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Subjects and methods: In this cross-sectional study, six hundred and thirty five (635) pregnant subjects attending antenatal care at the Alex Ekwueme Federal University Teaching Hospital were recruited and followed up through pregnancy till delivery. Weight and height were measured at booking and weight repeated at each visit. Values obtained from the above measurements were then inserted into appropriate formulae to calculate the body mass index and body surface area. A mini-questionnaire was used to extract information such as age and parity. Variables were coded and analysed with SPSS version 20. Data were presented as percentages and tables. The level of statistical significance was set at 0.05 (providing 95% confidence interval). Associations between variables were tested using linear regression models. A receiver operating characteristic curve was used to determine the sensitivity and specificity of the anthropometric parameters in predicting the birth weight (low birth weight- <2.5 kilogrammes or macrosomia- ≥ 4 kilogrammes).

Results: The mean age of participants was 29 ± 6.6 years. The mean parity was 2.3. The mean weight of all participants in the first, second and third trimesters were 70.6 ± 11.2 kilograms, 77 ± 6.7 kilograms and 77.3 ± 13.9 kilograms respectively. The mean height of respondents was 1.63 ± 0.13 meters. The mean first, second and third trimester BMIs were27.2 ± 3.2, 27.9 ± 4.5 and 29.8 ± 4.2 respectively. The mean birth weight of babies was 3.3 ± 0.46 kilograms. The mean first, second and third trimester body surface area were 1.71 ± 0.254, 1.80 ± 0.167 and 1.87 ± 0.157 respectively.

53.2% of babies born were females. Linear regression analysis showed there was a positive correlation between first, second and third trimester BMI and birth weight, which was not statistically significant for the first and third trimesters but statistically significant for second trimester (r= 0.017, p= 0.037). There was also a positive correlation between parity and birth weight which became statistically significant with increasing parity (r_0 = 0.145, p_0= 0.875 and r_5= 0.204 and p_5= 0.017).

Body surface area (BSA) also showed statistically significant correlation with the birth weight of the neonate in the first, second and third trimesters (r= 0.56, p= 0.0098, r=0.58, p= 0.0076 and r= 0.611, p= 0.0086). Its correlation was stronger than that of body mass index. Maternal height and weight did not show statistically significant correlation with the birth weight of the baby. BMI had a sensitivity of 73% and specificity of 31% in determining if a baby would be macrosomic (birth weight greater than or equals 4 kilograms) or low birth weight(weight less than 2.5 kilogrammes) while BSA had a sensitivity of 84% and specificity of 65% in predicting same.

Conclusion: From the study it can be concluded that determinants of birth weight are multifactorial. Mid-trimester body mass index and body surface areas in the three trimesters with their inexpensive ways can offer hope as predictors of birth weight of the neonate, with BSA showing more sensitivity and specificity than BMI. More studies are needed especially for BSA to validate or refute the foregoing.

Keywords: *body mass index, body surface area, weight, height, neonatal birth weight.*

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I. Introduction

Anthropometry is the systematic collection and correlation of measurements of the human body. It is one of the principal techniques of physical anthropology[1]. It originated in the 19th century, when early studies of human biological and cultural evolution stimulated an interest in the systematic description of populations both living and extinct[1]. In the latter part of the 19th century, anthropometric data were applied, often subjectively, by social scientists attempting to support theories associating biological race with levels of cultural and intellectual development[1].

The body mass index also known as Quetelet index, is proxy for estimating human body fat based on an individual's weight and height[2]. It is defined as the individual's body mass divided by the square of his or her height. The formula universally used is in a unit of kg/m^2 (height measured in meters and weight measured in kilograms). The WHO categorized BMI to assess how much an individual's body weight departs from what is normal or desirable for his or her height. The WHO categorization is the most popular and is as follows[2]: Underweight (<18.5), normal (18.5 to 24.99), overweight (25 to 29.99), obesity class 1(30 to 34.99), Obesity class 11(35 to 39.99) and obesity class 111(40 and above). BMI has not been vastly used in estimating foetal weight but in Obstetrics, a pregnant woman's weight is an extremely important factor in the course of pregnancy as not only obesity but being underweight may lead to complications in pregnancy such as preterm delivery and low neonatal birth weight[3]. In recent years, infant birth weight has been increasing in many countries, representing an Obstetric hazard and a potential public health problem. Infant survival and birth weight are dependent on the health of the mother during pregnancy so also maternal weight gain as relates BMI, a good predictor of infant birth weight (Shrestha I & Sunuwar L, 2010).Some of the limitations of BMI include its inexactness of the distribution between lean mass and adipose tissue due to its dependence only weight and height. Body surface area (BSA) on the other hand is the measured or calculated surface area of a human body. For many clinical purposes BSA is a better indicator of metabolic mass than body weight because it is less affected by abnormal adipose mass. Estimation of BSA is simpler than many measures of volume[2]. BSA is calculated as follows: BSA= √W X H/60 if H is in centimetres or BSA =√W X Ht/6. The average BSA for men is 1.91 m^2 and for women was 1.6 m^2. However, there is some evidence that BSA values are less accurate at extremes of height and weight, where it may be a better estimate. The normal ranges of average body surface area of the population (WHO, 2014): neonate (0.25 m^2), children 2 years (0.5 m^2), and children 9 years (1.07 m^2). Values for adult male and female respectively are: 1.9 m^2 and 1.6 m^2 respectively.

Infant birth weight has been increasing in recent times with the risk of obesity later in life[5]. Birth weight is an important determinant of infant's well-being and as such its prediction will aid in reducing the risks associated with obesity[4]. Maternal anthropometry is a potential veritable tool in evaluation of pregnancy status and prediction of foetal weight[5]. Policy makers need evidence about the state of maternal and child health to make the practice of Obstetrics safer, as facilities for prediction and estimation of birth weight of the newborn during pregnancy are not readily available in our environment. Identification of reliable anthropometric parameters for the estimation and prediction of the birth weight of the newborn will bridge this gap and make practice safer.

II. Subjects and Methods

Between 14th January, 2017 and 13th October, 2017, we conducted a prospective cohort study of 700 pregnant subjects at the antenatal clinic of Alex Ekwueme Federal University Teaching Hospital, Abakaliki. Out of this number 65 were lost to follow up, with 635 being followed up till delivery. Alex Ekwueme Federal University Teaching Hospital is located in the heart of Abakaliki which is the capital of Ebonyi State, South east Nigeria. It offers specialized Medical care to people resident in Ebonyi and neighbouring states of Benue, Cross River and Enugu. The Antenatal clinic is run by Consultant Obstetricians from the department of Obstetrics and Gynaecology. There are five teams of doctors led by the Consultant who take care of pregnant women at the clinic, in addition to Midwives and other support staff. The clinic runs Mondays through Fridays. During the year prior to commencement of this study, there were 10,651 pregnant subjects who registered for antenatal care at the centre. All consenting pregnant subjects who booked in the first trimester were recruited and followed up till delivery. Unbooked subjects and those with medical illnesses like diabetes, hypertensive disorders of pregnancy and HIV that complicate pregnancy and affect birth weight were excluded from the study. Subjects with twin gestation and those with physical deformities were also excluded from the study. Subjects were recruited from the antenatal clinic after approval was obtained from the ethical committee of the institution. The research topic, procedure and benefits were thoroughly explained to them. The pregnant subjects were recruited at the waiting area of the Antenatal clinic using a systematic random sampling technique where the 3rd seated pregnant subject was recruited after randomly selecting a starting point. The weight and height measurements of recruited subjects were made by the use of a standard and functional stadiometer. Two assistants were recruited and all procedures as regards measurements were explained to them to maintain quality assurance. The body surface area was calculated with the weight and height measurement for each trimester, using the formula √height in centimetres multiplied by weight in kilograms divided by 3600. The body mass index was calculated using the formula: weight in kilograms divided by the square of height in metres. A mini questionnaire was also structured to collect information that included the responder's age, parity, weight at each visit, height and birth weight of the baby at delivery. The pregnant subjects were weighed with minimal clothing and with shoes removed. The measurements were made to the nearest 0.1kg by the use of a standard Secastadiometer[R]. The scale was ensured to be at the zero mark. The patient was made to stand at the centre of the scale without support, with weight evenly distributed on both feet. The process was repeated as above. If the measurements differed by 0.4kg, then another measurement was made. If two measurements were taken then, the average value was recorded while the median value was recorded if three measurements were taken.

For height, the stretch stature method was used. The stature is the maximum distance from the floor to the vertex of the skull (the highest point on the skull when the head is in the Frankfort plane). The shoes were also removed while the patient was asked to stand with the back, buttocks and heels against the stadiometer. The patient's feet were placed flat and together on the floor. The patient's head was placed in the Frankfort's position. The patient was instructed to take and hold a deep breath while maintaining the position above. The head board was placed firmly on the vertex, crushing the hair as much as possible. The measurement was then taken to the nearest 0.1 cm at the end of the subject's deep breath. The steps taken above were repeated again. If two measurements differ by more than 0.4cm, a third measurement was taken. If two measurements were taken, the average value was recorded. If three, the median value was recorded

III. Results

A total of 635 subjects were enrolled into the study and followed through antenatal care and delivery. Most (58.1%) of the participants belonged to the age group 25-29 while expectedly the age group 15-19 and 40-44 had the least number each (2%). The mean age of patients was 29 ± 6.6 years while the mean parity was 2.3.

The mean weight in the first trimester was 70.6 ± 11.2 kilograms, mean weight for the second trimester was 77 ± 8.9 kilograms for all subjects while that for the third trimester was 77.3 ± 13.9. The mean height was 1.63 ± 0.15 metres. The mean first trimester BMI was 27.2 ± 3.2, mean second trimester BMI was for participants was 27.9 ± 4.5 while that for third trimester was 29.8 ± 4.2. Of the babies born, 338 (53.2%) were females while the males were 297 (46.8%). The mean birth weight was 3.3 ± 0.46 kilograms. The mean first, second third trimester body surface area were 1.71 ± 0.254, 1.80 ± 0.167 and 1.87 ± 0.157 respectively.

The socio-demographic characteristics of participants are presented in the frequency tables below.

Table 1: Showing the frequency distribution of sociodemographic parameters of the subjects

Age	Frequency N=635	Percentage
15-19	4	0.6%
20-24	108	17.1%
25-29	260	40.9%
30-34	167	26.3%
35-39	92	14.5%
40-44	4	0.6%
Parity	Frequency N= 635	Percentage
0	150	23.6%
1-4	416	65.5%
5 and above	69	10.9%

The 25-29 age group had the highest number of subjects while expectedly the 40-44 had the least number of subjects. The 1-4 parity group had the highest frequency while 5 and above had the least number of subjects.

Table 2: Showing linear regression analysis of the relationship of some parameters with birth weight of the baby

Parameter	Co-efficient (r)	P-value
Parity		
0	0.01	0.723
1-4	0.145	0.875
5 and above	0.204	0.017
Age of subjects		
15-19	-0.11	0.816
20-24	0.116	0.802
25-29	-0.041	0.929
30-34	-0.015	0.975
35-39	0.054	0.907
40-44	0.400	0.554
Body mass index		
First trimester	0.021	0.026
Second trimester	0.017	0.037
Third trimester	0.016	0.065

Body surface area First trimester Second trimester Third trimester	 0.489 0.580 0.611	 0.0060 0.0076 0.0086
Weight First trimester Second trimester Third trimester	 -0.345 -0.870 0.328	 0.283 0.352 0.024
Height	0.175	0.464
Sex of baby	0.296	0.003

Parity had a positive correlation with the birth weight of the baby which became stronger and statistically significant with increasing parity. Age range of 40-44 also had a stronger positive correlation with the birth weight of the baby compared with other age ranges. This relationship was however not statistically significant. The first and second trimester mean body mass index had a positive correlation with weight which was statistically significant. The first, second and third trimester body surface areas had positive correlation with the birth weight of the baby which were statistically significant. The sex of the baby also had a positive correlation that was statistically significant while the weight of the baby in the third trimester and height correlated positively with the birth weight of the baby while that of the third trimester weight was statistically significant, that of height was not statistically significant.

Table 3: Showing the predictive values of body mass index and body surface area

Parameter	Sensitivity	Specificity	Negative predictive value	Positive predictive value
Body mass index	73%	31%	97.8%	64%
Body surface area	84%	65%	99.4%	73%

Overall, body surface area had a better sensitivity, specificity, negative and positive predictive value in predicting a large or small baby than body mass index.

IV. Discussion

This study was carried out in the Obstetrics and Gynaecology department of Federal Teaching Hospital, Abakaliki among 635 booked pregnant subjects attending antenatal care in the facility. These subjects were followed through antenatal care and delivery. It was aimed at determining if there was any correlation between maternal anthropometric measurements and the birth weight of the baby. There is considerable evidence that the birth weight of a baby is dependent on the mother, whose influence acts more through genes transmitted to the baby. Trans-placental exchange provides all the metabolic demands of fetal growth. Uterine and umbilical flow rates are in turn dependent to a large extent on the vascularisation of the placenta. Hence, factors influencing placental vascular development are likely to impact on fetal growth and development.[4]

The findings of this study highlighted the interrelations between the body physique of the mother (BMI at different trimesters, weight at different trimesters, height), socioeconomic class, parity, sex of the baby, age of the mother and the birth weight of the baby. Significant positive correlations were observed as regards the parameters. The results of the study are in agreement with many other studies which indicated that neonatal growth, as reflected by the birth weight are mostly influenced by maternal BMI (evidenced by weight and height of participants), body surface area and several other factors including the sex of the baby, parity and socio-economic factors which also has some on the health of any pregnancy.[4,6,7,8,9] One study however did not find any statistically correlation between the neonatal birth weight and BMI as found in this study[3].As was noted in most of the literature reviewed, pre-pregnancy BMI and BSA could not be measured as pre-conception care is an evolving field in Obstetrics care in those study areas, as in our environment.

Linear regression analysis showed positive and negative correlation between age and the birth weight of baby, though this was not statistically significant. This shows that age as a possible confounding variable did not influence the birth weight as much and cannot be grouped as a factor that affects the neonatal birth weight and any increment in neonatal weight attributed to age may be due to chance. Parity has long been attributed as a predictor for birth weight of the baby with weight of the baby thought to increase with increasing parity. This was supported by the index study where there was a positive correlation between parity and birth weight for all levels of parity but became statistically significant with increasing parity especially for parity level, 5 and above. The sex of the baby has also been known to be predictor for birth weight. Male babies are generally thought to weigh more than female babies. This study also supported the foregoing as there was a statistically significant positive correlation between birth weight and sex of the baby. The mean body surface area in the first, second and third trimesters differed from the average body surface area of 1.61 for women and may have been caused by the increase in weight occasioned by pregnancy. Weight is a significant variable in the calculation of body surface area and as such any increment in it would likely also increase the body surface area. The body surface area in all the trimesters correlated with the birth weight of the baby and were statistically significant. There are at the moment no studies comparing body surface area of pregnant women and the birth weight of the baby. However, BMI and body surface area are similar and use height and weight for their calculations, the statistically significant result of correlations between the trimester body surface area and the birth weight of the baby is not surprising (although it was first and second trimester BMI that showed a statistically significant positive correlation in this study).

V. Conclusion and Recommendations

From the study it can be concluded that determinants of birth weight are multifactorial. Mid-trimester body mass index and body surface areas in the three trimesters with their inexpensive ways can offer hope as predictors of birth weight of the neonate, with BSA showing more sensitivity and specificity than BMI. More studies are needed especially for BSA to validate or refute the foregoing. Maternal anthropometric measurements are potentially veritable tools in the evaluation of pregnancy status and prediction of birth weight to assist policy makers with evidence about the state of maternal and child health.

Conflict of Interest

The authors have no conflict of interest to declare.

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