($r^2 = 0.9944$) in the 12, 080 fetuses scanned during this study.

In the prediction of femur length from Symphysio-Fundal Height (SFH), the predictive formula is:

Femur length (FL):

$$FL = 0.0006SFH^3 - 0.064SFH^2 + 4.3915SFH - 32.499$$
$$r^2 = 0.9941$$

A fetus's femur length could be predicted using symphysis-fundal height. Symphysis-fundal height could explain the prediction of a fetus's femur length by 99.41% ($R^2 = 0.9941$) in the 13,740 fetuses scanned during this study

In conclusion, femur length mean values together with percentiles for Nigerian fetuses have been derived using a large sample size and a positive correlation have been found to exist between femur length and other fetal parameters as mentioned above.

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