Original Article

Maternal determinants of estimated fetal weight (EFW) at mid-pregnancy

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ABSTRACT

Background: Assessmentof fetal biometry is a vital component of prenatal care in many parts of the world.

Objective: To assess correlation between some maternal variables and fetal weight estimated from mid-pregnancy ultrasound biometric data with a view to identifying significant maternal predictors of fetal weight in a sample of Nigerian women.

Methods: A prospective study involving 87 pregnant women scanned at 18-23 weeks of pregnancy was carried out. The fetal measurements were head circumference (HC), abdominal circumference, femur length, and biparietal diameterwhile the maternal variables were age, parity, height, weight and BMI.

Results: Maternal weight and BMI were the most correlated variables (r = 0.92; P < 0.001). The significant correlation between maternal age and weight (r = 0.28; P < 0.01) and between maternal age and BMI (r = 0.30; P < 0.01), onsimple correlation,vanished with partial correlation (P > 0.05). In contrast, significant correlation which was not observed between estimated fetal weight (EFW) and maternal weight (r = -0.06; P > 0.05); EFW and maternal height (r = 0.03; P>0.05); and between EFW and BMI appeared with partial correlation (P < 0.05). Multiple regression analysis gave statistically significant models (ANOVA: F = 22.2; P < 0.01).

Conclusion: Maternal height, weight, parity, BMI, and estimated gestational age at scan (EGA) are significant predictors or determinants of EFW.

Key words: Correlation; fetal; maternal; regression; ultrasound scan.

Introduction

An ultrasound measurement of fetal biometry is a vital component of prenatal care in many parts of the world.[1,2] Importance of these and other fetal parameters in counseling and taking proper decisions during obstetric management is well recognized.[3,4] The most commonly measured parameters *in* utero during ultrasound scans are biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) as these measurements allow an estimation of fetal weight.[5,6]

Taken separately, these fetal biometric measurements have been used for various fetal attributes such as use of fetal AC for predicting neonatal weight,[7] fetal FL for determining age of pregnancy,[8] fetal BPD sometimes used for determining gestational age,[9] and fetal HC, one of the most important fetal parameters, used in assessing fetal size.[9] However, the most important use of these fetal parameters lies in

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their application for estimating fetal weight.[2] Accurate estimation of fetal weight is important in obstetric practice for fetal growth monitoring and decision-making.[3,4,10] Inaccurate assessment of fetal weight may therefore lead to faulty decision and inappropriate counseling. Abnormal fetal and neonatal weights have adverse prenatal, perinatal, and postnatal health implications.[10] Growth restriction leading to low fetal and neonatal weight is associated with high perinatal morbidity and mortality.[4,11] On the other hand, fetal macrosomia may be associated with delay in labor and various complications during delivery.[12,13] Unfortunately, fetal weight cannot be measured directly *in utero*, but it can be estimated indirectly from fetal and maternal parameters.[14]

There are concerns about the existing methods of determining estimated fetal weight (EFW). In particular, their accuracy and validity are open to question.[6] Maternal anthropometrics are not usually included in the estimation of fetal weight. The impact of parental anthropometrics on birth weight of neonates have been studied widely,[15,16] but few studies have focused on the influence of parental anthropometric attributes on ultrasound fetal biometrics *in utero*.[17,18] Some studies have analyzed variation in ultrasound measurements with maternal height or weight in multiparous and high-risk women without regard to paternal characteristics.[19-21]

Since each parent contributes 50% genetic material to the fetus, it is expected that parents should make significant contribution in determining the weight of fetuses. Thus, accuracy, predictive validity, and estimating efficiency of the currently existing strategies might increase if parental anthropometric and other variables, not previously considered, are included in various models and formulas with a view to obtaining more accurate estimation or, at least, prediction of fetal weight.

In this regard, maternal contribution is of particular interest because of the close association between mothers and their offspring during prenatal and postnatal development. Apart from their genetic contribution, mothers continue to impact on the developing fetuses through the mechanism of "maternal effect" and maternal inheritance during fetal and early postnatal life.[22-24]

In this study, we intend to determine the maternal contribution to EFW with a view to improving accuracy and predictive validity of the currently existing models. In developing countries like Nigeria, ultrasound equipment is expensive and the procedure for taking measurements necessary for estimating fetal weight is time-consuming and requires skill and highly-trained personnel.[6] Information about parity and maternal anthropometric parameters considered in this study are noninvasive and easy-to-obtain with little or no financial implications. The use of such low-budget, easy-to-obtain parameters would hopefully ameliorate the problem of cost and accuracy associated with the current strategies. The aim of this study is, therefore, to ascertain whether these maternal parameters are useful in generating models with predictive or estimating validity for fetal weight.

Materials and Methods

The subjects for the study were women with uncomplicated singleton pregnancies. Ninety-five women were recruited for the study, of which eight were either lost to follow-up or not selected because of nonfulfillment of inclusion criteria. Eighty-seven subjects participated in the study. The study was conducted from April 1, 2017, to September 30, 2017. Detailed methodology including inclusion/exclusion criteria had been reported in an earlier study.[25] Thus, only pertinent aspects of the procedure would be reported here. Independent variables (IVs) were mostly of maternal origin, and they included age, height, body weight, body mass index (BMI) and parity. The estimated gestational age (EGA) at scan is a variable of fetal origin; however, it was included as an IV in this study because of its influence on ultrasound fetal measurements in mid-pregnancy.[25] These maternal variables are easily obtained routine data in obstetric care. The EFW was taken as the response or the dependent variable (DV).

The main DV (EFW) was obtained by expressing it in terms of BPD, HC, FL, and AC according to Hadlock *et al.*:[26]

$$\text{Log(EFW)} = 1.356 - 0.00386 \times \text{AC} \times \text{FL} + 0.0064 \times \text{HC} + 0.0061 \times \text{BPD} \times \text{AC} + 0.0424\ \text{AC} + 0.174 \times \text{FL}.$$

The fetal measurements (BPD, HC, AC, and FL) were obtained as described in an earlier study conducted by our team.[25]

Data analysis

The maternal and fetal variables were subjected to statistical analysis using IBM SPSS Version 23 software package (IBM® Software). The maternal variables were regarded as the IVs while the fetal variable (EFW) was regarded as the DV. We initially obtained maternal and fetal descriptive statistics before performing inferential statistics namely *t*-test and one-way ANOVA as appropriate. Independent-samples *t*-test was used to assess significant difference between means of two groups while ANOVA was used if more than two groups were involved. In *t*-test, ANOVA, and other analyses, $P < 0.05$ was considered statistically significant. Significant ANOVA results were followed by Tukey *post hoc* analysis. We visualized linear associations between variables by scatter plots before performing simple bivariate Pearson product

moment correlation analysis to evaluate the strength of linear associations. Effects of confounding variables were removed by partial correlation. Possibility of predictability or determination of EFW from maternal variables was tested by multiple regression procedure to generate possible models for indirectly estimating or predicting fetal weight from maternal anthropometric measurements.

Results

Descriptive statistics

Parity of subjects that participated in this study ranged from 0 to 4. Forty-six (52.9%) subjects were nulliparous while only 3 (3.5%) subjects had the parity of 4. Apart from parity, other characteristics of subjects considered in this study are summarized in Table 1. Maternal weight was the most varied parameter (coefficient of variation = 22.4%). EGA at scan was the least varied (coefficient of variation = 5.2%). Mean EFW of male fetuses was 412.0 ± 110.89 g (mean ± standard deviation), a value not significantly different from that of female fetuses (380.8 ± 76.5 g; $P > 0.05$). However, in 39 cases (44.89%), the gender of the fetus could not be determined with certainty. Distribution of EFW of male and female fetuses was similar as revealed in the dual bar chart as shown in Figure 1. Thus, data for male and female fetuses were combined along with that of the undetermined gender to increase the power of statistical analysis.

Association between variables

Pearson product moment correlation analysis revealed that many of the variables were associated as shown in Table 2 (upper panel). Inspection of two-variable scatter plot matrix [Figure 2] gave maternal weight and BMI as the most linearly correlated pair of variables. This is more clearly appreciated in the enlarged isolated view in Figure 3. Some other variables were also correlated; however, many of the associations vanished with partial correlation as shown in Table 2 (lower panel). Conversely, many variables that were not correlated under simple correlation analysis gave significant correlation with partial correlation [Table 2]. For instance, neither the significant correlation between maternal age and maternal weight ($r = 0.28$; $P < 0.01$) nor between maternal age and BMI ($r = 0.30$; $P < 0.05$) was observed with partial correlation. In contrast, associations between maternal weight and EFW ($r = 0.06$; $P > 0.06$); maternal height and EFW ($r = 0.03$; $P > 0.05$); or BMI and EFW ($r = -0.07$) which were not significant ($P > 0.05$) when analyzed with simple correlation ($P > 0.05$) became significant ($P < 0.05$) after partial correlation. It is important to note that maternal age is not a significant correlate of EFW, neither under simple nor partial correlation.

Regression analysis

In view of the observed pattern of correlation between EFW and maternal variables, we regressed parity, height, weight, and BMI (IVs) against EFW (DV). Multiple regression

Table 1: Summary statistics of maternal and estimated fetal weight

	Age	Height	Weight	BMI	EFW	EGA
Mean	31.4	1.7	74.7	27.4	377.1	20.4
SD	4.2	0.1	16.7	6.0	79.1	1.1
Coefficient of variance (%)	13.4	4.2	22.4	22.0	21.0	5.2
Minimum	23.0	1.5	50.0	18.4	247.0	19.0
Maximum	44.0	1.8	132.0	46.1	700.0	24.0
Range	21.0	0.3	82.0	27.73	453.0	5.0

BMI, Body mass index; EFW, Estimated fetal weight; EGA, Estimated gestational age

Table 2: Correlation matrix of strength of association between pairs of variables

	Age	Parity	Height	Weight	BMI	EFW	EGA
Age	1.00	0.30**	−0.06	0.28	0.30**	0.04	0.10
Parity	0.27**	1.00	0.16	0.08	0.00	0.35**	0.22*
Height	−0.20	−0.10	1.00	0.26*	−0.13	0.03	0.02
Weight	0.19	0.14	0.98**	1.00	0.92**	−0.06	−0.01
BMI	−0.16	−0.14	−0.97	0.99**	1.00	−0.07	−0.03
EFW	−0.08	0.34	0.23*	−0.24*	0.24*	1.00	0.74**
EGA	0.08	−0.14	−0.24*	0.25*	−0.25*	0.75**	1.00

*Correlation coefficients below 0.27; **0.27 and above. Results of simple correlation (above the diagonal); results of partial correlation (below the diagonal). BMI, Body mass index; EFW, Estimated fetal weight; EGA, Estimated gestational age

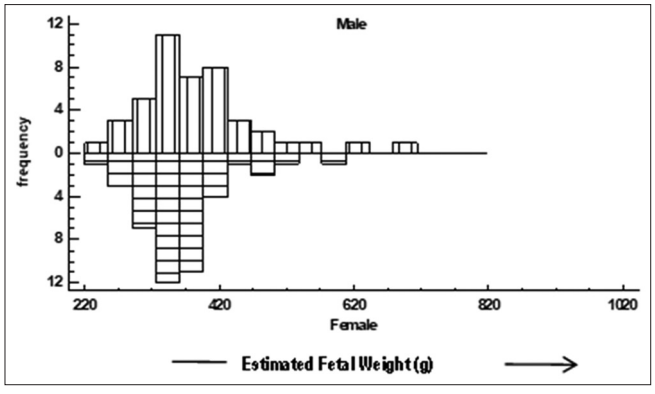

Figure 1: Dual bar chart showing similarity in frequency distribution of estimated fetal weight of male and female fetuses

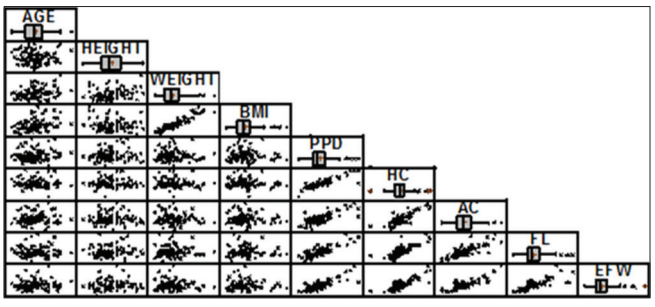

Figure 2: Matrix plot illustrating simple correlation pattern between pairs of some normally distributed continuous variables in the study

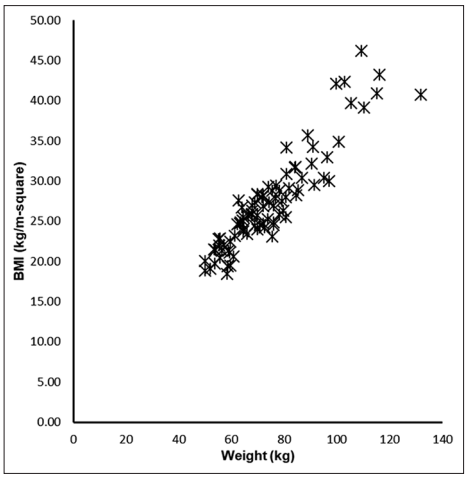

Figure 3: Scatter plot of relationship between maternal weight and BMI. BMI, Body mass index

analysis gave ANOVA results that indicated statistically significant relationship between the maternal variables and EFW ($F = 22.2$; $P < 0.001$). According to R-squared value, the maternal variables chosen for regression explained 62.22% of variability in EFW and gave regression coefficients of maternal variables that were all significant ($P < 0.05$) in the fitted model. Figure 4 displays association between observed EFW and the EFW predicted by the fitted model. The points lie close to the diagonal line indicating that the standardized and the unstandardized models (given below) are satisfactory. This strongly suggests that parity, height, weight, and BMI are good predictors or determinants of EFW:

Unstandardized model

EFW = 54.0 (EGA) + 22.9 (parity) − 8.2 (weight) +21.7 (BMI) + 7 36.8 (height) − 1906.4.

Standardized model

EFW = 0.7 (EGA) + 0.2 (parity) – 1.7 (weight) + 1.7 (BMI) + 0.6 (Height).

Discussion

There are several approaches and formulas for the ultrasound estimation fetal weight. We chose Hadlock *et al.*'s[26] formula because it is one of the most widely used formulas for estimating fetal weight in obstetrics ultrasound practice. The analytical procedure used in this study, viz., simple correlation, partial correlation, multiple regression, and multivariate data techniques, were appropriate because EFW is a quantitative or a complex trait influenced by multiple genetic factors interacting with several environmental determinants. In view of the involvement of many genes and several environmental factors in controlling such traits, it is always very difficult or even impossible to follow

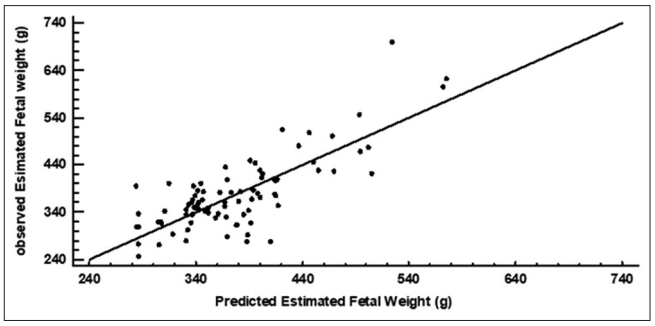

Figure 4: Relationship between observed values of estimated fetal weight and the values predicted by the model generated in the study

segregation of individual genes influencing complex traits using Mendelian principle.[27] Thus, additive gene model and statistical genetic procedure are usually employed in analyzing such traits.[27]

The mean BMI of the study population is 27.4 kg/m^2, which compares similarly with 26.1 kg/m^2 as reported by Okafor *et al*.[28] in Nigeria. Conversely, 65% of the study population were underweight in a study conducted in India by Wills *et al*.[17] The mean parity of 0.67 is low compared with other findings in this environment. Gwarzo and Ugwa[29] reported a parity of 2.47 in a study in Northern Nigeria. Since BMI, parity, ethnicity, and racial differences may influence fetal weight, our results may not be comparable with those of some of the previous studies mentioned above.

This study obtained lower mean measurements for EFW of 377 g, compared to finding by Albouy-Llaty *et al*.,[18] who found mean measurements of 539 g. Among other factors, the discrepancy may be explained by the mean EGA at scan which was 20.4 weeks in this study and 22.3 weeks in the French study above. An important finding in this study is that male and female fetuses have similar EFW in mid-pregnancy, and this prompted us to combine the EFW data obtained from fetuses of both sexes and those of undetermined sex to increase the power of statistical analysis. Albouy-Llaty *et al*.,[18] however, reported gender effect in EFW and suggested that fetal growth curves should be gender specific. Schwärzler *et al*.[2] observed the gender effect at 35-week gestation. The reason for this discrepancy between our study and those of these workers is not yet clear. However, since our study was carried out at mid-pregnancy, the discrepancy might be because effect of fetal sex on EFW becomes more and more manifest with advancing gestation. It had been suggested that growth velocities are different at early, mid-, and late pregnancy.[17] The smaller sample size of our study might have also contributed to the discrepancy.

Many of the variables considered in this study were correlated. However, majority of these correlations were

spurious because they vanished after partial correlation analysis. This is as reported in our earlier study.[25] For example, the disappearance of significant correlation between maternal age and maternal weight after partial correlation implies that many of the variables are confounders because simple correlation as a statistical tool does not take care of confounding factors. Thus, association between variables as assessed by simple correlation should be viewed with caution. In contrast, partial correlations measure the strength of the linear relationship between variables having first adjusted for their relationship to other variables. They are therefore more helpful in judging how useful one variable would be in improving the prediction of the second variable given that information from all the other variables has already been taken into account. The correlation in maternal variables exemplifies phenotypic correlation, i.e., association of two or more characteristics in the same individual.[27] When the association is influenced by the same set of genes, it is genetic correlation; however, if the phenotypic correlation is by the same set of environmental factors, it is environmental correlation. Nevertheless, it is not yet clear whether the associations observed among maternal variables in this study were due to genetic or environmental correlation.

Multiple regression analysis done generated predictive models for EFW using the four maternal variables mentioned above. Judging from the regression weights of unstandardized and standardized models, EGA at the time of scan was the important predictor of EFW. Parity, maternal BMI, and height were also valid positive predictors, but maternal weight was inversely correlated to EFW at mid-pregnancy. Albouy-Llaty *et al*.[18] found that maternal BMI influenced fetal HC and EFW and also confirmed that ultrasound measurements depend on fetal sex from the second trimester onward. Findings by Wills *et al*.[17] suggest that paternally inherited genes influencing skeletal growth are expressed throughout gestation, while those from the mother are expressed in late gestation. Unlike the aforementioned studies that included both paternal and maternal anthropometric variables in their study, the present study considered only maternal contributions to fetal anthropometry in mid-pregnancy. It was very difficult to ensure paternal participation in the study, and this constitutes a shortcoming of this study. Noninvolvement of fathers may have some impact on conclusions reached in this study considering the joint genetic contribution by both parents to fetal development. In this regard, the finding of Taiwo and Akinde[30] that mid-parental weight is the most explanatory variable of birth weight is pertinent.

Conclusion

Our study suggests that EGA, parity, maternal BMI, and maternal height have predictive validity for EFW in mid-pregnancy. Thus, fetal weight measurements in mid-pregnancy can be predicted using our suggested models. The results of this study, if confirmed by others, would have important implications for obstetric practice especially in low-resource settings where ultrasound estimation of fetal weight is not readily available.

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Conflicts of interest

There are no conflicts of interest.

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