Original Article

# Maternal contribution to ultrasound fetal measurements at mid-pregnancy

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**ABSTRACT**

**Background:** Maternal variables are known contributors to fetal variables and can be assessed during pregnancy.

**Objective:** To assess maternal contribution to some mid-pregnancy fetal ultrasound measurements.

**Materials and 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 (AC), femur length (FL), and biparietal diameter (BPD) while the maternal variables were age, parity, height, weight, and BMI.

**Results:** There were intercorrelations between some maternal and fetal variables respectively. Parity correlated significantly with all the ultrasound fetal measurements ($P$ <.05), but the association vanished with partial correlation ($P$ >.05). Significant correlation between parity and age remained the same with simple and partial correlations ($P$ < 0.01). Canonical correlation analysis gave four sets of canonical variables; however, none was statistically significant. Regressing fetal parameters against parity through parent-fetus regression procedure gave significant model fit ($P$ < 0.05), but low $r^2$ value suggesting that variations in parity did not explain much of the variations observed in the fetal ultrasound measurements (3.9% < $r^2$ < 6.7%). The generated models revealed HC having the highest standardized regression coefficient (b = 5.07; $P$ <.05) while FL had the least (b = 1.08; $P$ <.05).

**Conclusion:** The results suggested that parity contributed significantly to fetal ultrasound measurements at mid-pregnancy while maternal height, weight, and BMI made no significant impact.

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

## Introduction

Birth weight (BW), birth length (BL), and head circumference (HC) are some of the vital statistics taken at birth. It is standard obstetric practice to take these measurements at birth because they are postnatal reflector of fetal health and development. The measurements are not only of obstetric importance, they also have implication for the role of genetics in intrauterine development. This is because BW, BL, and HC are complex traits that are exposed to the influence of multiple hereditary factors interacting with several intrauterine environmental determinants.[1] Thus, increasing attention has been focused on heritability of these common birth parameters as a tool that enables researchers to determine the proportions of total phenotypic variability that are accounted for by genetic differences in the traits.[2]

Considerable attention has been directed towards genetic (parental) and environmental factors that affect fetal growth

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and neonatal size.[3-6] It is equally important to focus attention on parental factors that may have influence on ultrasound fetal measurements with a view to assessing the influence of such factors on size during prenatal and neonatal development. Genetic contribution to growth is maximal in the first half of pregnancy, reduce from second trimester until birth and then increase from birth to adulthood.[2,7]

Some studies had produced models of fetal anthropometrics from neonatal measurements.[8] However, such models lack predictive validity for fetal development since growth velocities are different during prenatal and postnatal life.[9] Fetal measurements cannot, therefore, be easily obtained from neonatal measurements by simple interpolation.

Few studies where ultrasound fetal measurements were used did not consider parental contribution despite the fact that each parent contributes 50% of his or her genes to the fetus.[1,10,11] The available publications on variations in ultrasound fetal measurements as influenced by parental anthropometrics especially weight and height considered only multiparous or high-risk women in non-African populations.[1,12,13] In view of relationship between results with parity, maternal health, and genetic differences between populations, problems associated with directly extrapolating results of study on one population to another population is well recognized.

Femur length (FL), HC, abdominal circumference (AC), and biparietal diameter (BPD), being the most frequently measured ultrasound fetal parameters, were used as the response variables in this study.[14,15] Maternal contribution to these fetal anthropometrics at mid-pregnancy was determined using apparently healthy singleton pregnant mothers. The end point of the study is to generate predictive models for the commonly measured fetal parameters using maternal variables that are easily and routinely obtained during antenatal ultrasonography. These models are proposed to provide basis for early identification of pregnancies with potential for abnormal fetal size to enable early commencement of antenatal surveillance measures and appropriate clinical management.

## Materials and Methods

### Participants and study criteria

The subjects for this study were pregnant women attending Georges Memorial Medical Center, Lekki, Lagos, Nigeria, and the Nigerian National Petroleum Corporation Clinic, Victoria Island, Lagos, Nigeria. The study was approved by the Clinical Practice Regulation Committee of Georges Memorial Medical Center, Lekki, Lagos, Nigeria. Written and signed consent for participation was obtained after counseling. Only consenting subjects with singleton pregnancies were included in the study. Pregnancies with coexisting medical conditions such as endocrine abnormalities, hypertension, anemia or pre-eclampsia/eclampsia, antepartum hemorrhage, were excluded.

### Maternal and fetal measurements

Gestational age at recruitment was determined from the date of last menstrual period (LMP). Sonographic fetal measurements were used to determine gestational age in cases of irregular menstrual cycle. Maternal weight and height were taken using standard digital scale (Seca 769 digital weighing scale). Body mass index (BMI) was calculated as:

$$\text{BMI (kg/m}^2) = \text{weight (kg)/height (m}^2) \quad \ldots\ldots(1)$$

Ultrasound fetal measurements were taken at scheduled anomaly ultrasound scan between 18 weeks and 23 weeks of gestational age. Sonographic measurement was according to Hadlock criteria.[14-16] BPD was measured from the outer margin of the proximal skull table to the inner margin of the distal skull table while HC was measured along the outer margin of the calvaria at the level of the BPD. The distance between the proximal and distal metaphyses represented the FL. We measured AC along the outer boundaries of the abdomen at the portal-umbilical vein complex and the $10^{th}$ and the $11^{th}$ thoracic vertebrae (T10 and T11). All measurements were by two certified sonologists to reduce interobserver variability.

### Data analysis

Sample size for the study was determined by the formula:

$$[(Z\alpha/_2)^2 P(1-P)]/E^2 \quad \ldots\ldots(2)$$

A total of nine variables were analyzed in the study using univariate and multivariate statistical techniques. The maternal variables were regarded as independent variables (IVs) while four fetal variables (i.e., FL, HC, AC, and BPD) were dependent variables (DVs). Statistical analysis was by IBM SPSS StatisticsVersion 23 software package. The initial analysis was to obtain summary statistics. Inferential statistics included independent sample *t*-test to compare sample means of two groups and analysis of variance (ANOVA) if more than two groups were involved. Multivariate analysis of variance (MANOVA) under general linear model (GLM) was employed for more than two DVs and their interactions. Appropriate post-hoc tests were done if significant differences ($p < 0.05$) were indicated for ANOVA or MANOVA. Strength of linear relationship between pairs of variables was assessed by simple and partial correlation analysis. Data reduction was by principal component analysis (PCA): models

were generated through multiple regression and canonical correlation analyses. In all cases differences was considered significant when $P < 0.05$.

## Results

Ninety five women were counseled, of which eight were either lost to follow-up or not selected because of non-fulfillment of inclusion criteria. The remaining 87 subjects participated in the study. Summary statistics of maternal and fetal variables are shown in Table 1. Majority of the subjects 46 (52.9%) were nulliparous. Mean age was 31.4 ± 0.45 years, and the mean BMI was 27.4 ± 0.65 kg/m$^2$. Fetal measurements for BPD, HC, AC, and FL are also shown in Table 1. Ultrasound confirmation of fetal showed that 44 fetuses were males and 43 were females giving a sex ratio of 1.0. Table 2 showed that there was no significant difference between the measurements obtained in both male and female fetuses ($P > 0.05$). Data for male and female fetuses were therefore combined to increase the power of statistical analysis.

The results of simple bivariate correlation analysis are shown in Table 3. Fetal and maternal variables show highly significantly intercorrelations. As regards correlation between maternal and fetal variables, parity shows significant correlations with the fetal variables ($P < 0.05$), but the correlations vanished with partial correlations. Partial correlation analysis [Table 4] revealed some variables as confounding factors because pattern of correlations of these variables were different for simple and partial correlations. For instance, there was significant linear association between maternal age and BMI with simple correlation analysis ($r = 0.30$; $P < 0.05$), but it vanished after partial correlation ($r = -0.21$; $P > 0.05$). Similarly, significant association between BPD and AC ($r = 0.78$; $P < 0.01$) was 0.09 ($P > 0.05$) with partial correlation [Tables 3, 4, and Figure 1]. Canonical correlation procedure revealed four sets of linear combinations of canonical variables. The first set with the highest canonical correlation is modeled by the following pair of expressions:

Set 1: −0.23(age) +1.00(parity) – 0.38(height)
+0.50(weight) – 0.75(BMI)..... (3)

Set 2: −0.15(BPD) +1.08(HC)
+0.20(AC) – 0.16(FL)..... (4)

However, the pair of canonical variables were not significantly correlated as represented by scatter plot in Figure 2 (canonical correlation = 0.3; $P = 0.74$).

PCA gave four components that accounted for 87.3% of the total variation in the data. Varimax rotation matrix with Kaiser normalization revealed that all the four fetal variables including parity had highest loading into component 1, which

**Table 1: Summary statistics of maternal and fetal variables**

| | Age | Height | Weight | BMI | BPD | HC | AC | FL |
|---|---|---|---|---|---|---|---|---|
| Mean | 31.4 | 1.7 | 74.7 | 27.4 | 48.6 | 178.2 | 152.8 | 33.8 |
| S.E | 05 | 1.5 | 132.0 | 46.1 | 0.4 | 1.6 | 1.7 | 0.4 |
| S.D | 4.2 | 0.1 | 16.8 | 6.0 | 4.1 | 15.1 | 16.3 | 4.0 |
| Coeff. of Var | 13.4% | 4.2% | 22.4% | 22.0% | 8.5% | 8.5% | 10.6% | 11.9% |
| Min | 23.0 | 1.5 | 50.0 | 18.4 | 41.0 | 128.3 | 120.5 | 26.3 |
| Max | 44.0 | 1.8 | 132.0 | 46.1 | 61.4 | 223.8 | 204.3 | 47.5 |
| Range | 21.0 | 0.3 | 82.0 | 27.73 | 20.4 | 95.5 | 83.8 | 21.2 |

**Table 2: Non-significant difference in results of fetal measurements in male and female fetuses**

| Fetal sex | Mean | Std. Deviation | *P* |
|---|---|---|---|
| Biparietal Diameter | | | |
| Male | 50.778 | 5.5964 | 0.086 |
| Female | 48.276 | 4.1786 | |
| Head Circumference | | | |
| Male | 184.452 | 19.5627 | 0.313 |
| Female | 179.047 | 17.0964 | |
| Abd.Circumference | | | |
| Male | 159.518 | 20.4375 | 0.280 |
| Female | 153.599 | 16.9090 | |
| Femur Length | | | |
| Male | 35.566 | 5.3024 | 0.376 |
| Female | 34.335 | 4.1743 | |

**Table 3: Simple bivariate correlation matrix of maternal and fetal variables**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | 1.00 | | | | | | | | |
| Height | −0.06 | 1.00 | | | | | | | |
| Weight | 0.28** | 0.02 | 1.00 | | | | | | |
| BMI | 0.30** | −0.13 | 0.90** | 1.00 | | | | | |
| BPD | 0.09 | 0.06 | −0.05 | −0.08 | 1.00 | | | | |
| HC | 0.01 | 0.03 | −0.07 | −0.09 | 0.86** | 1.00 | | | |
| AC | 0.02 | −0.06 | −0.08 | −0.05 | 0.78** | 0.81** | 1.00 | | |
| FL | 0.02 | −0.02 | 0.01 | −0.00 | 0.83** | 0.78** | 0.80** | 1.00 | |
| Parity | 0.28** | 0.16 | 0.08 | 0.00 | 0.25* | 0.28** | 0.23* | 0.22* | 1.00 |
| | Age | Height | Weight | BMI | BPD | HC | AC | FL | Parity |

Note: *$P$<0.05; **$P$<0.01

**Table 4: Partial bivariate correlation matrix of maternal and fetal variables**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | 1.00 | | | | | | | | |
| Height | −0.24* | 1.00 | | | | | | | |
| Weight | 0.24* | 0.97** | 1.00 | | | | | | |
| BMI | −0.21 | −0.97** | 0.99** | 1.00 | | | | | |
| BPD | 0.19 | 0.02 | 0.00 | −0.02 | 1.00 | | | | |
| HC | −0.09 | −0.02 | 0.03 | −0.03 | 0.52** | 1.00 | | | |
| AC | 0.01 | 0.01 | −0.05 | 0.05 | 0.09 | 0.38** | 1.00 | | |
| FL | −0.10 | −0.02 | 0.03 | −0.01 | 0.45** | 0.05 | 0.36** | 1.00 | |
| Parity | 0.28** | −0.03 | 0.07 | −0.08 | −0.06 | 0.15 | 0.03 | 0.02 | 1.00 |
| | Age | Height | Weight | BMI | BPD | HC | AC | FL | Parity |

Note: *$P$<0.05; **$P$<0.01

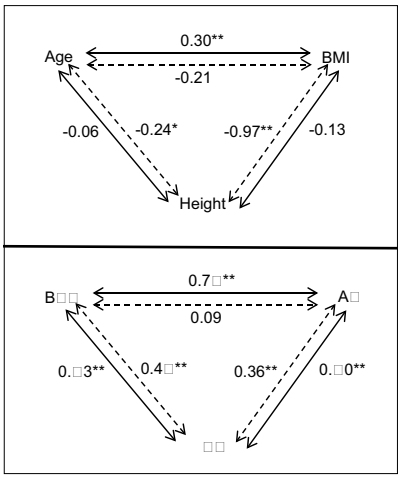


**Figure 1: Path diagram obtained from simple and partial correlations illustrating confounding nature of some maternal and fetal variables**

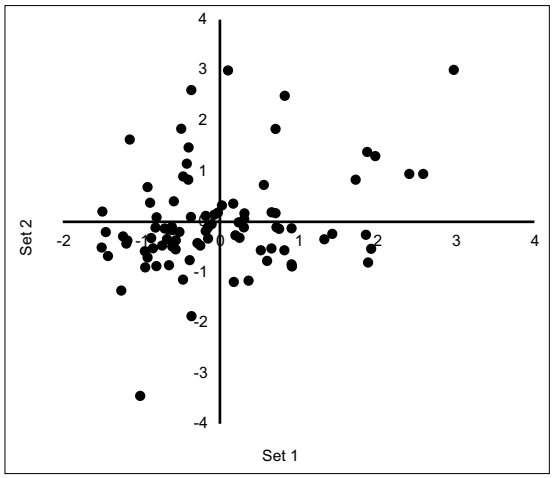


**Figure 2: Plot of first pair of canonical variables**

could be renamed fetal factor [Table 5] while the maternal variables had significant loadings in components 2–4. When combined in multiple regression analysis to produce models that can be used to predict fetal measurements from maternal variables, the study did not reveal any significant regression equations ($P > 0.05$). However, parity had significant ($P < 0.05$) regression coefficient in the regression equations to give the following predictive models:

BPD = 1.24 (parity) +47.76 ..... (5)

HC = 5.07 (parity) +174.82 ..... (6)

AC = 4.46 (parity) +149.88 ..... (7)

FL = 1.08 (parity) +33.01 ..... (8)

## Discussion

The study shows that many parameters in the mothers were positively correlated with fetal parameters as expected, while some maternal correlations were spurious because of confounding factors. Of these, the parity contributed significantly to fetal ultrasound measurements at mid-pregnancy while maternal height, weight, and BMI made no significant impact. Other factors were, however, observed to contribute to the variations in ultrasound fetal parameters apart from the significant contribution of parity. Correlation between maternal age and BMI was cofounded by height because when height was held constant through partial correlation procedure, the association between age and BMI vanished. Similar explanation goes for the correlation between BPD and AC that vanished when FL was held constant through partial correlation procedure. The fact that there was no significant simple or partial correlation between maternal and fetal variables suggests that mothers do not contribute significantly to fetal measurements at mid-pregnancy in this study.

**Table 5: High loadings of fetal variables into component 1 (fetal component)**

| | Components | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Age of Mothers | −.026 | 0.291 | 0.784 | −.219 |
| Parity | 0.220 | −.084 | 0.790 | 0.263 |
| Body Weight of Mothers | −.030 | 0.966 | 0.099 | 0.227 |
| Height of Mothers | −.003 | 0.049 | 0.026 | 0.970 |
| Body Mass Index | −.033 | 0.973 | 0.070 | −.152 |
| Biparietal Diameter | 0.928 | −.037 | 0.109 | 0.048 |
| Head Circumference | 0.928 | −.063 | 0.082 | 0.038 |
| Abd. Circumference | 0.914 | −.041 | 0.049 | -0.072 |
| Femur Length | 0.922 | 0.041 | 0.031 | 0.021 |

The maternal anthropometric variables were of primary interest in this study because of previous study conclusion that maternal anthropometric parameters, being largely genetic, would contribute significantly to fetal growth *in-utero*. For a non-anthropometric maternal variable to be included in a study, it must be easily and objectively assessed by direct measurement or obtained from maternal family and social history. Thus, we included maternal parity and age, but not maternal smoking, cocaine use, alcohol intake, or infection despite their well-known effects on fetal growth.[17-19] The fetal parameters chosen for this study are those that are usually obtained from ultrasound scan and most commonly used in obstetric practice to assess fetal weight and fetal growth.

Maternal underweight is a well-known risk factor for small-for-gestational-age (SGA) fetuses.[20] Similarly, maternal overweight/obesity causes predisposition to large-for-gestational-age (LGA) and macrosomic fetuses

through well-known mechanisms.[21] Moreover, based on ordinary genetic principles, mothers, being first-degree relatives of their babies, share 50% of their genes with the fetuses. Consequently, the maternal anthropometric parameters like height, weight, and BMI were anticipated to be strongly correlated with fetal ultrasound measurements in this study. The study, however, showed that maternal height, and especially, maternal weight, and BMI had weak influence on fetal ultrasound measurements. This does not agree with previous study that showed that height of the mother had significant impact on ultrasound measurements.[1] Parity, a non-genetic variable, was the only maternal variable associated with fetal measurements.

The present study was carried out at mid-pregnancy, a period of gestation that coincides with the second trimester. Thus, poor regression of maternal variables against fetal variables was in concordance with the finding and conclusions of the previous study that low heritability of body size at this stage of fetal life may explain why maternal anthropometrics, despite being largely genetic, did not have significant impact on the variations in fetal measurements.[2] The implication, therefore, is that genes may indeed not play important role in fetal growth at this period of fetal life as previously suggested.[2] In addition to the conclusion from the above study, our study finding also suggest that low heritability does not indicate the degree to which genes determine a trait, but rather the degree to which differences in inherited genes influence variation observed in a trait.[16] Our findings support the assertion that inherited genes play important role in growth and development throughout prenatal and postnatal life. What actually varies during development is the heritability and not contributions of genes to the trait.

Our study has some limitations. It would be better to include paternal variables in order to capture the full picture of parental contribution to fetal growth since each parent makes 50% genetic contribution to the genetic constitution of the fetus. The study inferences are, however, not seriously affected by the absence of paternal variables, because it is known that mothers have a larger shared environment with their fetuses and neonates than fathers. Moreover, some of the fathers may not be biological fathers leading to underestimation of parental contribution to fetal parameters.[2] Another limitation of this study is the sample size, which is partly due to the prospective nature of study, while most of the previous studies were retrospective. It is strongly recommended that similar future studies in Nigeria should include paternal parameters in order to capture the total genetic contribution by both parents and involve a larger sample size to increase the power of statistical analysis. An implication of the finding in this study is that parity should be considered for inclusion in the currently existing models for accurate prediction and determination of fetal size.

Previous studies and other workers had shown that parental anthropometrics are important determinants of neonatal birth parameters such as BW, BL, and HC.[7] It had also been shown that the first years of life is when children tend to catch-up or catch-down as they tend to compensate respectively for growth restriction or growth enhancements caused by maternal intrauterine environment.[17] Thus, humans approach the target growth dictated by their inherited genes as development progresses from neonate to infancy and finally to adulthood.

The present study supports the view that variation in intrauterine growth at mid-pregnancy, especially as assessed by fetal weight, is more influenced by variation in feto-maternal environment while variation in postnatal growth is more influenced by inherited genetic differences. An important lesson from this study is that fetal measurements, especially those obtained at mid-pregnancy, should be extrapolated to neonatal birth parameters with caution.

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### Conflicts of interest
There are no conflicts of interest.

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