DETERMINATION OF GESTATIONAL AGE BY ULTRASOUND

PhD Thesis

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PhD Thesis

Submitted by

ALEYA FERDOUSI

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Dedicated
To
My Parents

Sayesta Khatun

and

Hafizuddin Ahmed

Declaration

I hereby declare that this thesis **"Determination of gestational age by ultrasound"** is based on work carried out by me. I further declare that no part of it has been presented previously for higher degree.

Aleya Ferdousi

Certificate

"Determination of gestational age by ultrasound" submitted by Aleya Ferdousi for the award of Ph.D Degree in Ultrasound, is an independent research work done at Institute Neuclear Medicine & Ultrasound Bangabandhu Sheikh Mujib Medical University, 122, Kazi Nazrul Islam Avenue, Shahbag, Dhaka & Maternal and Childhealth Training Institute Azimpur, Dhaka under the Faculty of Postgraduate Medical Science & Research Dhaka University, Dhaka, Bangladesh and this thesis has not been used as the basis for the award of any degree or fellowship.

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ABSTRACT

Objective: To create reliable reference ranges for early pregnancy using parameter CRL from 8 week to 12 weeks and fetal head, abdomen, femur ultrasound biometry from 13-40 weeks of pregnancy using a large sample size which is evenly distributed.

Design: A prospective, cross-sectional study.

Sample: The study data were obtained from 6600 pregnant women.

Methods: Only the first ultrasound examination between 8 and 40 weeks of each fetus with exactly established gestational age was used for analysis. Exclusions were made on the grounds of fetal small-for-date or maternal menstrual abnormality which may hamper determinations of LMP or gestational age. Separate regression models were fitted to estimate the mean and standard deviation at each gestational age for each parameter.

Results: A total of 6600 fetal head biparietal diameters, head circumference, abdominal circumference and femoral length were measured. Fetal head biparietal diameters, head circumference, abdominal circumference and femoral length could be measured on the same fetus. The centile charts, tables and regression formulae for fetal head biparietal diameters, head circumference, abdomen circumference and femoral length are presented. An application to calculate Z scores was developed using Excel (Microsoft Corporation) USA to reveal the normal standard distribution. The rate of growth of BPD and FL were approximately 2-4 mm per week from 13 to 23 weeks, 4-5 mm per week from 24 weeks to 36 weeks and thereafter it was 5-6 mm per week till 40 weeks. Whereas the rate of growth of HC and AC were approximately 9-11 mm per week from 13 weeks to 36 weeks and thereafter it was 3-4 mm per week till 40 weeks.

Conclusion: The study result was used to compute nomogram for each parameter of total growth as well as equations were derived to calculate estimated total weight & gestational age in our population.

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List of Abbreviations

2D	Two Dimenational
AC	Abdominal Circumference
AF	Amniotic Fluid
ASUM	Australasian Society of Ultrasound in Medicine
AVol	Fractional Arm Volume
BAEC	Bangladesh Atomic Energy Commission
BMI	Body mass index
BMRC	Bangladesh Medical Research Council
BP	Blood Pressure
BPD	Biparietal Diameter
BSMMU	Bangabadhu Sheikh Mujib Medical University
BW	Birth Weight
C/S	Cesarean Section
CCD	Cheek-to-Cheek Diameter
CRL	Crown-Rump Length
DMCH	Dhaka Medical College Hospital
EDD	Expected Date of Delivery
EFW	Estimation of Fetal Weight
EPs	Emergency Physicians
FDL	Femur Diaphysis Length

FH	Fundal Height
FL	Femur Length
FWV	Family Welfare Visitor
GA	Gestational Age
gm	Grams
GS	Gestational Sac
Hb	Haemoglobin
HC	Head Circumference
HT	Height in cm
INMU	Institute of Nuclear Medicine and Ultrasound
IUGR	Intrauterine Growth Retardation
IVF	In Vitro Fertilization
LGA	Large-For-Gestational-Age
LMP	Last Menstrual Period
MA	Medical Assistant
MBBS	Bachelor of Medicine and Bachelor of Surgery
MCHTI	Maternal Child Health Training Institute
MCR	Maternal care receptivity index
MDS	Mean Gestational Sac Diameters
mm	Millimeter
mmHg	mm of mercury
MUAC	Mid-upper arm circumference

N	Total Number
OFT	Occipito Frontal Diameter
Or	Odd Ratio (The ration of odds of exposure among the
P	Probability (Measure of chance of occurrence by chance)
PsOG	Periods of Gestation
r	Correlation Coefficient (The degree or extent of relationship between two variables is measured in terms of a another parameter)
SD	Standard Division
SFD	Small For Date
SGA	Small-For-Gestational-Age
TBA	Traditional Birth Attendant
TGA	True Gestational Age
TVol	Fractional Thigh Volume
USG	Ultasonogram
Wt.	Weight in kg

1.1 INTRODUCTION:

Accurate gestational age assessment is of great importance in obstetric practice (Verburg et al. 2008; Kalish and Chervenak, 2009). Appropriate estimation of gestational age requires good judgment by the obstetrician caring for the patient. Since clinical data such as the menstrual cycle or uterine size often are not reliable, the most precise parameter for pregnancy dating should be determined by the obstetrician early in the pregnancy (Kalish and Chervenak, 2009). It was Nagele and his contemporaries who first suggested counting 40 weeks from the first day of the last menstrual period (LMP) to predict the day of confinement (Kalish and Chervenak, 2009; Johnsen et al. 2008). Subsequently, WHO has also defined the normal length of pregnancy to be 40 weeks (280 days), but studies of population-based birth registries suggest a longer pregnancy duration based on LMP (mean 281–283.6 days). A problem with the LMP-method is that 45–68% of women have irregular periods or uncertain information of their LMP. Moreover, the fertile women occurs over a range of days in the menstrual cycle (Johnsen et al. 2008). Ultrasound is an accurate and useful modality for the assessment of gestational age in the first and second trimester of pregnancy and, as a routine part of prenatal care, can greatly impact obstetric management and improve antepartum care (Kalish and Chervenak, 2009).

Accurate gestational dating is one of the most important assessments obstetrical providers make in pregnancy, given that all of the various management strategies are dependent on knowing where the patient is in gestation Kalish and Chervenak, 2009). Accurate pregnancy dating may assist obstetricians in appropriately counseling women who are at risk of a preterm delivery about likely neonatal outcomes and is also essential in the evaluation of fetal growth and the detection of intrauterine growth restriction (Kalish and Chervenak, 2009). Correct assessment of gestational age and fetal growth is essential for optimal obstetric management (Kalish and Chervenak, 2009; Verburg et al.

2008). Gestational age is usually determined by the date of the woman's last menstrual period. Sometimes a woman may be uncertain of the date of her last menstrual period. Ultrasound scans offer an alternative method for estimating gestational age. It is currently considered to be a safe, non-invasive, accurate and cost-effective investigation of the foetus and there is no strong evidence to suggest that ultrasound harms babies. It has progressively become an indispensable obstetric tool and plays an important role in the care of every pregnant woman (Abeysena and Jayawardana, 2011). In addition to traditional biometry, ancillary biometric and nonbiometric measurements can help narrow the biologic variability between fetuses. Moreover, one can employ these nontraditional measurements both in late gestation to assist in determining appropriate gestational age and fetal lung maturity, and in other specific clinical situations-such as oligohydramnios, in which compression of the fetal head and abdomen can lead to difficulty in obtaining an accurate biparietal diameter and abdominal circumference (Kalish and Chervenak, 2009).

The last two decades have seen a tremendous progress in application of ultrasound as a diagnostic modality revolutionizing the management towards better care. This is particularly due to its non-invasive and non –ionizing nature besides its cost effectiveness leading to wider acceptability. The exemplary safety record of diagnostic ultrasound is probably an important reason that is has become so widely used. Ultrasound is safe for the patient, the fetus and the sonologist. There is no reported risk of ionizing radiations as in X-rays or any other known biological or embroytoxic effect. It does not require the injections such as radio-opaque dye as sometimes needed in radiology. Ultrasonography has advanced obstetric practice by enabling relatively detailed assessment of the fetus in utero, including an accurate estimate of gestational age when performed in the first half of pregnancy (Mongelli et al. 1996). Fetal development is normally evaluated by comparing morphological measurements of the fetus, obtained from non-invasive ultrasound examinations, against fetal growth curves. These curves are generated from collected data representing the ethnographic population statistics for fetal development (Altman and Chitty, 1994; Chitty et al. 1994a; Chitty et al. 1994b; Chitty et al. 1994c). Neonatal morphometric measurements are usually taken for femur length, abdominal circumference, biparietal diameter and head circumference in ultrasound examinations of a fetus in its second trimester, while the fetal crown-rump length is the measurement used in the first trimester (Robinson, 1979; Greene 1990; Dombrowski et al. 1992). Once the gestation age of the fetus has been determined by a clinician it is then used as a basis to determine the normality of growth of the fetus. It becomes the common factor when parameters indicative of fetal development are checked. The estimate of fetal age is also important in the determination of treatment after delivery of the fetus, although other means of gestation age estimation are taken such as the Dubowitz Score (Cloherty 1990). Obstetrical ultrasound technicians routinely measure biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) to estimate gestational age in an outpatient setting (Shah et al. 2010). Assessment of gestational age is one of the most important aims of ultrasonography in obstetrics. As pregnancy progresses influences of factors which make the growth of the fetuses different, cumulates. It has been revealed that the earlier in pregnancy the ultrasound examination was performed the better precision in the assessment of gestational age was obtained (Pajak et al. 1998). Ultrasound dating was thought to overcome some of these problems by using fetal size to determine gestational age and thus to predict day of confinement independently of LMP. Based on fetal BPD in the second trimester, pregnancy duration is calculated to be somewhat shorter (mean 280.6 days) than previously thought. Today ultrasound dating has spread to common use and has had the clinically desirable effect of reducing the number of inductions of labour for presumed post-term pregnancies (Johnsen et al. 2008).

While ultrasound dating is useful for those women with uncertain LMP, it is less obvious that this is also valid for pregnancies with reliable information of a regular LMP. Even in this group, ultrasound dating does, however, predict day of confinement more precisely than LMP. As a consequence ultrasound dating has been recommended as the preferred dating method, although this view has repeatedly been disputed. The reason is that charts for ultrasound dating are based on fetal biometry in pregnancies with certain and regular LMP in the first place. It therefore seems unlikely that the ultrasound method could better predict day of confinement independents of LMP itself, unless the ultrasound method also includes a factor that is not yet accounted for (Johnsen et al. 2008). Reliable fetal age assessment is now possible using antenatal sonography. Crown-rump length, biparietal diameter, head perimeter and femur length are the most widely used parameters, while biocular distance and humerus length are of ancillary value. Techniques of sonographic measurement and clinical applications are reviewed and nomograms relating these parameters to gestational age are presented. Multiple sonographic parameters have been used to diagnose altered fetal growth. Clinical applications and pitfalls in the diagnosis of IUGR are discussed when biparietal diameter, abdominal perimeter, head to abdomen ratio, total intrauterine volume, qualitative amniotic fluid determination, fetal urine production rate and estimated fetal weight are used (Johnsen et al. 2008).

The main uses of ultrasonography are determination of gestational age and assessment of foetal size. Foetal body measurements reflect the gestational age of the foetus. This is particularly true in early gestation. In patients with uncertain last menstrual periods, such measurements must be made as early as possible in pregnancy to arrive at a correct dating for the patient. In the latter part of pregnancy measuring body parameters will allow assessment of the size and growth of the foetus and will greatly assist in the diagnosis and management of intrauterine growth retardation. The most accurate measurement for dating is the crown-rump length of the foetus, which can be done between 8 and 13 weeks of gestation. After 13 weeks of gestation, the foetal age may be estimated by the BPD (the transverse diameter of the head), the HC and the FL (the longest bone in the body). The AC of the foetus may also be measured and this gives an estimate of the weight and size of the fetus as well. Reliability refers to the consistency of a measure. A test is considered reliable if we obtain the same result on repetition of the measurement. Even though it is impossible to calculate it exactly, there are different ways to estimate it (Abeysena and Jayawardana, 2011). Infants born for small for date (SFD) fetuses have an increased risk of perinatal mortality and morbidity. Different methods have been applied to identify these fetuses including history, clinical examination and ultrasonography. Ultrasonography has a better predictive value and majority of such fetuses can be identified. Measurements of the fetal BPD, AC and FL charts are widely used in dating pregnancies and follow-up of pregnant women in assessing fetal growth, identification of small for date (SFD) and growth retarded fetuses (Ashrafunnessa et al. 2003). Ultrasound is used to assess foetal age, foetal weight and growth. The error of such measurements is considerable, but the technique of averaging repeated measurements restricts random error. The use of customised foetal weight charts, that is, adjusting for ethnicity and maternal and foetal factors helps in classifying foetal weight appropriately. Commonly used cross-sectional reference ranges are useful for the foetal weight assessment at any stage of pregnancy, but not for foetal growth. Growth assessment requires serial measurements and longitudinal reference ranges, which provide conditional terms for individual foetuses. That is, an initial measurement is used for calculating individual ranges for the rest of pregnancy. Compared to the ranges for the entire population, the conditional ranges for a small foetus are narrower and skewed in the direction of the initial measurement. Quality control is recommended to ensure that such methods work when applied to the local population (Ashrafunnessa et al. 2003). Sonographic measurements of fetal ultrasound parameters are the basis for accurate determination of gestational age and detection of fetal growth abnormalities. Selection of the most useful single biometric parameter depends on the timing and purpose of measurement and is influenced by specific limitations. CRL (crown-rump length) is the best parameter for early dating of pregnancy. BPD maintains the closest correlation with gestational age in the second trimester. In cases of variation in the shape of the skull, head circumference is an effective alternative. AC is the most useful dimension to evaluate fetal growth, and femur length is the best parameter in the evaluation of skeletal dysplasia. Use of multiple predictors improves the accuracy of estimates. An individual approach to each pregnancy is recommended for fetal growth assessment. The various epidemiological factors involved in fetal growth should be considered and specific charts for different communities should be used when possible. The methods of fetal weight estimation with their limitations and potential errors are presented. Clinical application of fetal biometry in abnormal growth is discussed in cases of small- and large-for-gestational-age fetuses, chromosomal aberrations, and skeletal dysplasias Benson 1998).

The purpose of the study was measuring BPD. FL, AC to determine to duration of gestational age & the monitoring fetal growth. Many obstetric abnormalities can not detected by clinical examination. The introduction of ultrasound to the practice of obstetrics has dramatically influenced the clinical management of the fetus and mother during pregnancy. Early identification of high risk pregnancy can be made safely by ultrasound examination. This study is done to assess the role of ultrasound in diagnosis of high risk pregnancy. The main objective of this study is to predict fetal weight in the third trimester in our population by using fetal biometry obtained by ultrasonography and correlate with the menstrual age for accurate calibration of fetal weight in Bangladeshi fetuses. In a poor country like ours, maternal malnutrition and consequent low birth weight of the neonate is quite common. A discrepancy of two weeks can be critical for the survival of an infant who has to be delivered early because of some antenatal complications (Benson 1998). Fetal weight estimation is also important, because although it is clear that decreased weight is associated with increased mortality and morbidity (Benson 1998) and malnutrition can produce significant neurology deficiencies in some individuals (Hill el al. 1992). For these reasons determination of fetal weight is very important. Because when dates are so vague and the patient reports late in her pregnancy to the doctor, the obstetrician has to take the help of fetal weight for making decision for proper management. This study has been done to get base line information about ultrasonographic fetal weight at third trimester. Efforts were made to correlate the estimated fetal weight with actual birth weight and to some socioeconomic variables in aspect of Bangladesh.

1.2. RATIONALITY OF THE STUDY:

Physicians and midwives rely on physical examination of the pregnant woman to estimate fetal size by uterine palpation and measurement of the fundal height. This technique is made more difficult by large maternal body habitus and uterine fibroids or other pelvic masses, which can give a false indication of size, as well as amniotic fluid and the bulk of the placenta (Benson 1998). Estimation of gestational age required for good judgment by the obstetrician caring for the patient as the menstrual cycle or uterine size often are not reliable. Accurate gestational age and size assessment is of great importance in obstetric practice as fetal size is associated with pregnancy outcome. The growth-restricted fetus is at increased risk of preterm delivery, perinatal death and infant morbidity and mortality due to hypoxia, acidosis, hypoglycemia and hypocalcemia. Fetal growth is determined by a complex interaction of genetic, environmental and socio-economic factors (Vorherr 1982) with normal birth standards based on a combination of gestational age at birth, head size, length and birth weight (Varner 1987). Normal fetal growth is not only reflected in birth weight but is defined according to population standards and percentiles. Ultrasonography is useful much accurate and already proved throughout the world. Almost every nation has its own ultrasonographic parameter for gestational age determination. So it is essential to have our own parameter in the context of our national character. Diagnostic ultrasound is mapped for position and intensity to build up an anatomical image. Gestational sac (GS) size, crown ramp length (CRL), biparietal diameter (BPD), femoral length (FL), head circumference, abdominal circumference, anterior posterior trunk diameter etc are the well practiced parameters to measure the gestational age of the fetus by ultrasound. By measuring the three basic parameters, BPD, FL and AC and estimating weight of fetuses of our population, national population standards can be prepared. This will go a long way to accurately predict the gestational age and growth of our fetuses for their best possible management and pregnancy outcome. All of the above parameters that use for ultrasound here in Bangladesh are either from the western reference or from the East Asian reference. Till now there is no established reference for Bangladeshi pregnant mother to measure the actual gestational age. It is obvious that the parameters from either western or East Asian references may not be suitable for the measurement of gestational age in Bangladeshi pregnant mothers because of the different socioeconomic conditions, nutritional status, racial influence, education level, different geographical area, life expectancy etc. The aim of the study would be to measure the gestational age of the fetus that correlates well with the pregnant mothers of Bangladesh.

1.3. HYPOTHESIS:

Prediction of gestational age by sonographic biparietal diameter (BPD), femur length (FL), head circumference (HC), and abdominal circumference (AC) measurements alone, as indicators of true gestational age of patients with known last menstrual period (LMP).

1.4. AIMS AND OBJECTIVES OF THE STUDY:

General object:

Determination of gestational age by ultrasound.

Specific object:

The specific object of this study is to create normograms of following parameters to calculate the gestation age of fetus in intrauterine pregnancy of Bangladeshi mother which will be a reference for practicing sonologists and obstetrician of this country as CRL, BPD, FL, AC, HC and EFW.

2. LITERATURE REVIEW:

2.1 Relevant of previous study:

Abramowicz et al. (1997) studied to improve the accuracy of sonographic fetal weight estimation in macrosomic (> 4000 g) fetuses by combining the cheek-to-cheek diameter (CCD), an indicator of subcutaneous tissue mass, with the biparietal diameter (BPD) and abdominal circumference (AC) in generating a new weight formula. Three hundred well-dated, uncomplicated singleton pregnancies > 32 weeks' gestational age (GA) were analyzed. Sonographic fetal measurements obtained in every case included BPD, head circumference, AC, femur length and CCD. Sonographic estimation of fetal weight (EFW) was derived by using BPD and AC. Actual birth weights (BW) of fetuses delivered within 7 days of the last sonographic examination and weighing over 1500 g (n = 123) were compared to EFW. A formula was derived by correlating BPD, AC and CCD with BW in these 123 fetuses using multiple regression analysis. A second formula was derived from the data of 39 macrosomic fetuses. The two formulae were then tested for accuracy of prediction of fetal weight in 157 other fetuses delivered within 7 days and grouped by birth weight, 44 of them weighing > 4000 g. The new formula for macrosomic fetuses was: EFW (g) = 1065 + 84.5 BPD (cm) + 41.29 AC (cm) + 111.0 CCD (cm). In the macrosomic fetuses, a difference of < 10% between EFW and BW was demonstrated in 72.7% by the BPD-AC formula and 95.5% when Incorporating CCD. In this group, the mean percentage error was significantly smaller: 4.14 vs. 7.97% ($p = 0.0005$). In the regression analysis, the contributions of BPD, AC and CCD to the variance in BW were 5.5%, 16%, and 18.3%, respectively ($p = 0.008$). In the non-macrosomic fetuses, CCD improved prediction of BW, but the trend did not reach statistical significance. Their results demonstrate that, in the macrosomic fetus, CCD explains more of the variance in BW than other parameters and incorporating it in the sonographic weight estimation greatly improves its accuracy (Abramowicz et al. 1997).

Abramowicz et al. (2005) studied to assess sonographic Fetal cheek-to-cheek diameter (CCD) in predicting mode of delivery. Two hundred sixty-four patients were considered in 2 parts. First, a retrospective analysis of 214 patients entered into a birth weight (BW) study. Measurements of the CCD, biparietal diameter (BPD), and BW, as well as labor data, were collected. Then a prospective study of patients at > or =38 weeks gestational age was conducted. Fetal weight (EFW) was estimated by routine measurements. Information regarding CCD was withheld from the delivering caregiver. Labor records were reviewed for BW and complications, defined as: instrumental delivery, cesarean section (C/S) for nonprogress of labor or "CPD," and "difficult" vaginal delivery. The CCD, BW (both parts), or EFW (prospective part) and mode of delivery were compared. Abnormal CCD (>2SD above previously published norms for each GA) was closely associated with cesarean delivery, regardless of EFW. At term, risk of C/S with a CCD >7.9 cm was 94%. They concluded that within limits, EFW alone has weak correlation with cesarean delivery. CCD, as a reflector of fetal adipose tissue, performs as well as actual BW and demonstrates good prediction for delivery by C/S (Abramowicz et al. 2005).

Abeysena and Jayawardana, (2011) studied to determine reliability of period of gestation determined by three independent raters using four different foetal measurements. One hundred and eighty pregnant women were divided into three equal groups. Each group was assigned a rater to perform ultrasound scan to measure bi-parietal diameter, femur length, abdominal circumference and head circumference and to compute the respective periods of gestation using these four measurements. For Raters I (F= 6.47; p=0.001) and II, (F= 4.80; p= 0.003), computations using abdominal circumferences resulted in the lowest mean periods of gestation (PsOG). For Rater III, computations using both femur length and abdominal circumference resulted in the lowest mean periods of gestation (F= 7.5; p=0.001). ICCs were 0.73 (95%CI 0.64–0.81) for Rater I. 0.78 (95% CI 0.70–0.85) for Rater II and 0.87 (95% CI 0.81– 0.91) for Rater

III When comparing CsOV, the highest variation for Raters I and III was observed for femur length. For Rater II it was bi-parietal diameter. The lowest variation for Rater I was observed for head circumference and for Raters II and III for abdominal circumference. The highest CsOV of all the PsOG were demonstrated by Rater III. When comparing the differences between the highest and the lowest values for each period of gestation determined, the difference was more than two weeks for 38% (n=23), 24% (n=14) and 22% (n=13) of observations made by Raters I, II and III respectively. They concluded that reliability of period of gestation depends on the type of measurement taken, method of assessment and the rater who performs the measurements. Their findings are not conclusive enough to recommend any PsOG based on specific measurement more reliable than others. In-service training of the obstetricians is likely to improve the reliability of PsOG determined using ultra sound scan measurements (Abeysena and Jayawardana, 2011).

Ashrafunnessa et al. (2003) conducted a prospective study to construct fetal chart for BPD, AC and FL at different gestational weeks from the Bangladeshi pregnant women. Seven hundred and ten women had ultrasonic measurements of fetal BPD, AC and FL between 12 to 42 weeks of pregnancy. Centiles, mean and the standard deviation (SD) were calculated for BPD, AC and FL. Mean maternal age was 24.73 ±4.48 (Mean ±SD) and 310 (43.7%) were primigravidae. There was a gradual increase of the BPD (outer-inner), AC and FL measurements of 5th, 10th, 50th and 90th Centiles upto 38th weeks of gestation with a gradual increase of SD showing increasing dispersion of data. In cases of BPD and AC, after 38th weeks of gestation the Centiles showed a slower growth rate towards 42 weeks of pregnancy. This slower growth rate from 38 weeks of pregnancy was not noted in case of femur length. Fetal charts with the raw data for each measurement with superimposed fitted lines derived from polynomial (quadratic) regression were constructed. Quadratic model showed good fit to the data during construction of fetal charts. The new fetal measurement charts of BPD, AC and FL are unique for the Bangladeshi (and have not been found similar in the later weeks of pregnancy to those published for other Caucasian populations. These charts will help the clinicians and sonographers in dating pregnancy, identifying SFD and growth retarded fetuses (Ashrafunnessa et al. 2003).

Ben-Haroush et al. (2007) studied to evaluate the accuracy of ultrasound-based fetal weight estimates made at 28-34 weeks of gestation in predicting small- and large-for-gestational-age infants (SGA, LGA) at term. In their study 259 patients with a healthy, singleton pregnancy in whom fetal biometry measurements were routinely performed between 28 and 34 weeks' gestation, were recruited at term delivery. The sonographic estimated fetal weight (EFW) and the birth weight were converted to percentiles on the basis of locally developed growth charts and compared. Multivariate linear stepwise regression analysis was used to predict the birth weight and birth weight percentile. The resulting equation (projectile formula) was used to determine the calculated birth weight, and that value was compared with the actual birth weight. The Bland and Altman plot and Passing and Bablok regression were used to compare between the calculated birth weight and the actual birth weight. Mean gestational age at ultrasound examination was 32±1.6 weeks (28-34), and mean age at delivery was 39±1.7 weeks (37-42). The multivariate correlation between the calculated birth weight and the birth weight (R2 = 0.524) was higher than the correlation between the sonographic EFW and the birth weight (R2 = 0.083). Both the sonographic EFW and the calculated birth weight are characterized by low positive Predictive values in predicting SGA or LGA infants. The calculated birth weight was more accurate in excluding SGA and LGA infants (negative predictive values of 99.5% and 100%, respectively). On method comparison tests, the calculated birth weight was not significantly different than the actual birth weight. They concluded that fetal weight estimation at the early third trimester poorly predicts the birth weight centile at term. It remains uncertain, however, if it would be useful to use the calculated birth weight in pregnancies with clinically suspected SGA or LGA fetuses (Ben-Haroush et al. 2007).

To compare the accuracy of Three-dimensional ultrasound-assessed fetal thigh volumetry in predicting birth weight with that of other commonly used formulas composed of BPD, AC and FL by two-dimensional ultrasound Chang et al. (1997) in a study assessed the thigh volume of 100 fetuses using three-dimensional ultrasound. Meanwhile, their BPD, AC, and FL were measured by two-dimensional ultrasound. All infants were delivered within 48 hours after the ultrasound examinations. From polynomial regression analysis, we generated a best-fit formula for the thigh volume to predict birth weight. The accuracy of this thigh-volume formula was compared with those of three formulas commonly used in the United States. In addition, another group of 50 fetuses was measured for prospective validation. The high volume assessed by three-dimensional ultrasound was highly correlated with birth weight ($r = 0.89$, $n = 100$, $P < .0001$). The best-fit formula for thigh volume to predict birth weight was linear, and it was superior to the other commonly used two-dimensional formulas in predicting birth weight. The predicting error (0 g), percent error (0.7%), absolute error (176.1 g), and absolute percent error (5.8%) of the thigh-volume formula were all smaller than those of the other formulas ($n = 100$, all $P < .05$). In addition, the thigh-volume formula predicted birth weight more accurately than the other two-dimensional formulas in the prospective-validation group. The three-dimensional formula had smaller mean values of predicting error (38.6 g), percent error (1.5%), absolute error (160.0 g), and absolute percent error (5.1%) than the two-dimensional formulas ($n = 50$, all $P <$ or $= .001$), as well as the smallest variances of the above errors (178.1 g, 5.6%, 84.3 g, and 2.9%, respectively). They concluded that the three-dimensional ultrasound-assessed thigh volume has better accuracy in predicting birth weight than the commonly used formulas by two-dimensional ultrasound, and it may improve fetal weight prediction in clinical practice. However, a large-scale prospective validation study may be needed to confirm their conclusions (Chang et al. 1997).

Chauhan et al. (2000) studied to compare clinical and sonographic estimates of birth weights with five new estimation techniques that involve measurements of soft tissue, for identifying newborns with birth weights of at least 4000 g. Over 1 year, each woman at or after 36 weeks' gestation and suspected of having a macrosomic fetus had clinical and sonographic estimates of fetal weight (EFW) based on femur length (FL) and head and abdominal circumference, followed by five additional ways to identify excessive growth: cheek-to-cheek diameter, thigh soft tissue, ratio of thigh soft tissue to FL, upper arm subcutaneous tissue, and EFW derived from it. Areas (± standard error) of receiver operating characteristic (ROC) curves were calculated and compared with the area under the nondiagnostic line. P <.05 was considered statistically significant. Among 100 women recruited, 28 newborns weighed 4000 g or more. The areas under the ROC curves with clinical (0.72 ± 0.06) and sonographic predictions using biometric characteristics (0.73 ± 0.06) had the highest but similar accuracies (P.05). Three of the five newer methods (upper arm or thigh subcutaneous tissue and ratio of thigh subcutaneous tissue to FL) were poor diagnostic tests (range of areas under ROC 0.52 ± 0.06 to 0.58 ± 0.07). Estimated fetal weight based on upper arm soft tissue thickness and cheek-to-cheek diameter (areas 0.70 ± 0.06 and 0.67 ± 0.06, respectively) were not significantly better than clinical predictions (P.05) for detecting macrosomic fetuses. About 110 macrosomic and nonmacrosomic infants combined would be needed to have 80% power to detect a difference between ROC curves with areas of 0.58 (thigh subcutaneous tissue) and 0.72 (clinical estimate). They concluded that ROC curves indicated that measurements of soft tissue are not superior to clinical or sonographic predictions in identifying fetuses with weights of at least 4000 g (Chauhan et al. 2000).

To construct new size Charts for all fetal limb bones a prospective, cross sectional study conducted by Chitty and Altman. (2002) where 663 fetuses scanned once only at gestations between 12 and 42 weeks. Centiles were estimated by combining separate regression models fitted to the mean and standard deviation, assuming that the measurements have a normal distribution at each gestational age. The main outcome measures: Determination of fetal limb lengths from 12 to 42 weeks of gestation. Size charts for fetal bones (radius, ulna, humerus, tibia, fibula, femur and foot) are presented and compared with previously published data. They concluded new size charts for fetal limb bones which take into consideration the increasing variability with gestational age. They have compared these charts with other published data; the differences seen may be largely due to methodological differences. As standards for fetal head and abdominal measurements have been published from the same population, they suggest that the use of the new charts may facilitate prenatal diagnosis of skeletal dysplasias (Chitty and Altman, 2002).

To construct new size charts for fetal head circumference, biparietal diameter and other head dimensions a prospective cross sectional study conducted by Chitty et al. (1994) where 663 women seen in the routine antenatal booking clinic whose ultrasound and menstrual dates agreed within 10 days. Fetuses were scanned once only for the purpose of the study at gestations between 12 and 42 weeks, when up to 20 dimensions were measured. For each measurement separate regression models were fitted to estimate the mean and standard deviation at each gestational age. Centiles were derived by combining these two regression models, assuming that the measurements have a normal distribution at each gestational age. A total of 594 fetuses had their biparietal diameter measured and their head circumference measured directly. Both head diameters were recorded for 587 fetuses and the circumference was also derived from these, as was the cephalic area. New charts are presented for biparietal diameter (both outer-outer and outer-inner), head circumference (directly measured and derived from diameters). The directly measured head circumferences were consistently (by about 1%) greater than those derived from measurement of the head diameters. The new charts are compared with previously published charts that are in wide use. Charts for occipitofrontal diameter, cephalic index and cephalic area are also presented. They concluded that the fetal biparietal diameter and for head circumference, both measured directly and derived from head diameters. They have demonstrated the difference between the size charts constructed from these two sets of values and hence the importance of using the appropriately derived chart when assessing the head circumference. The differences between the new charts for biparietal diameter and head circumference and previous ones may be largely due to methodological differences (Chitty et al. 1994).

To construct new size charts for fetal abdominal circumference and area a prospective, cross sectional study conducted by Chitty et al. (1994a) where 663 women seen in the routine antenatal booking clinic whose ultrasound and menstrual dates agreed within 10 days. Fetuses were scanned once only for the purpose of the study at gestations between 12 and 42 weeks, when up to 20 dimensions were measured. Separate regression models were fitted to estimate the mean and standard deviation as functions of gestational age. Centiles were derived by combining these two regression models, assuming that the measurements have a Normal distribution at each gestation. A total of 610 fetuses had their abdominal circumference measured directly. Abdominal diameters were recorded for 425 fetuses and the circumference was also derived from these, as was the abdominal area. New charts for abdominal circumference (directly measured and derived from diameters) are presented. The directly measured circumferences were consistently (by about 3.5%) greater than those derived from measurement of the abdominal diameters. The new charts are compared with previously published charts that are in wide use. A chart for abdominal area is also presented. They concluded that the fetal abdominal circumference, both measured directly and derived from abdominal diameters. They have demonstrated the difference between the size charts constructed from these two sets of values and hence the importance of using the appropriately derived chart when assessing the abdominal circumference.

The differences between the new charts and previous ones may be largely due to methodological differences (Chitty et al. 1994a).

Ultrasound estimating of fetal weight is one of the most frequent examinations during pregnancy. Hitherto, foreign fetometry curves have mostly been used in Poland as there are no national available reference charts that are based on ultrasound fetal biometry. Dubiel et al. (2008) studied to construct new charts based on ultrasound fetometry reference for Polish population. A group of 959 healthy volunteers with uncomplicated singleton pregnancy joined in a cross-sectional study. The study was designed prospectively to evaluate normal reference charts for fetal ultrasound measurements and estimated fetal weight. Four biometric parameters were studied: biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL). Estimated fetal weight (EFW) was calculated using Hadlock et al. formula from 1985. In the course of normal pregnancy an acceleration of growth rate was seen, but with a slight decline at the end of pregnancy. Reference curves for mean, 90th and 95th percentile were constructed for BPD, HC, AC and FL. Estimated fetal weight curves were outlined for both boys and girls. They concluded that the reference charts for Polish population are similar to foreign curves. Less variation was seen in comparison with national charts based on postnatal weight. Ultrasound method seems to be better than birthweight curves especially in preterm pregnancies. This will improve the diagnosis of a small for gestational age newborn (Dubiel et al. 2008).

Hedriana and Moore, (1994) studied to determine whether two or more ultrasonographic fetal growth assessments provide a superior estimate of birth weight than does a single examination. Five hundred and eighty five ultrasonographic procedures were performed in 263 patients, divided into single (n = 249) and multiple (n = 247) examination groups. Ultrasonographically estimated fetal weight percentiles and abdominal circumference percentiles were compared with gestationally corrected birth weight percentiles. After the gestational age range with the fewest errors in birth weight percentile prediction (32 to 36 weeks) was determined, patients with a single examination in this range were assigned to the single examination group. In the group with multiple examinations averaged ultrasonographic percentiles were used to predict birth weight percentile. Mean absolute and percentage errors were compared for predictive accuracy by means of analysis of variance and Student t test. There was a linear correlation between the estimated fetal weight and abdominal circumference percentiles and the birth weight percentile, ($r = 0.72$, $p < 0.0001$). The accuracy of birth weight percentile predictions was similar whether one or multiple examinations were performed in the third trimester. Both the abdominal circumference percentile and estimated fetal weight percentile underpredicted birth weight, although the abdominal circumference percentile errors (1% to 2%) were statistically smaller than those derived from estimated fetal weights percentile (9% to 11%, $p < 0.0001$). Both abdominal circumference percentile and estimated fetal weights percentile consistently overidentified fetuses < 10th percentile (small for gestational age) and underidentified fetuses > 90th percentile (large for gestational age). However, multiple abdominal circumference percentile measurements resulted in improved predictions for small for gestational age (sensitivity 100%, specificity 88%) and large for gestational age (sensitivity 84%, specificity 100%). They concluded that with either the single or multiple examination approach birth weight percentile estimates were within 10% of the actual birth weight percentile approximately 50% of the time. Multiple ultrasonographic examinations provided little improvement in prediction of birth weight compared with a single observation. Multiple measurements of the abdominal circumference percentile may provide improved accuracy in identifying large for gestational age and small for gestational age fetuses (Hedriana and Moore, 1994).

Jung et al. (2007) studied to construct new reference charts and equations for fetal biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur diaphysis length (FDL) from Korean fetuses at

12-40 weeks. In their study prospective cross-sectional data obtained in one center for 5 years from a population of pregnant women undergoing ultrasound examination between the 12th and 40th week of gestation. Exclusion criteria comprised all maternal and fetal conditions possibly affecting fetal biometry. No fetuses were excluded on the basis of abnormal biometry. For each measurement, regression models were fitted to estimate both the mean and the standard deviation at each menstrual age. Biometric measurements were obtained for 10 455 fetuses. New charts and reference equations are reported for BPD, HC, AC and FDL. Reference equations are cubic models. They concluded that the present new Korean reference charts and equations for fetal biometry. They can be easily used in obstetric ultrasound studies for the Korean population (Jung et al. 2007).

Kayem et al. (2009) studied to compare the diagnostic value of fundal height and sonographically measured fetal abdominal circumference in the prediction of high and low birth weight in routine practice between 37 and 41 weeks' gestation. Data were obtained from a multicenter study of 19 415 women in France and Belgium. In this study we included 7138 low-risk women from that population who underwent fundal height measurements no more than 8 days before delivery (Population A). they also included another 1689 women with both fundal height measurements and fetal ultrasound measurements obtained no more than 8 days before delivery (Population B). Population A was used to calculate the parameters of equations for estimating fetal weight according to fundal height alone (EFW(FH)) or fundal height in combination with other clinical indicators (EFW(FH+)). The ultrasound fetal weight estimation was based on fetal abdominal circumference (EFW(AC)) using Campbell and Wilkins' equation. The correlation between the estimated fetal weight calculated using each of the formulae and the birth weight was then evaluated in Population B, and the diagnostic value of each of the methods for predicting birth weight <or=2500 g or >or=4000 g was also compared. EFW(AC) was better correlated with birth weight than was either EFW(FH) or EFW(FH+).

With specificity set at 95%, the sensitivity of EFW(AC) in screening for neonates weighing <or=2500 g was significantly higher than that of EFW(FH) (50.7% vs. 41.2%, P < 0.05) or EFW(FH+) (50.7% vs. 40.4%, P < 0.05). Similarly, its sensitivity for predicting a birth weight of >or=4000 g was significantly higher than that of EFW(FH) (54.0% vs. 37.1%, P < 0.05) or EFW(FH+) (54.0% vs. 45.1%, P < 0.05). They concluded that the sonographic measurement of fetal abdominal circumference predicts high and low birth weight better than does clinical examination based on fundal height in routine practice between 37 and 41 weeks' gestation (Kayem et al. 2009).

Konje et al. (2002) studied to evaluate the application of kidney length measurement to the determination of gestational age between the 24th and 38th weeks and to compare its accuracy with that of other fetal biometric indices. Seventy-three women with singleton uncomplicated pregnancies underwent standard ultrasound fetal biometry and kidney length measurement every 2 weeks between 24 and 38 weeks' gestation. These measurements were used to date the pregnancies relative to crown-rump length dating between 8 and 10 weeks' gestation. Linear regression models for estimation of gestational age were derived from the biometric indices and kidney length. In addition, stepwise regression models were constructed to determine the best model for determining gestational age between 24 and 38 weeks. Comparisons were then made between the accuracy of these models in the determination of gestational age. The best model for estimating gestational age in late pregnancy included the variables kidney length, biparietal diameter, head circumference, femur length and abdominal circumference. This model accurately predicted gestational age with a standard error of ±8.48 days. A model including kidney length, biparietal diameter, head circumference and femur length accurately predicted gestational age with a standard error of ±8.57 days. These models were slightly more accurate than models derived from the biometric indices of biparietal diameter, head circumference and femur length (±9.87 days), biparietal diameter, head circumference, femur length and abdominal circumference (± 9.45 days) and biparietal diameter and femur length (±9.9 days). Kidney length and femur length were the most accurate single parameters for predicting gestational age using simple linear regression models (± 10.29 and 10.96 days, respectively); the abdominal circumference was the least accurate (±14.54 days). They concluded that the kidney length is a more accurate method of determining gestational age than the fetal biometric indices of biparietal diameter, head circumference, femur length and abdominal circumference between 24 and 38 weeks' gestation. When combined with biparietal diameter, head circumference and femur length, the precision of dating is improved by 2 days. This measurement is easy to make and could therefore be easily incorporated into the model for dating pregnancies after 24 weeks of gestation, in particular when measurements of the biparietal diameter and head circumference are difficult (Konje et al. 2002).

Kurmanavicius et al. (1999) studied to create reliable reference ranges and calculate Z scores for fetal Head ultrasound biometry using a large sample size which is evenly distributed from 12 to 42 weeks of pregnancy. In their prospective, cross-sectional study 6557 pregnant women were included. Only the first ultrasound examination between 12 and 42 weeks of each fetus with exactly established gestational age was used for analysis. No exclusions were made on the grounds of small-for-date birthweight, prematurity or other events several weeks after the examination. Separate regression models were fitted to estimate the mean and standard deviation at each gestational age for each parameter. A total of 6217 fetal head biparietal diameters and 5510 occipito-frontal diameters were measured. Both head circumference and cephalic index were derived in 5462 cases where both biparietal diameter and occipito-frontal diameter could be measured on the same fetus. The centile charts, tables and regression formulae for biparietal and occipito-frontal diameters, head circumference and cephalic index are presented. An application to calculate Z scores was developed using Excel (Microsoft Corporation, USA) and macros are presented in detail in the Figure 8 footnote. The comparison of our charts with those of the two most recent studies revealed almost no differences in biparietal diameter centiles. In one publication, occipito-frontal diameter charts, and in another, head circumference charts were different from the current study. They concluded that the presented centile charts, tables and regression formulae for fetal head ultrasound biometry derived from a large and minimally selected sample size in a carefully designed cross-sectional study. Complete tables and regression formulae to calculate reference ranges and Z scores are presented for use in computer-aided evaluation of fetal ultrasound biometry (Kurmanavicius et al. 1999).

Lee et al. (2009) studied to determine the accuracy and precision of new fetal weight estimation models, based on fractional limb volume and conventional two-dimensional (2D) sonographic measurements during the second and third trimesters of pregnancy. In their prospective cross-sectional study 271 fetuses was performed using three-dimensional ultrasonography to extract standard measurements-biparietal diameter (BPD), abdominal circumference (AC) and femoral diaphysis length (FDL)-plus fractional arm volume (AVol) and fractional thigh volume (TVol) within 4 days of delivery. Weighted multiple linear regression analysis was used to develop 'modified Hadlock' models and new models using transformed predictors that included soft tissue parameters for estimating birth weight. Estimated and observed birth weights were compared using mean percent difference (systematic weight estimation error) and the SD of the percent differences (random weight estimation error). Birth weights in the study group ranged from 235 to 5790 g, with equal proportions of male and female infants. Six new fetal weight estimation models were compared with the results for modified Hadlock models with sample-specific coefficients. All the new models were very accurate, with mean percent differences that were not significantly different from zero. Model 3 (which used the natural logarithms of BPD, AC and AVol) and Model 6 (which used the natural logarithms of BPD, AC and TVol) provided the most precise weight estimations (random error = 6.6% of actual birth weight) as compared with

8.5% for the best original Hadlock model and 7.6% for a modified Hadlock model using sample-specific coefficients. Model 5 (which used the natural logarithms of AC and TVol) classified an additional 9.1% and 8.3% of the fetuses within 5% and 10% of actual birth weight and Model 6 classified an additional 7.3% and 4.1% of infants within 5% and 10% of actual birth weight. They concluded that the precision of fetal weight estimation can be improved by adding fractional limb volume measurements to conventional 2D biometry. New models that consider fractional limb volume may offer novel insight into the contribution of soft tissue development to weight estimation (Lee et al. 2009).

Correct assessment of gestational age and fetal growth is essential for optimal obstetric management. Verburg et al. (2008) studied to develop charts for ultrasound dating of pregnancy based on crown-rump length and biparietal diameter and to derive reference curves for normal fetal growth based on biparietal diameter, head circumference, transverse cerebellar diameter, abdominal circumference and femur length from 10 weeks of gestational age onwards. A total of 8313 pregnant women were included for analysis in this population-based prospective cohort study. All women had repeated ultrasound assessments to examine fetal growth. Charts for ultrasound dating of pregnancy, based on crown-rump length and biparietal diameter, were derived. Internal validation with the actual date of delivery showed that ultrasound imaging provided reliable gestational age estimates. Up to 92% of deliveries took place within 37-42 weeks of gestation if gestational age was derived from ultrasound data, compared with 87% based on a reliable last menstrual period. The earlier the ultrasound assessment the more accurate the prediction of date of delivery. After 24 weeks of gestation a reliable last menstrual period provided better estimates of gestational age. Reference curves for normal fetal growth from 10 weeks of gestational age onwards were derived. They concluded that the charts for ultrasound dating of pregnancy and reference curves for fetal biometry are presented. The results indicate that, up to 24 weeks of pregnancy, dating by ultrasound examination provides a better prediction of the date of delivery than does last menstrual period. The earlier the ultrasound assessment in pregnancy, preferably between 10 and 12 weeks, the better the estimate of gestational age (Verburg et al. 2008).

Leung et al. (2008) studied to construct new reference charts and equations for fetal biometry in the Hong Kong ethnic Chinese population, and to compare them with existing references from different populations. This was a prospective observational study involving 709 women with singleton pregnancies and confirmed gestational age. For the purposes of this study, each woman was scanned once only, between 12 and 40 completed weeks of gestation, and the following fetal biometric measurements were recorded: biparietal diameter, head circumference, abdominal circumference and femur length. For each measurement, regression models were fitted to estimate the mean and SD at each gestational age. For comparison, the fetal biometric measurements of other populations at each gestation were expressed as Z-scores calculated with our reference equations. Results were presented graphically across the different gestational ages to allow visual comparison. New charts and reference equations are reported in this Hong Kong Chinese population for fetal outer-inner and outer-outer biparietal diameter, head circumference, abdominal circumference and femur length. Equations for dating of pregnancy are presented. Our charts were very similar to those of the Singaporean population for most parameters. The main difference in our fetal biometric measurements compared with those of the UK and French populations was in FL. They concluded that the new set of reference centiles for fetal biometric measurements and equations for dating of pregnancy in a Hong Kong Chinese population are ready for clinical use and research in appropriate ethnic Chinese groups (Leung et al. 2008).

Loetworawanit et al. (2006) in a prospective clinical trial evaluated the diagnostic value of sonographic measurement of fetal abdominal circumference (AC) for the prediction of fetal macrosomia. The study consisted of 361 singleton pregnant women who were admitted for delivery at labor room. All women underwent sonographic measurements of the fetal abdominal circumference (AC) during the early Intrapartum period. The AC values were correlated to actual fetal birth weight. The cut-off value of AC for predicting of fetal macrosomia was analyzed. Among 361 cases, the mean maternal age was 29.0 ± 5.5 years (range, 15-46). The median gestational age was 39 weeks (range, 31-42). The mean fetal birth weight was 3,179.83 ± 450.91 gm (range, 1,180-4,560). The prevalence of macrosomia was 11.08% (40/361). A cut-off value of abdominal circumference > or = 35 cm was the best predicting of fetal macrosomia. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were 87.50%, 84.74%, 85.04%, 41.67%, and 98.19%, respectively. They concluded that the intrapartum fetal AC measurement was useful in predicting of fetal macrosomia. An AC measurement of > or = 35 cm was the best value of fetal macrosomia prediction (Loetworawanit et al. 2006).

Meyer et al. (1994) prospectively evaluated the accuracy of a gestational age-independent method of detecting abnormal growth, the transverse cerebellar diameter/abdominal circumference ratio, and compared this with standard Ultrasonographic methods of growth assessment. They prospectively studied 825 low-risk obstetric patients and 250 patients having risk factors for fetal macrosomia (n = 92) or growth retardation (n = 158). Measured fetal parameters included the biparietal diameter, head circumference, transverse cerebellar diameter, abdominal circumference, and femur length. The estimated fetal weight, head circumference/abdominal circumference, cerebellar diameter/abdominal circumference, and femur length/abdominal circumference ratios were calculated. Reference curves for these parameters were created from a cross-sectional analysis of the low-risk group. Univariate analysis was used to determine the sensitivity, specificity, predictive values, and odds ratios of each individual parameter in identifying a small- or large-for-gestational-age infant. A multivariate logistic regression model with a variable selection procedure was then used to determine whether significance remained when we controlled for other parameters. Within the low-risk group, the transverse cerebellar/abdominal circumference ratio was gestational age independent between 14 and 42 weeks with a mean of 13.68 ±0.96. A value exceeding 2 SD of the mean was significantly associated with birth or a small-for-gestational-age infant, being abnormal in 98% and 71% of asymmetrically and symmetrically growth-retarded infants, respectively. Significance was maintained in the multivariate regression model. The ratio was not helpful in detecting the large-for-gestational-age infant. They concluded that the fetal transverse cerebellar diameter/abdominal circumference ratio is an accurate, gestational age-independent method of identifying the small-for-gestational-age but not the large-for-gestational-age infant (Meyer et al. 1994).

Pielet et al. (1987) Data from previous studies have suggested that birth weight prediction was enhanced by using formulas specifically derived from preterm fetuses. However, no prospective comparison of different formulas was performed. They obtained Ultrasonic data on 61 pregnancies at risk for preterm delivery with a gestational age of 29.0±3.0 weeks (mean ± SD). In all women birth weight was predicted within 7 days of delivery. Of the 61 pregnancies, 49 (80%), 41 (67%), 30 (49%), and 17 (28%) weighed less than 1750, 1500, 1250, and 1000 gm, respectively; 14 published formulas were compared for accuracy in predicting birth weight in these four categories. The formulas with the smallest absolute mean percent errors incorporated head and abdominal circumferences and femur length. The formula of Weiner et al., derived from low birth weight infants, produced the smallest absolute mean percent error and SD, 10.9% ±7.9%; this error was further reduced to 7.7% ±6.5% in infants weighing less than 750 gm. These findings suggest that birth weight in the preterm fetus is best predicted by a formula targeted to such a population (Pielet et al. 1987).

Robson et al. (1993) studied to derive a formula for calculating fetal weight in small for gestational age (SGA) fetuses and to determine prospectively whether the use of such a targeted formula reduces birth weight prediction errors. Standard Ultrasonic measurements were made in 159 SGA fetuses within 7 days of delivery. Three classes of fetal weight formulas (linear, quadratic, and cubic) were fitted to the data using stepwise regression analysis. Birth weight predictions using these three formulas were then compared prospectively with five previously reported formulas in 187 SGA fetuses. R2 was 0.97 for each of the three derived formulas. The 95% prediction intervals were comparable for the three formulas (eg, cubic model -11.6, 17.8%), and none were statistically superior to previous formulas. Each of the formulas evaluated prospectively had a systematic error and, with the exception of the present study's linear formula, all had percentage errors that varied systematically over the range of actual birth weights. They concluded that clinically useful birth weight predictions can be made in SGA fetuses, although no particular formula estimates birth weight significantly more accurately than any other (Robson et al. 1993).

Salomon et al. (2007) studied to formulate reference charts and equations for estimated fetal weight (EFW) from a large sample of fetuses and to compare these charts and equations with those obtained for birth weight during the same study period and in the same single health authority. Biometric data were obtained at 20-36 weeks' gestation from routine screening examinations spanning 4 years. Exclusion criteria were a known abnormal karyotype or congenital malformation and multiple pregnancies. No data were excluded on the basis of abnormal biometry. EFW was calculated based on Hadlock's formula. They used a polynomial regression approach (mean and SD model) to compute a new reference chart for EFW. This chart was compared with that of birth weight at 25-36 weeks' gestation during the same study period and in the same health authority. Total 18,959 fetuses were included in the study. New charts and equations for Z-score calculations at 20-36 weeks' gestation are reported. Comparison with the birth-weight chart showed that the EFW was noticeably larger at 25-36 weeks' gestation. At 28-32 weeks' gestation, the 50th centile for birth weight compared approximately with the 10th centile for EFW. They concluded that the new reference charts and equations for EFW is computed throughout gestation based on measurements in healthy fetuses. However, before full term, birth-weight charts reflect a significant proportion of growth-restricted fetuses that deliver prematurely. They provide additional evidence that comparing EFW with birth-weight charts is misleading (Salomon et al. 2007).

Salomon et al. 2007 studied to establish reference values for fetal age assessment in Cameroon using two different ethnic groups (Fulani and Kirdi). In their prospective cross sectional study 200 healthy pregnant women from Cameroon were included. The participants had regular menstrual periods and singleton uncomplicated pregnancies, and were recruited after informed consent. The head circumference (HC), outer-outer biparietal diameter (BPDoo), outer-inner biparietal diameter and femur length (FL), also called femur diaphysis length, were measured using ultrasound at 12-22 weeks of gestation. Differences in demographic factors and fetal biometry between ethnic groups were assessed by t- and Chi-square tests. Compared with Fulani women ($N = 96$), the Kirdi ($N = 104$) were 2 years older ($p = 0.005$), 3 cm taller ($p = 0.001$), 6 kg heavier ($p < 0.0001$), had a higher body mass index (BMI) ($p = 0.001$), but were not different with regard to parity. Ethnicity had no effect on BPD ($p = 0.82$), HC ($p = 0.89$) or FL ($p = 00.24$). Weight, height, maternal age and BMI had no effect on HC, BPDoo and FL ($p = 0.2$-0.58, 0.1-0.83, and 0.17-0.6, respectively). When comparing with relevant European charts based on similar design and statistics, we found overlapping 95% CI for BPD (Norway & UK) and a 0-4 day difference for FL and HC. They concluded that significant ethnic differences between mothers were not reflected in fetal biometry at second trimester. Their results support the recommendation that ultrasound in practical health care can be used to assess gestational age in various populations with little risk of error due to ethnic variation (Salpou et al. 2008).

Santolaya-Forgas et al. (1994) in cross-sectional study analyses the accuracy of ultrasonographic Intrapartum measurement of fetal abdominal circumference, estimated fetal weight, and fetal subcutaneous tissue/femur length ratio in predicting large-for-gestational-age fetuses. Total 173 normal patients delivered of normal, appropriate-for-gestational-age infants (group 1) was performed to determine the normal changes of standard fetal biometric parameters and subcutaneous tissue throughout pregnancy. Measurements of fetal subcutaneous tissue were made at the level of the femoral diaphysis. A second group of 101 well-dated patients had these measurements obtained within 24 hours of delivery (group 2). Large for gestational age was defined as a birth weight > 90th percentile for gestational age. The sensitivity and specificity for prediction of large for gestational age of an intrapartum measurement of an abdominal circumference > 90th percentile, estimated fetal weight > 90th percentile, and fetal subcutaneous tissue/femur length ratio > 2 deviations of the mean was calculated. In group 1 the mean gestational age was 31.4±5.4 weeks (range 17 to 41 weeks). The femur length, abdominal circumference, and fetal subcutaneous tissue correlated well with gestational age ($p < 0.0001$). The fetal subcutaneous tissue/femur length ratio was stable throughout pregnancy, with a mean of 0.05 ± 0.014 (range 0.02 to 0.09, R2 0.09). In group 2 mean gestational age was 38 ± 2.5 weeks (range 30 to 42 weeks). Mean birth weight was 3280 ± 740 gm (range 1513 to 4801 gm). Nineteen (19%) fetuses were large for gestational age. Significant differences were found between the appropriate- and large-for-gestational-age fetuses for birth weight, abdominal circumference, estimated fetal weight, and fetal subcutaneous tissue/femur length ratio ($p < 0.0001$). The sensitivity and specificity of the fetal abdominal circumference, estimated fetal weight, and fetal subcutaneous tissue/femur length ratio were 44% and 98%, 68% and 85%, and 82% and 96%, respectively. They concluded that the fetal subcutaneous tissue/femur length ratio is a gestational age-independent parameter that has a greater sensitivity than the fetal abdominal circumference or estimated fetal weight formula for the intrapartum identification of large-for-gestational-age fetuses (Santolaya-Forgas et al. 1994).

Spinnato et al. (1988) in a study among the 259 cases, 245 were selected in which a live-born infant was delivered within 35 days of a complete fetal ultrasound evaluation. Multiple linear regression using the least-squares method enable us to generate an equation that incorporated lapse time (examination-to-Birth interval) with the natural logarithm of head circumference, femur length, and abdominal circumference to estimate birth weight. With a lapse time mean±SD of 16 ±11 days and a range of zero to 35 days, the generated equation accurately predicted birth weight (R2 = 0.84; P less than or equal to .0001). For all birth weights, the mean error was -15±306 g, the percent mean error was 0.51 ±10.2%, and the mean absolute error of the estimate was 82 g/kg birth weight. This accuracy was maintained across the full range of lapse time observed. For examinations performed within one week of delivery (N = 71), this formula more accurately predicted birth weight than five existing static formulas tested. The accuracy observed during model development was confirmed during testing upon 167 non-model cases. The accurate prediction of birth weight from remote ultrasound data is possible when lapse time is included in the predicting equation. The clinical value of this model is suggested when ultrasound is unavailable or unreliable (Spinnato et al. 1988).

Weiner et al. (1985) examined the predictive accuracy of three published sonographic formulas in 69 preterm fetuses scanned within 48 hours of delivery. The mean birth weight was 1396 g. Thirty-nine of the infants were less than 1500 g. Sixty-two percent were products of pregnancies complicated by premature rupture of membranes. The results were compared with new equations derived from combinations of head and abdominal circumferences, biparietal diameter, and femur length obtained from the first 33 fetuses and then tested on the remaining 36. Whereas each formula correlated highly with birth weight, the selected new formula was more accurate than the published formulas by each criteria examined. In contrast to the latter, the mean error (actual minus predicted weight) of most new equations did not significantly differ from zero when tested prospectively. In addition, it appeared that the accuracy of two new formulas not incorporating femur length could be further enhanced in the group of fetuses whose femur length differed from the mean by at least 2 standard deviations by multiplying the predicted weight by the ratio of actual to mean femur length. They concluded that the use of head circumference and femur length coupled with a population restricted to the preterm fetus enhances the accuracy of sonographic weight predictions (Weiner et al. 1985).

Weiner et al. 1985 studied to determine the relationship between gestational age and measurement of mean diameter of gestational sac, volume of sac, and crown-rump length in a group of pregnant women who had regular cycles and certain dates. In their study measurements of gestational sac diameter, volume, and crown-rump length (CRL) were collected from 417 normal singleton fetuses. Charts and predictive equations were constructed from data obtained from pregnancies in which the CRL was between 6 and 60 mm and for which the outcome was normal. CRL maintained the highest correlation with gestational age (r=0.935, p less than 0.0001). The standard error of estimates using CRL was significantly lower than that using mean gestational sac or volume of the sac. The 95% reference interval was, ±4.86 days for CRL, The best fit regression equation was the quadratic model. Age (week) = 5.822+1.610 CRL (cm) - 0.080(CRL)^2 (cm). A chart for CRL derived from the regression equation are presented and compared with those obtained by Robinson & Fleming and Hadlock. Linear relationships were found between the mean gestational sac diameters (MDS) and gestational age (r=0.886, p less than 0.0001), and volume of gestational sac (r=0.814, p less than 0.0001). They concluded that there were no significant differences between the Iranian and European parameters for the CRL and mean gestational sac curves. Crown-rump length (CRL) between 6 and 12 weeks is the most accurate parameter for first trimester dating (Razaee and Baradaran, 2006-2007).

Rapid and accurate determination of gestational age may be vital to the appropriate care of the critically ill pregnant patient. Before the use of emergency ultrasound, physical examination of fundal height (FH) in the nonverbal patient was considered the quickest method to estimate gestational age. Shah et al. (2010) conducted a prospective, observational study of the performance of bedside sonography to determine gestational age. They enrolled a convenience sample of women in their second or third trimester of pregnancy. Emergency physicians (EPs) made ultrasound measurements of fetal biparietal diameter (BPD) and femur length, followed by a measurement of FH. These measurements were compared with true gestational age (TGA), sonography by an ultrasound technician, and measurement of FH performed by an obstetrician. Main outcome measures of their study were the average time needed to complete measurements; correlation coefficients between EP measurements and those made by an ultrasound technician, an obstetrician, and TGA, and overall accuracy to determine fetal age greater than 24 weeks. The average time to complete ultrasound measurements was less than 1 minute. When physician-performed measurements were compared with TGA, the correlation coefficients were 0.947 (0.926-0.968) for BPD, 0.957 (0.941-0.973) for femur length, and 0.712 (0.615-0.809) for FH. When determining fetal viability, EP's overall accuracy was 96% using ultrasound and 80% using FH. They concluded that the with brief training, EPs can quickly and accurately determine gestational age using ultrasound, and these estimates may be more accurate than those obtained through physical examination. Emergency physicians should consider using ultrasound in emergent evaluation of pregnant patients who are unable to provide history (Shah et al. 2010).

Johnsen et al. (2008) analysed the duration of gestation for 541 women who had a spontaneous delivery having previously been recruited to a cross-sectional study of 650 low-risk pregnancies. All had a regular menses and a known date of their last menstrual period (LMP). Subjects were examined using ultrasound to determine fetal head circumference (HC), abdominal circumference (AC) and femur length (FL) at 10–24 weeks of gestation. Length of the pregnancy was calculated from LMP, and birth weights were noted. The effect of fetal size at 10–24 weeks of gestation on pregnancy duration was assessed also when adjusting for the difference between LMP and ultrasound based fetal age. In their study small fetuses (z-score -2.5) at second trimester ultrasound scan had lower birth weights ($p < 0.0001$) and longer duration of pregnancy ($p < 0.0001$) than large fetuses (z-score +2.5): 289.6 days (95%CI 288.0 to 291.1) vs. 276.1 (95%CI 273.6 to 278.4) for HC, 289.0 days (95%CI 287.4 to 290.6) vs. 276.9 days (95%CI 274.4 to 279.2) for AC and 288.3 vs. 277.9 days (95%CI 275.6 to 280.1) for FL. Controlling for the difference between LMP and ultrasound dating (using HC measurement), the effect of fetal size on pregnancy length was reduced to half but was still present for AC and FL (comparing z-score -2.5 with +2.5, 286.6 vs. 280.2 days, $p = 0.004$, and 286.0 vs. 280.9, $p = 0.008$, respectively). They concluded that the fetal size in the second trimester is a determinant of birth weight and pregnancy duration, small fetuses having lower birth weights and longer pregnancies (up to 13 days compared with large fetuses). Their results support a concept of individually assigned pregnancy duration according to growth rates rather than imposing a standard of 280–282 days on all pregnancies (Johnsen et al. 2008).

ULTRASOUND ASSESSMENT OF GESTATIONAL AGE

Ultrasound assessment of gestational age has become an integral part of obstetric practice in recent times. Correspondingly, assessment of gestational age is a central element of obstetric ultrasonography. Fetal biometry has been used to predict gestational age since the time of A-mode ultrasound. Currently, the sonographic estimation is derived from calculations based on fetal measurements and serves as an indirect indicator of gestational age. Over the past three decades, numerous equations regarding the relationship between fetal biometric parameters and gestational age have been described and have proven early antenatal ultrasound to be an objective and accurate means of establishing gestational age (Kalish and Chervenak, 2009).

Ultrasound parameters: When choosing the optimal parameter for estimating gestational age, it is essential that the structure has little biologic variation, and can be measured with a high degree of reproducibility. In the past, the biparietal diameter (BPD) had been described as a reliable method of determining gestational age. While the BPD was the first fetal parameter to be clinically utilized in the determination of fetal age in the second trimester, more recent studies have evaluated the use several other biometric parameters including head circumference (HC), abdominal circumference (AC), femur length (FL), foot length, ear size, orbital diameters, cerebellum diameter and others. In a large study by Chervenak et al that evaluated pregnancies conceived by *in vitro* fertilization and thus had known conception dates, head circumference was found to be the best predictor of gestational age compared with other commonly used parameters. This finding is in agreement with that of Hadlock, Ott and Benson who compared the performance of HC, BPD, FL and AC in different populations (Kalish and Chervenak, 2009).

The fetal head circumference should be measured sonographically in a plane that is perpendicular to the parietal bones and traverses the third ventricle and thalami. The image should demonstrate smooth and symmetrical calvaria and the presence of a cavum septum pellucidum. The calipers should be placed on the outer edges of the calvaria and a computer-generated ellipse should be adjusted to fit around the fetal head without including the scalp. The biparietal diameter can be taken in the same plane by placing the calipers on the outer edge of the proximal calvarium wall and on the inner edge of the distal calvarium wall. The BPD, while highly correlated with HC, is less accurate as a predictor of gestational age as a result of variation in head shape (Kalish and Chervenak, 2009).

Using multiple parameters, the accuracy of gestational age assessment can be improved.48 Along with head circumference, the addition of one parameter (AC or FL) or two parameters (AC and FL) is slightly superior to head circumference alone in the assessment of fetal age. The use of multiple parameters also reduces the effect of outliers caused by biologic phenomena (*i.e.* congenital anomalies or growth variation) or technical error in measurement of a single structure. Still, with multiple parameters, it is essential to take the images in the proper plane and place the calipers appropriately. For example, when assessing FL, the long axis of the femur should be aligned with the transducer measuring only the osseous portions of the diaphysis and metaphysis of the proximal femur. While not included in the FL measurement, the proximal epiphyseal cartilage (future greater trochanter) and the distal femoral epiphyseal cartilage (future distal femoral condyle) should be visualized to assure that the entire osseous femur can be measured without foreshortening or elongation. Similarly, the AC must be measured appropriately in order to obtain an accurate estimate. The image should be taken in a transverse abdominal diameter, with the liver, stomach, spleen and junction of the right and left portal veins visualized (Kalish and Chervenak, 2009).

Modern ultrasound machines are equipped with computer software that will automatically calculate the estimated gestational age based on the entered measurements. Using a large singleton in vitro fertilization (IVF) population from 14-22 weeks, Kalish and Chervenak (2009) derived an optimal gestational age prediction formula using stepwise linear regression with a standard deviation (SD) of 3.5 days between the predicted and true gestational age. This formula was compared it to 38 previously published equations. Nearly all equations produced a prediction within one week demonstrating that fetal biometry in the midtrimester for assessment of gestational age is applicable and accurate across populations and institutions. Clinically, when a discrepancy greater than seven days (2SD) exists between the menstrual and ultrasound dating in the second trimester, the biometric prediction should be given preference (Kalish and Chervenak, 2009).

In addition, we published a study evaluating and comparing the accuracy of first- and second-trimester ultrasound assessment of gestational age using pregnancies conceived with in vitro fertilization. Data showed that first- and second-trimester estimates of gestational age had small differences in the systematic and random error components for an estimated gestational age that was based on fetal crown-rump length or biometry. On the basis of this data derived from pregnancies with known conception dates, ultrasound scanning can determine fetal age to within <5 days in the first trimester and <7 days in the second trimester in >95% of cases. This data further confirms the findings of Wisser et al and Chervenak et al, regarding the precision of ultrasound scans to assess gestational age in the first and second trimester, respectively (Kalish and Chervenak, 2009).

First trimester ultrasound: Gestational age assessment can be predicted with ultrasound most accurately in the first trimester of pregnancy. During this time, biological variation in regards to fetal size is minimal. The gestational sac is the earliest sonographic sign of pregnancy. Historically, gestational sac size and volume had been used as a means to estimate gestational age. This structure sonographically resembles a fluid filled sac surrounded by a bright echogenic ring, the developing chorionic villi, within the endometrial cavity. This sac can be visualized as early as five menstrual weeks using transvaginal sonography. However, studies have shown that fetal age assessment by gestation sac measurement is not reliable, with a prediction error up to two weeks. Another imprecise yet often used modality is the sonographic visualization of distinct developing structures. During the fifth menstrual week, the yolk sac, the earliest embryonic structure detectable by sonography, can be visualized prior to the appearance of the fetal pole. And, by the end of the sixth menstrual week, a fetal pole with cardiac activity should be present. Subsequently, the presence of limb buds can be seen at approximately 8 weeks gestation.

However, these developmental landmarks can only provide rough estimates to the actual fetal age (Kalish and Chervenak, 2009). In 1973, Robinson reported using the crown rump length (CRL) for determining gestational age. Since that time, ultrasound equipment, techniques and prediction formulas have substantially improved and allow for more precise measurement of the crown rump length and determination of gestational age. For the best results, the fetus should be imaged in a longitudinal plane. The greatest embryonic length should be measured by placing the calipers at the head and rump of the fetus. Three adequate CRL measurements should be taken and the average used for gestational age determination. The accuracy of the CRL measurement has been well documented in the medical literature. Specifically, gestational age can be estimated safely with a maximal error of three to five days in the first trimester. In summary, first trimester ultrasound is a useful and reliable modality for assessment of gestational age. In particular, sonographic measurement of the CRL during the first trimester is the best parameter for estimating gestational age and is accurate within five days of the actual conception date (Kalish and Chervenak, 2009).

Second trimester ultrasound: Routine ultrasonography at 18-20 weeks gestation while historically somewhat controversial, it is currently practiced by most obstetricians in the United States. In addition to screening for fetal anomalies, sonographic gestational age assessment is of clinical value in that it has been shown to decrease the incidence of post-term as well as preterm diagnoses and thus the administration of tocolytic agents. In addition, uncertain gestational age has been associated with higher perinatal mortality rates and an increase of low birth weight and spontaneous preterm delivery (Kalish and Chervenak, 2009).

Third trimester ultrasound: While ultrasound has proven to be useful in the assessment of gestational age in the first and second trimesters, accuracy in the third trimester is not as reliable. Biologic variation can be a major factor that affects accuracy in gestational age prediction, and this variability greatly increases with advancing pregnancy. Doubilet and Benson evaluated late third trimester ultrasound examinations of women who had also received a first trimester exam and found the disparity in gestational age assessments to be three weeks or greater. However, more recent data has revealed that ultrasound estimation of gestational age in late pregnancy may be better than indicated in older publications. Still, third trimester sonographic estimates of gestational age should be used with caution, if at all (Kalish and Chervenak, 2009).

Ultrasound pitfalls: Modern improvements in ultrasound image quality and the wide availability of accurate biometric formulas have greatly improved physicians' ability to calculate gestational age. However, properly dating a pregnancy sonographically still depends on adherence to good ultrasound technique. Obtaining a clear and precise image of each biometric indicator is essential. Errors in estimation may arise from technical difficulties including obtaining the proper axis for measurement, movement of the mother or fetus, machine sensitivity settings or caliper placement. If a certain biometric indicator is not well visualized or is difficult to measure, it is better to use an alternative indicator rather than include a suboptimal measurement. In addition, it is helpful to obtain several measurements of each indicator and use an average to ensure a more precise calculation of fetal age (Kalish and Chervenak, 2009).

Factors influencing the fetal weight

Fetal weight has a fairly linear relationship with increasing gestational age up to 38weeks pregnancies after which it remains steady.

Fetus could be classified by birth weight as

1. Small for gestational age (SGA)
2. Appropriate for gestational age
3. Large for gestational age (LGA)

Newborn weighing 2500 gms and above is termed as normal or appropriate and below 2500gms is termed as low birth weight (WHO 1986). Macrosomic baby is one when birth weight is more than 4000gms (Campbell and Macintosh, 1960).

Two major processes govern birth weight

A). Duration of pregnancy

B). Intrauterine fetal growth.

Duration of pregnancy:

Gestational age is the single most important factors that influences birth weight of a fetus, which has a fairly relationship with increasing gestational age up to 38weeks and after which growth remains steady.

Intrauterine fetal growth:

Intrauterine fetal growth is affected by the some intrinsic factors and some extrinsic factors.

Intrinsic factors:

1. Genetic factors: Growth of the fetus is adversely affected by certain genetic factors. Chromosomal abnormalities like turner's syndrome and gene mutation may result in inherited disorders of growth e.g. in Cystic fibrosis.
2. Biologic and constitutional factors:

   Race: Incidence of low birth weight is 2-3 times more in black than white (Cogwel & Roy 1995). Black indian and pakistani had lower birth weight than European and North african whites (Kramer and Roy 1995).

Sex: Study done by cogwet et al and found that white male infants are 135gm heavier than white female infants and black male infants are 125gms heavier than black female infant (Cogwel and Roy, 1995).

Multiple gestations: It is a bilogical determinant of birth weight. Twin, Triplet and even higher order of birth have greater risk of low birth weight increased risk of low birth weight for multiple pregnancy is partly due to association with short period of gestation (Cogwel & Roy 1995).

Extrinsic factors: It includes: Maternal factors

Placental factors

Environmental factors.

Maternal factors:

Maternal age- The excellent data available in the swedish Medical Birth Register have been utilized to show that after adjustment for social and medical factors there was gradient with increased maternal age for rates of Perinatalmortality, pre-term birth, low birth weight (Keith. D et al 1995). The maternal age reflects biologically immaturity in case of teen age mother and consequences of aging in an elderly mother.

Maternal Nutrition- The pregnant women require more calories, proteins minerals vitamins etc. than non- pregnant to ensure proper or optimal growth of the fetus. It has been shown that there is a close relationship between birth weight and protein quality of mothers diet. A study was done by Shama et al (1978) showed that 64.4% of the babies born of anemic mother with low birth weight. Maternal anemia has adverse effect on the fetus resulting in preterm of small for date baby.

Maternal weight- There is a strong correlation between maternal weight gain and fetal weight. In normal pregnancy maternal weight gain distribution like this pattern 1kg in first trimester and 5kg each in second and third trimester. Low rate weight gain of mother during pregnancy has its greatest influence on fetal birth weight (Hoffman GR Gutter 1991) women at the extreme of Weight may be at higher risk of problem. Those who are under weight having risk of fetus with small for gestational age, while the obese are at risk of fetal macrosomy and pre-eclampsia (Keith et al 1995)

Maternal disease- In underdeveloped country maternal infection appears to be especially important. Some systemic maternal disease like hyper tension, diabetes, renal disease, cardiac disease etc. reduce uteroplacental blood flow causing direct effects on fetus.

Measurement of Fetal Parameters

Sac Volume:

The gestational sac can be visualised from around 4.5 weeks gestation. In a normal pregnancy the gestational sac contains a yolk sac, which should be present from 5 weeks. The sac volume gives an accurate indication of gestational age to around 8 weeks gestation. The sac should be assessed for size, shape and clarity. The imaging planes required for measuring purposes is a transverse cut at the widest point and a sagittal cut at the longest axis.

Sac volume = (Length x Breadth X Width) / 0.56 (Hellsman et al)

Image 2/1 Sac Volume - Sagittal

Image 2/2 Sac Volume - Transverse

The Crown-Rump Length:

The crown rump length (CRL) has been described by many authors, including Hadlock (1991), Jeanty (1991), Benson as the most reliable ultrasonic parameter for determining gestational age in the first trimester. The original definition for the CRL was by Mall in 1907, and stated that the crown rump length is measured at sitting height, mid brain to the lowest point of breech (Figure 2/1). Ultrasonically the CRL is measured between the fetal poles, cephalic edge to rump and should be measured when the fetus is in a neutral position (Image 2/3). CRL is performed form 5 to 14 weeks and it is important to assess fetal position as fetal flexion can cause variations of up to 7days.

Figure 2/ Image 2/3 Crown Rump Length Measurement

Biparietal Diameter, Occipito-frontal Diameter and Head Circumference:

The imaging plane required for the head measurements is usually easily obtained up to thirty weeks gestation. In the late third trimester, satisfactory images may not be achieved due to the fetus being too deeply engaged. The plane of section of the fetal head at which the biparietal diameter (BPD) is measured should be a transverse axial image obtained at the widest section of the fetal head. The landmarks to be included in the image are the falx cerebri anteriorly and posteriorly, cavum septum pellucidum anteriorly in the midline, and the choroid plexus in the antrum of each lateral ventricle. This plane lies above the cerebellum and midbrain, and below the bodies of the lateral cerebral ventricles and can be used to obtain all head measurements (Image 2/4). In 1991 this image plane was put forward by the American College of Obstetricians and Gynaecologists and accepted as an international standard. When comparing head measurement charts it is essential to use the same imaging plane for measuring as in the original work.

The measuring methods chosen for this study are those recommended by ASUM. The BPD (Figure 2/2) is measured from the outer edge of the nearer parietal bone to the inner edge of the more distant parietal bone and the occipito-frontal diameter (OFD) perpendicular to the BPD, mid skull to mid skull. Head circumference (HC) can either utilise the ellipse method, which traces an ovoid line around the outer perimeter of the head bones ensuring that, particularly in the third trimester, hair is not included or can be calculated independently using the formula: HC = (BPD + OFD) x 1.57

This method, according to Hadlock et al (1982) and Jeanty (2001) gives equivalent results to the ellipse method. Nisbet et al (2002) criticised this method of calculating the head circumference, pointing out that a true HC traced around the outer edge of the bones compared with using the combination of BPD which is measured outer parietal to inner parietal and the OFD that is measured mid bone to mid bone. Although this may cause a discrepancy, it has been deemed by Dudley and Chapman (2002) as being similar to the error caused by using the ellipse mode versus trace mode for circumferences.

Figure 2/2 Biparietal Diameter, OFD and Head Circumference Measurement

HC ellipse around
Outer edge of skull

BPD measured
Outer to inner

Frank Hadlock (1990) Ultrasound Determination of Menstrual Age

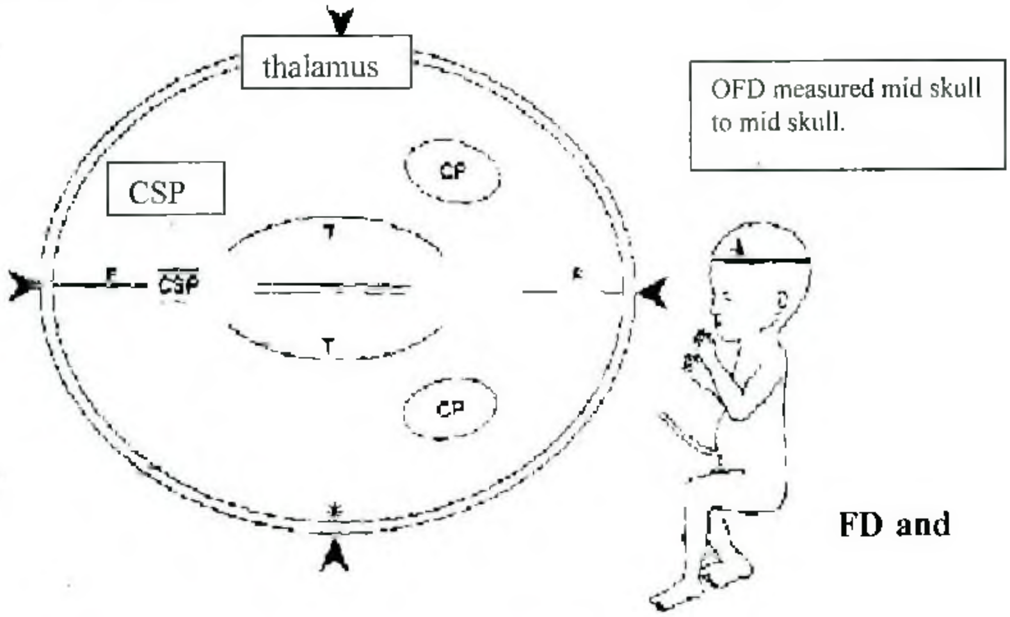
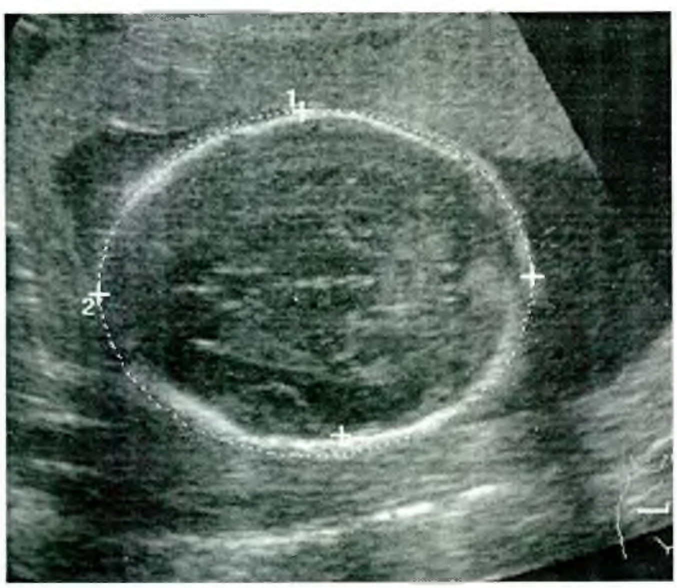


Image **FD and**

HC



Head measurements are reliable from 11 weeks gestation. In late pregnancy it can be difficult to obtain the ideal imaging plane due to the head lying low in the pelvis. A change in head shape due to moulding, can cause dolichocephaly (flattened and elongated) or brachycephaly which can affect the BPD measurement. When this occurs the OFD measurement can be utilised as the denominator in the calculation of the cephalic index (CI) where:

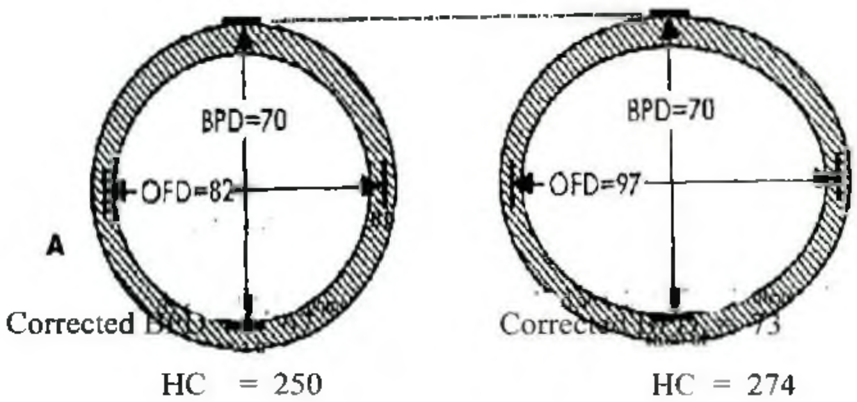
$$CI = (BPD/OFD) \times 100\% \qquad \text{(Normal range = 73.9 - 82.7\%)}$$

In the third trimester the BPD should only be used to estimate gestational age, or in a fetal weight formula, if the CI lies within the normal range. The BPD and OFD measurements can also be used to calculate a corrected BPD where:

$$\text{Corrected BPD} = \sqrt{\frac{BPD \times OFD}{1.265}}$$

The corrected BPD will be more accurate than just a BPD as it allows for variations in head shape. Using only a BPD, two heads with the same BPD would be assigned the same gestational age, but taking the OFD into account, the head with a larger OFD would be given a greater gestational than the head with the lesser OFD. The same charts are used for the corrected BPD and BPD (Figure 2/3).

Figure 2/3 Corrected BPD

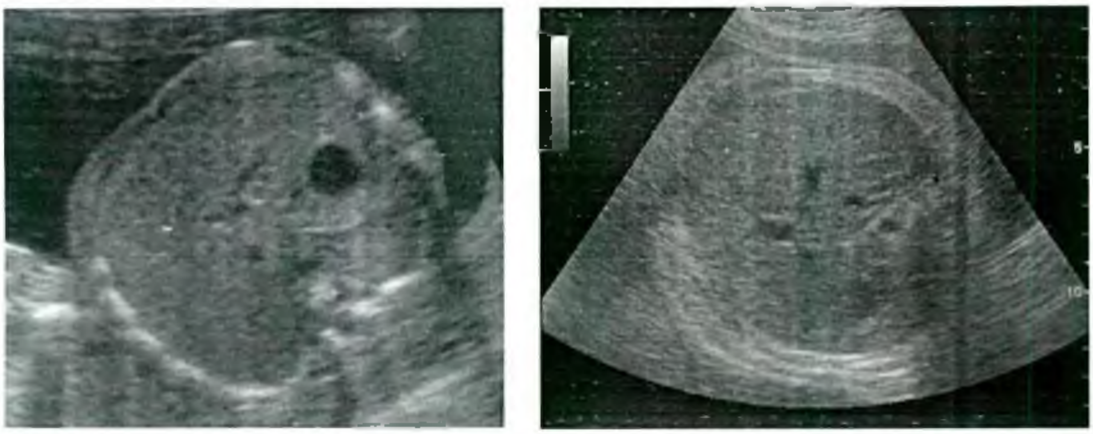


Benson and Doubilet (1991) Fetal Measurements – Normal and Abnormal Fetal Growth.

The Abdominal Circumference:

The abdominal imaging plane should be a true transverse cut at the level of the fetal liver and stomach, including the left portal vein at the umbilical region and ensuring that the aorta and IVC are circular. In the third trimester it may be difficult to achieve this plane due to fetal size and position. Deter et al (1982), Jeanty et al (1984) and Benson and Doubilet (1995) commented that this imaging plane is the most difficult to obtain. especially in late pregnancy, and yet is one of the most essential for inclusion in a fetal weight formula. Although the abdominal circumference can be measured using the ellipse mode, in the third trimester it is usually more accurate to trace around the perimeter of the abdomen (Dudley and Chapman 2002). As indicated by Jeanty (1982) the fat layer must be included (Image 2/5B). Measurement of the abdominal circumference can be performed from 12 weeks gestation.

Image 2/5A Abdominal Circumference Imaging Plane. 2/5B– Fat Layer



Femur Length:

Long bone measurements are easily obtainable from 12 weeks gestation and are particular useful when the lie of the fetus makes accurate head measurements difficult. Long bones are best imaged when perpendicular to the beam and the transducer should be rotated until the longest possible image of the bone is achieved and both cartilaginous ends are seen as blunt ends with a strong acoustic shadow posterior to the shaft (Image 2/6). Oblique view measurements greater than fifteen degrees off the perpendicular tend to underestimate the length, as one end of the bone will appear straight, whilst the end in the far field has a curved edge (Image 2/7). Historically the axial resolution of an ultrasound machine is invariably better than the lateral resolution, although the newer systems have vastly superior resolution in both axes than the previous generation of machines. McNay and Flemming (1983) found that: *"the potential error from foreshortening the femur in the axial plane is greater than the error caused by the difference in resolution."* Between twenty-nine and thirty-four weeks of gestation, the distal femoral epiphysis (DFE) ossifies and can be easily visualized. The femur should be measured along the diaphyseal shaft, excluding the DFE (Figure 2/4). The proximal humeral epiphysis (PHE) can also ossify prenatally, usually by thirty-eight weeks and, as with the femur, should not be included in the measurement of the humeral shaft. A cross reference for long bone measurement reliability is the ratio of both the femur and BPD measurements shown by Hohler et al (1982) where:

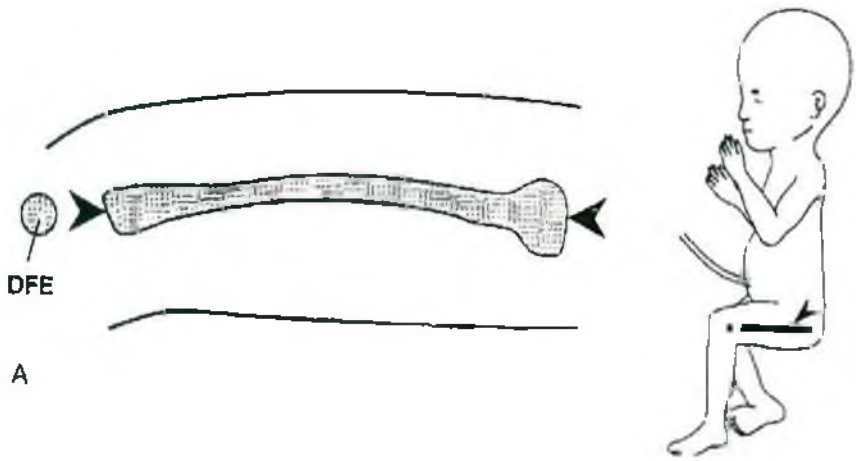
FL = 79 (Normal Range = 73 - 85)

Image 2/6 Correct Long Bone Imaging Plane

Image 2/7 Long Bone at an Unsuitable Angle

Figure 2/4 The Fetal Femur Length Measurement

Frank Hadlock (1990) Ultrasound Determination of Menstrual Age



3. MATERIALS AND METHODS

3.1 Place and period of study:

The study was done over a period study from July 2008 to June 2010. The study was done in the Institute of Nuclear Medicine & Ultrasound, BSMMU Campus, Shahbagh, Dhaka and Maternal and Childhealth Training Institute Azimpur, Dhaka, Bangladesh.

3.2: Study design:

It is better to collect data specifically for the purpose of developing a reference range, with each fetus being included only once. Reference data should relate to normal fetuses, and therefore it is important to have as unselected a group as possible. Cross sectional data were used to develop reference centiles for fetal size.

3.3: Sample size determination:

It is not easy to specify the appropriate sample size for developing centile charts. The larger the sample size the greater precision the resulting centiles will have. Because attention is concentrated on the tails of the distribution (the extreme values), several hundred observations are necessary to get reasonable estimates of extreme centiles.

The standard error of the 100αth centile ($C_{100\alpha}$) can be expressed as a multiple of the age-specific standard deviation (SD) as

$$SE(c_{100\alpha}) = \sqrt{\ }[(1+z^2/2)/n]$$

where z is the appropriate value from the standard normal distribution (Royston 1999). This ignores any error due to inappropriate modelling of the relation to gestational age. Thus the width of, for example, a 95% confidence interval for the 90th centile (for which $z = 1.282$) is $\pm 1.96SE(c_{90}) = 2.65$ SD/ $\sqrt{n}$, which for $n = 1000$ is ±0.08SD, for $n = 500$ is ±0.12SD and for $n = 250$ is ±0.17SD. More extreme centiles are less precisely estimated.

For $n = 200$ is ±0.19SD. So, 200 samples for each weeks of gestation. Therefore, final sample size was 6600 (8 weeks to 40 weeks; 33x200).

3.4: Sampling selection:

Only one scan of each fetus was included in the study. When a patient was scanned more than once between 8 to 40 weeks of her pregnancy, her first scan was only included. All study subjects were Bengalis, residing in Dhaka and the adjoining areas but belonging to different districts of Bangladesh, Caucasians. Mongols (Chinese, Japanese and tribal people) and other ethnic groups were excluded.

3.4.1: Criteria for inclusion

- Subjects, who were confirm of their last menstrual period (LMP) dates, had regular 28±2 days menstrual cycles and no unusual bleeding.
- Patient who reported here with a previous ultrasound scan done before 20 weeks gestational age which confirmed the gestational age within 2 standard deviations (7 to 10 days).
- Singleton pregnancy.
- No oral contraceptive taken 3 months prior to conception.

3.4.2: Criteria for exclusion

- Maternal malnutrition with a BMI of less than 18.5.
- Any major maternal systemic disease. like hypertension, diabetes mellitus, gestational diabetes. and cardiac or renal disease.
- History of tobacco or substance abuse.
- Ethnic groups like foreigners and tribal people.
- Uterine anomaly or large fibroids.

- Bad obstetric history.
- Congenital fetal anomalies.
- Rhesus (R) incompatibility.
- Oligo and polyhydramnios.
- When the head shape was not optimum.
- Ultrasonic evaluation was considered inadequate if any of the fetal measurement could not be obtained and the patient was excluded from the study.

3.5: Ethical consideration

3.5a: Approval

The research protocol was approved by the Independent Review Board (IRB) and by the Institutional Ethical Research Committee (ERC) of BSMMU.

3.5b: Consent

Informed written consent was obtained from the patients before scan, for including in the study. A copy of it is attached in the appendix, page iv and v.

3.5c: Safety

Although ultrasonography is in use for a long time no adverse affect has been found on the patient or the fetus. So it is now considered safe for clinical use with the modern machines.

3.6: Methodology

All healthy gravid patients underwent a ultrasound examination for pregnancy profile including measurement of fetal biparietal diameter (BPD), head circumference (HC), femur length (FL), and abdominal circumference (AC), using standard methodology. Measurements were made by electronic calipers. Only one measurement was taken of each variables. Measurements were recorded on specifically designed data sheets and entered into a computer at a later date. At the time of data analysis any outlying values were rechecked for transcription errors. The few remaining outliers were not excluded from the analysis. Using measurements from poor images or images that depicted fetal anomalies was avoided. The estimated fetal weight (EFW) was computed by using Hadlock and colleague's formula (1985), in grams. All the fetal biometric measurements were taken by the researcher.

3.7: Description of the instrument & transducer

A Power Vision 6000 ultrasound scanner (model SSD-350 from Toshiba Medical Systems, Tokyo, Japan) and a Voluson 730 PRO (R) scanner (General Electric Medical Systems, Milwaukee. Wisconsin, USA) with a 3.5 mHz transabdominal convex transducer, adopted as the standared equipment for obstetrical examinations, were used for all the ultrasonography scans carried out in this study. In medical ultrasound imaging, the sound waves are mechanical disturbances generated by a crystal in a hand held transducer. The crystal converts electrical energy into sound energy using a pulse-echo technique and this sound wave travels through the body, bouncing back from the different tissue interfaces to be converted back to electrical energy. The returned echo is mapped for position and intensity to build up an anatomical image. Gestational sac (GS) diameter, crown rump length (CRL), biparietal diameter (BPD), femoral length (FL), head circumference, abdominal circumference. All are the well practiced parameters to measure the gestational age of the fetus by ultrasound.

3.8: Patient's preparation & examination procedure

I. Patient's Preparation:

- No preparation was needed except optimally full bladder in early pregnancies.

II. Examination Procedure:

- Position of Patient-

Patient was laid in a supine position on a firm bed. Her abdomen was exposed up to the symphysis pubis and gel was applied on the lower part of her abdomen which was to be scanned. The transducer was thus coupled to the abdomen by a coating of gel.

- Gain setting-

Gain was adjusted to get the best possible images.

3.9: Record

The findings were recorded in predesigned data collection sheet. A copy of it is attached in the appendix, page i.

3.10: Test for hypothesis

Correlation co-efficient (R) test:

This test was done to see the degree of relationship between two variables, when one variable was dependent on the other, such as gestational age and BPD. The quality of the fit of the equation was measured by the coefficient of multiple correlation, R, or by the square of this value (the coefficient of determination .R^2). The better the correlation. the closer these coefficients were to 1. Parameters that correlated very well had R^2 values in the 0.90 to 0.99 range. Among the curves with a high R value, the most appropriate one was the curve with the lowest order. Accuracy of estimated fetal weight (EFW) was determined by using a t-test for paired two-sample means between Hadlock's weight standards and the birth weights.

3.11: Outcome variabels/ Study parameters

3.11.1 CROWN RUMP LENGTH (CRL)

First ultrasonogram is to use identifying the gestational sac and the fetal pole. Then ultrasound beam was placed perpendicular along the long axis of the fetal pole. Visualizing the entire fetal pole in its long axis and keeping it in a straight position. (not in a flexed or in a hyperextended position) The distance from the top of the head to the bottom of the rump was measured (CRL). Sometimes an average of these readings was taken, when getting a true long axis of the fetus was in doubt. Precautions were taken not to include any limbs or yolk sac in the measurement.

3.11.2 BIPARIETAL DIAMETER (BPD)

First, the lie of the fetus was determined and then the longitudinal axis was found. By sliding movements and alterations in the angle of the transducer, longitudinal section of spine was determined and a strong midline echo in the fetal head demonstrated. With midline in view the transducer was rotated through 90° until a transverse axial section of the fetal head was obtained.

Correct section demonstrated the following features:

a). Oval shaped head.

b). Falx cerebri anteriorly and posterior only. These are meninges dividing the cerebrum into two equal halves.

c). The cavum septum pellucidum, anteriorly in the midline. It is an anechoic fluid filled box like structure, located anterior to thalamus in the midline.

d). Choroid plexus in the atrium of each lateral ventricle.

e). Thalamic nuclei, it is a diamond shaped structure in the centre of the section, which is divided equally into right and left halves by a hyperechoic line or slit, known as third ventricle.

After freezing the image, the BPD was measured form the outer surface of the skull table nearest transducer to the inner of the opposite skull table (Outer to inner) or leading edge to leading edge. The instrument was set at medium gain. So that the parietal bones were 3mm in thickness (Hadlock 1994). The soft tissue over the skull was not included.

3.12.3: HEAD CIRCUMFERENCE (AC)

The aim of the technique was to obtain a horizontal section of fetal head which included both the bipaietal (coronal plane) and the occipital-frontal diameter (saggital plane). The procedure was identical to that described for the measurement of fetal BPD. Transverse scans were made so that a horizontal section of the fetal head was obtained; this was recognized the appearance of the mid-line echo. The transducer was rotated until the head was ovoid and third ventricle was detected in the mild-line, one-third of the distance from the synciput. This ensured that the occipito-frontal HC section had been achieved. The correct plane of section was through the third ventricle and thalami in the central position of the brain (as with the BPD), and the cavum septi pellucidi was visible in the anterior protion of the brain (Campbell and Thomas 1977). The calvarium was smooth and symmetric bilaterally. After the proper plane of section was obtained, the calipers were positioned at the outer edges of the near and far calvarial walls. The equipment then allowed a computer-generated ellipse to fit to the calvarial margins or open to the outline of the fetal head. The ellipse adequately estimated the head perimeter even when it was not entirely imaged. To obtain an accurate HC measurement. 60% to 70% of the skull outline should be displayed on the screen (Hobbins et al. 1983). It was made certain that the ellipse fitted to the calvarium nad not to the skin of the scalp.

3.11.4 FEMUR LENGTH (FL)

The fetal femur was located by finding a cross section of the fetal body and then sliding the transducer caudally along the fetal trunk a cross section of the femur was visualized. The transducer was then rotated until the full length of the bone was displayed. Both ends of the femur were clearly visualized and the gain was reduced. The transducer was then aligned along the long axis of the bone, with the beam exactly perpendiculr to the shaft. The measured ends of the bone were blunt and not pointed. After 32menstrual weeks, the distal femoral epiphysis was visible but not included in the measurement of the femoral shaft (Hadlock 1994), that is the "distal femur point" was excluded from the measurement. Only the length of diaphysis, which casts acoustic shadow, was measured (Pearce, Chazal 1993).

3.11.5 ABDOMINAL CIRCUMFERENCE (AC)

The measurement of the fetal AC was made from a transverse axial image of the fetal abdomen at the level of the liver. The appropriate plane of section demonestrated a short tubular segment of the umbilical part of the left portal vein approximately one third of the posterior from the anterior abdominal wall (Deter et al. 1982). The fetal stomach represented a secondary landmark (Hadlock 1990). Trunk section was more or less round at the level of measurement and the umbilical vein, aorta, stomach and spine were visible. If the kidneys were present, the section was too low or angled improperly (Sanders 1998). So it was corrected. This circumference can be traced along its outer margin with a map measured or electronic digitizer, or by using the antero-posterior and transverse diameters measured outer to outer, the circumference then equals (D1+D2) x1.57. In this study the later method was used in which electronic ellipse cursor measured the perimeter of the fetal abdomen.

3.11.5 ESTIMATED FETAL WEIGHT (EFW)

The fetal weight was determined at different gestational age. The prenatal weight was estimated by Hadlock's calculations, determined by using ultrasound measurement of fetal biparietal diameter and abdominal circumference.

Prior to the availability of ultrasound, manual examination of the maternal abdomen was the only approach that could be used to estimate fetal size. Physical examination provides only a rough approximation of fetal weight because the palpated dimensions of the uterus are affected by several factors other then fetal size. These are amniotic fluids volume, placental bulk and maternal obesity (Benson, Doubilet 1998). Sonographic measurements of fetal body parts provide a direct way of assessing fetal size. Numerous formulas have been published for estimating fetal weight from one or more of the following fetal body measurements:

Head (BPD and HC)

Abdomen (Abdominal circumference)

Femur (FL)

(Campbell wilkin 1975, Warsof Gohari 1977 and Shepard Richards 1982)

Fetal weight has been the primary parameter used in identifying infants with intrauterine growth retardation (Deter et al 1982) and it is well known that the outcome of the pregnancy is related to the weight of the fetus (Royston (1995). Almost al studies have assumed that birth weight below 10precentile was the appropriate criterion for identifying the growth retarded fetus (Deter, Hadlock 1983). For these reasons estimating fetal weight from parameters determined by ultrasound has been the objective of a great many investigations (Deter, Harrist et 1981). The most widely used formula were generated by Shepard et al using the BPD and AC plus those of Headlock et al using the FL and AC

(Warsoft, Gohari et al 1977). Recently the later have revised their formula & introducing their formula of using AC along with BPD & FL (Yarkoni, Reece et al 1986). Abdominal circumference (AC) may be among the most sensitive indicators of impending intrauterine growth retardation (IUGR) (Deter et al 1983). Therefore a substantial literature indicates that measurement of AC together with BPD provides the best estimates of fetal weight (Deter, Harrist et al 1981). A study revealed that the accuracy of BPD/ AC and BPD/ AC/ FL formulae in estimating fetal weights are comparable and better then of the FL/ AC formula. The mean percentage error with the former two is 0.99 and 2.43 percent whereas with FL/ AC it is 3.82 percent (Royston (1995), Reece et al 1986). In this study following Hadlock's formula ultrasonographic estimation of fetal weight was measured.

3.12 Procedure of data collection:

Interviewing: Data were collected in pre-designed structured questionnaire by face-to-face interview on socio-demographic parameters, patients history and clinical information.

Ultrasound report: Measurement of fetal crown-rump length (CRL), biparietal diameter (BPD), head circumference (HC), femur length (FL), and abdominal circumference (AC), were recorded in Ultrasound report.

3.13 Procedure of data analysis:

Data were analyzed as recommended by Altman and Chitty (1993) and Royston (1995). For pregnancy dating curves gestational age based on a reliable LMP was plotted against CRL and BPD. This study used previously published relationships to identify the unlikely data points. For CRL, this was the relationship used by Robinson and Fleming (1975). For BPD, it was that used by Altman and Chitty (1997). Data points more than two SDs from the regression line, fitted on data, were considered to be unrealistic and were therefore removed. For derivation of charts for ultrasound dating, gestational age was log-transformed to stabilize variance (Altman and Chitty 1993; and Royston 1995). The best fitting curve was determined using second-degree fractional polynomials (Royston, Ambler and Sauerbrei 1999). The curve was fitted using repeated measurement analyses, taking into account the dependency in the data by specifying a constant covariance between measurements of the same subject. Subsequently, in pregnancies in which both CRL and BPD were measured, the mean and the SD of estimated gestational age were compared to derive the optimal cut-off point for ultrasound dating of pregnancy. SPSS version 16.0 for Windows (SPSS Inc, Chicago, IL, USA) was used to analyze the data.

To clarify the procedures this study present the statistical methods used as a series of steps. Amplification and discussion of the methods are given by Royston (1999) and Altman (1993).

Step 1: Modelling the mean

The mean was modeled by fitting a polynomial regression model to the raw data. A quadratic or cubic curve gave a good fit to the data. The linear-cubic model, given by

$$Y = b_0 + b_1 X + b.X^3,$$

where *X* is gestational age and Y is the measurement, seems to work well as an alternative for fetal size data. The model chosen is the simplest that gives a good fit to the data.

Step 2: Calculating residuals

The differences or residuals between the observed values and the fitted line were calculated. The residuals were plotted against gestational age to show if and how the variability changes with gestation.

Step 3: Modelling the variability

A key element of the method is that the standard deviation (±SD) is also modeled as a function of gestation. The obvious approach is again to use polynomial regression to model the ±SD as a function of gestation. The most common method was used ±SD for each completed week of gestation, which is regressed on the mean age in each group rather than the midpoint of the age group. Because the number of measurements at each week of gestation may vary, the sample sizes should be used as weights in the regression. For fetal size a linear or quadratic model usually work well. Similar considerations apply to choosing this model as for the model for the mean.

Step 4: Calculating standard deviation scores

For each observation there is a standard deviation score (SDS); this is also called a standardized residual and is calculated as:

$$SDS = \frac{Observed\ value - fitted\ mean}{fitted\ SD}$$

These values are the basis for checks of the assumptions underlying the modelling (Step 5) and for calculating the centile corresponding to any observation (Step 6).

Step 5: Checking the goodness of fit of the models

The standard approach to assessing the goodness of fit of a regression model is to calculate the statistic R^2, which represents the proportion of variability in the data explained by the model. R^2 was used to compare models. but it does not follow that a model with a high R^2 is a good fit to the data (Royston (1995).

Also, most researchers consider R^2 only in relation to the modelling of the mean, although the modelling of the SD is a crucial part of the procedure. More appropriate methods in this context are: 1. to examine a plot of the SDS against gestational age for the existence of any patterns; 2. to check that the SDS have a close to normal distribution; and 3. to check that the appropriote proportion of observations falls between and outside the fitted centiles; this can be checked separately for, say, three subranges of gestation.

Step 6: Deriving the centiles

After the required centiles have been calculated they are superimposed on a scatter diagram of the observations as a final check of the fit. This study showed 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} centiles for the measurements of CRL, BPD, FL, HC and AC, the outer centiles being obtained as mean ±2SD. For measurements for which the data needed transformation the centiles are calculated from the mean and SD in the transformed scale, and are then back-transformed to the original scale. The above method was used to produce the centile charts in the accompanying papers (Chitty et al. 1994a, b, c).

3.14 Operational definitions:

Gestational age (menstrual age)=Conceptual age + 2 weeks.

Macrosomia: Has classically been defined as a birth weight of 4000g or greater or above the 90^{th} percentile for its estimated gestational age. With respect to delivery, however, any fetus that is too large for the pelvis through which it must pass is macrosomic.

Large for gestational age (LGA): Is defined as a weight above the 90^{th} percentile for gestational age.

Dolichocephaly: The head is shortened in the transverse plane, biparietal diameter (BPD) and elongated in antero-posterior (fronto-occipital diameter) plane.

Brachyeephaly: The head is elongated in the transverse plane and shortened in anterior-posterior diameter.

Appropriate for gestational age: Are babies with birth weights between the 10^{th} and the 90^{th} percentile for gestational age.

Intrauterine growth retardation/restriction (IUGR): The term is applied to a fetus whose growth velocity is less than expected due to some pathological process. Not all the SFD fetuses are IUGR. Most cases of symmetrical SFD have no demonstrable cause and represent the lower end of the normal range.

Low birth weight infants (LBW): Are those that are born with a birth weight of under 2.5 kg. This includes both preterm and small for date. This term is still used in the third world countries where many patients are unsure of their LMP.

In countries where routine ultrasound confirmation of gestational age is practiced this term is replaced by SFD or SGA.

Circumference: $\pi\sqrt{[(d_1^2+d_2^2)/2]}$. Where d_1 and d_2 are the two maximum diameters of the ellipse.

Education: Educational attainment is defined as the highest grade completed or attained by a person in the system of regular, special and adult education of his own or some other country.

Occupation: Any activity or activities of a person involving his / her earning is considered as his / her occupation.

Type of family: In this study families were classified as follows:

a) Nuclear family: Parents or parent (either father or mother) one or more unmarried children.
b) Joint family: Parents or parent with married and unmarried children eating from the same kitchen.
c) Extended family: Parents and parent with married and unmarried children along with other relatives (e.g. father-in-law, mother in-law etc).

Income: Material return in kind or cash earned in exchange for good and services by the household members is defined as household income. Household income may consist of total income of all the members of family members living in the same household and taking food from the same cooking pot.

Socio-economic index: A composite index for socio-economic status of the urban population was developed on the basis of socio-economic characteristics.

Education (husband):

0 = non 1 = 1-5 years 2 = 6years and above

Education (respondent):

0 = non 1 = 1-5 years 2 = 6years and above

Occupation (respondent):

0 = non 1 = working

Occupation (husband):

0 = unemployed 1 = manual worker (laborer) 2 = service / business.

Monthly income in Taka:

0= < 2000 1 = 2000-3999 2 = 4000+

Housing index:

Floor: 1 = mud/ bamboo 2 = wood/ tin 3 = cement work

Wall : 1 = mud/ bamboo 2 = wood/ tin 3 = cement work

Roof: 1= bamboo/polythene 2= wood/tin 3= cement work

Asset index:

0 = non 1= simple belongings 2 = other than 1 (watch, radio etc)

Latrine facility:

0 = non- sanitary 1 = sanitary

Drinking water:

1 = piped water 0 = other than 1

Electricity:

0 = none 1 = present

Cooking:

1 natural gas 0 = other than 1

Adding the individual score, an aggregate score for socio-economic index was computed.

Score: Poor (0-5), Moderate (6-10), High (11+)

Pregnancy outcome: The pregnancy outcome was expressed in the following terms:-

a. Live birth: Birth in which after delivery the newborn breathed or showed any other evidence of life

b. Neonatal death: Live birth followed by death under 28days of age.

c. Post-neonatal death: Live birth followed by death of the infant between 28 days and one year of age.

d. Infant death: Live birth followed by death of the infant within one year of liver that is it consists of neonatal and post-neonatal deaths.

Abortion: Termination of pregnancy before the fetus became viable that is 28 weeks of gestation which may be induced or spontaneous.

Parity: Number of previous viable births (after 28weeks of gestation) of the mother.

Weight for age: A nutritional status indicator of malnutrition (either acute or chronic malnutrition) based on the principle that a child has an expected weight for that child's age. The weight for age was computed by using the following formula.

$$\text{Weight for age (WA)} = \frac{\text{Weight of child given age and sex}}{\text{Median weight of reference, given age and sex}} \times 100$$

Height for age: A nutritional status indicator of chronic malnutrition or stunting based on the principle that a child has an expected height for its age. The height for age was computed by using the following formula.

$$\text{Height for age (HA)} = \frac{\text{Height of child, given age and sex}}{\text{Median height of reference, given age and sex}} \times 100$$

Weight for height: An age independent nutritional status indicator of acute malnutrition (wasting) based on the principle that a child of certain height has an expected weight. The weight for height was computed by the following formula.

$$\text{Weight for height (WH)} = \frac{\text{Weight of child, given sex and height}}{\text{Median weight of reference, given sex and height.}} \times 100$$

Maternal nutrition: Maternal nutrition was assessed by anthropometry.

a. Weight in kg. In this study, maternal weight was taken in pounds and then converted into kg.
b. Height in cm: In this study, standing height was taken by locally made stick marked with contemeter.
c. Mid-upper arm circumference (MUAC): The circumference of the upper arm measured at the midpoint between the tip of the acromial process and the tip of the olecranon process. It was measured by flexible measuring tape.

d. Body mass index (BMI): Body mass index was calculated by dividing weight in kilograms by square of height in meters.

$$BMI: \frac{\text{Body weight in kg}}{(\text{height in meter})^2}$$

Maternal care receptivity index (MCR): A composite index for utilization of maternal care services of the urban population was developed on the basis of the following characteristics.

a. Time of commencement of antenatal care:

0 = > 8 months 1 = 7-8 months. 2= 4-6 months
3= 3 moths

b. Frequency of antenatal care received:

0 = nil 1 = 1-2 visits 2 = 3-4 visits
3 = 5 visits

c. Persons providing antenatal care:

0 = none 1 = FWA/ NGO worker

2 = MA/ FWV/ Midwife/ nurse 3 = MBBS doctor

d. Persons providing postnatal care:

0 = non 1 = FWA/ NGO worker

2 = MA/ FWV/ Midwife/ nurse 3 = MBBS doctor

e. Tetanus Toxoid immunization:

0 = non 1 = One dose 2 = two or more dose

f. Person (s) attending the delivery:

0 = Relative/ neighbor/ untrined TBA   1 = HA/ NGO Worker/ trained TBA

2 = MA/FWV/ Midwife/ nurse   3 = MBBS doctor

4. RESULTS

The study was done over a period study from July 2008 to June 2010 The research work was done in institute of nuclear medicine and ultrasound, Bangabadhu Sheikh Mujib Medical University (BSMMU), Maternal and Child Health Training Institute (MCHTI), Dhaka. A relaxed and informal atmosphere helps to increase the patient confidence, not only in the scanning abilities but also to ask any question that the doctor may feel important. The majority of obstetric ultrasound examinations should be pleasant, painless and reassuring to the patient, but the benefits, be they medical of emotional, are directly dependent upon the quality of operators input. A total number of 6600 consecutive health gravid women were studied. All of them were referred by qualified obstetricians from hospitals, clinics and form private practice.

Table 1: Distribution of the respondents by age (n=6600)

Age (y)	Frequency	Percent
≤25	3162	47.9
25-30	2488	37.7
>30	950	14.4
Total	6600	100.0
Mean (±SD)	**25.75±4.79**	

Table 1 shows the distribution of the respondents by age. Mean (±SD) of age of the respondents was 25.75±4.79 years with a range of 18 to 38 years. Among the respondents 3162 (47.9%) were in the age group of ≤25 years, 2488 (37.7%) were in the age group of 25 to 30 years and rest 950 (14.4%) were in the age group of more than 30 years.

Table 2: Distribution of the respondent's by educational level

Educational level	Frequency	Percentage
Illiterate	2528	38.3
Non-formal education	1175	17.8
Class I-V	1564	23.7
Class VI-X	1201	18.2
SSC and above	0132	02.0
Total	**6600**	**100.0**

Table 2 shows the distribution of the respondent's by educational level. Among the respondents 2528 (38.3%) were illiterate, 1175 (17.8%) had non-formal education, 1564 (23.7%) had educational level Class I-V, 1201 (18.2%) had educational level Class VI-X and rest 132 (2.0%) were SSC and above.

Table 3: Distribution of the respondent's husband by educational level

Educational level	Frequency	Percentage
Illiterate	396	06.0
Non-formal education	1241	18.8
Class I-V	1326	20.1
Class VI-X	1782	27.0
SSC and above	1855	28.1
Total	**6600**	**100.0**

Table 3 shows the distribution of the respondent's husband by educational level. Among them 396 (6.0%) were illiterate, 1241 (18.8%) had non-formal education, 1326 (20.1%) had educational level Class I-V, 1782 (27.0%) had educational level Class VI-X and rest 1855 (28.1%) were SSC and above.

Table 4: Distribution mean±SD of height, weigh, Hb%, monthly family income, age at marriage and duration of marriage of the respondents

Anthropometric measurement	Mean ±SD	Min-Max
Height	155.5±8.94	147-164.00
Weight	53.5±9.52	41-66
Haemoglobin	10.04±1.14	8.30-13.00
Monthly family income	4519.28±1512.52	2500-10000
Age at Marriage	19.71± (2.47)	15-25
Duration of marital life	6.04±3.7	2-16

Table 4 shows the distribution of mean±SD of height, weigh, Hb%, monthly family income, age at marriage and duration of marriage of the respondents. Mean ±SD of height of the respondents was 155.5±8.94 cm with a range of 147-164 cm, mean ±SD of weight 53.5±9.52 kg with a range 41-66 kg. Mean ±SD of haemoglobin was 10.04±1.14 gm/dl with a range of 8.30-13.00 gm/dl. Mean ±SD of monthly family income of the respondents was 4519.28±1512.52 BDT with a range of 2500-10000 BDT. Mean ±SD of age at marriage was 19.71± (2.47) years with a range of 15 to 25 years. Mean ±SD of duration of marital life was 6.04±3.7 years with a range of 2 to 16 years.

Table 5: Distribution of the respondents by reproductive history

	Frequency	Percentage
Gravida		
Primi gravida	3571	54.1
Multi gravida	3029	45.9
Para		
1	3590	54.4
2	2350	35.6
3	660	10.0
Planned pregnancy		
Yes	6316	95.7
No	053	0.8
Missing information	231	3.5
Mode of delivery		
Vaginal	5392	81.7
C/S	1208	18.3

Table 5 shows the distribution of the respondents by reproductive history. Among the respondents 3571 (54.1%) were primi gravida and 3029 (45.9%) were multi gravida. 3590 (54.4%) had the history of para 1, 2350 (35.6%) were para 2 and rest 660 (10.0%) were para 3. Most of the respondents (95.7%) gave history of planned pregnancy. Mode of delivery among 5392 (81.7%) cases was vaginal and rest 1298 (18.3%) had history of cesarean section.

CROWN-RUMP-LENGTH

Table 6 shows summary of measurements of crown-rump-length (CRL) (cm) as a function of gestational age. It gives the observed values. Total number of patients was 6600. The table gives the number of observation in each week, from 13 to 40 weeks gestational age and 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles of crown-rump-length at each week of gestation. It also gives the mean and ±2 standard deviations (±2SD) of the observed values. Table 7 shows the fitted 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles of crown-rump-length (cm) with 95% confidence of interval (CI). It also gives estimated mean and ±2 standard deviations (±2SD) of the data. The coefficient of multiple correlation R^2=0.982 ($p<0.001$), which indicates a good correlation between the two variables.

There was gradual increase of 2 standard deviations towards twelve weeks, from 3.4 mm to 6.9 cm. Graph 1 shows raw data for crown-lump-length with fitted, 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} centile curves superimposed on it and in Graph 2, the values ±2 standard deviations are superimposed on the residual plot to see how well the standard deviation has been modeled. Plot of standard deviation score (standardized residuals) against gestational age for crown-rump-length, shows expected 2 standard deviations.

Table 6: Summary of measurement of crown-rump length (Observed)

				Crown-Rump-Length						
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
8	200	19.2	2.9	16.9	17.1	17.9	19.2	20.4	21.2	21.4
9	199	26.6	5.3	23.2	23.6	24.7	26.6	28.5	29.6	30.0
10	200	35.5	5.5	31.9	32.3	33.5	35.5	37.5	38.7	39.1
11	201	46.4	5.7	41.8	42.3	43.9	46.4	49.0	50.5	51.0
12	200	59.2	8.9	54.5	55.0	56.6	59.2	61.8	63.4	63.9

Table 7: Fitted Centiles of Crown-Rump-Length (Estimated)

		Crown-Rump-Length								
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
8	200	21.5	3.4	19.0	19.3	20.1	21.5	22.9	23.7	24.0
9	199	27.9	4.8	23.7	24.1	25.5	27.9	30.2	31.6	32.1
10	200	37.1	5.6	32.5	33.0	34.5	37.1	39.6	41.2	41.7
11	201	48.4	4.9	43.8	44.3	45.9	48.4	51.0	52.5	53.0
12	200	59.8	6.9	53.1	53.9	56.1	59.8	63.5	65.8	66.5

Fitted model CRL

Mean=0.108-3.462w+0.666w^2

SD=2.1940+0.08*w*

R^2=0.982(p<0.001)

Table 7 fitted percentiles of crown-rump-length (cm) estimated values. As can be seen above, the regression of best fit is given when *a*=0.108, *b*=3.462 and *c*=0.666. Where a, b coefficient and c is constant. The form of quardratic equation of regression is given by y=aw^2+bw+c. Here, w=independent variable (gestational age) and y is dependent variable (Crown-rump-length). Substituting the values for a, b and c into this form gives the equation for the quadratic function best fitting the data set.

y=0.108-3.462w+0.666w^2

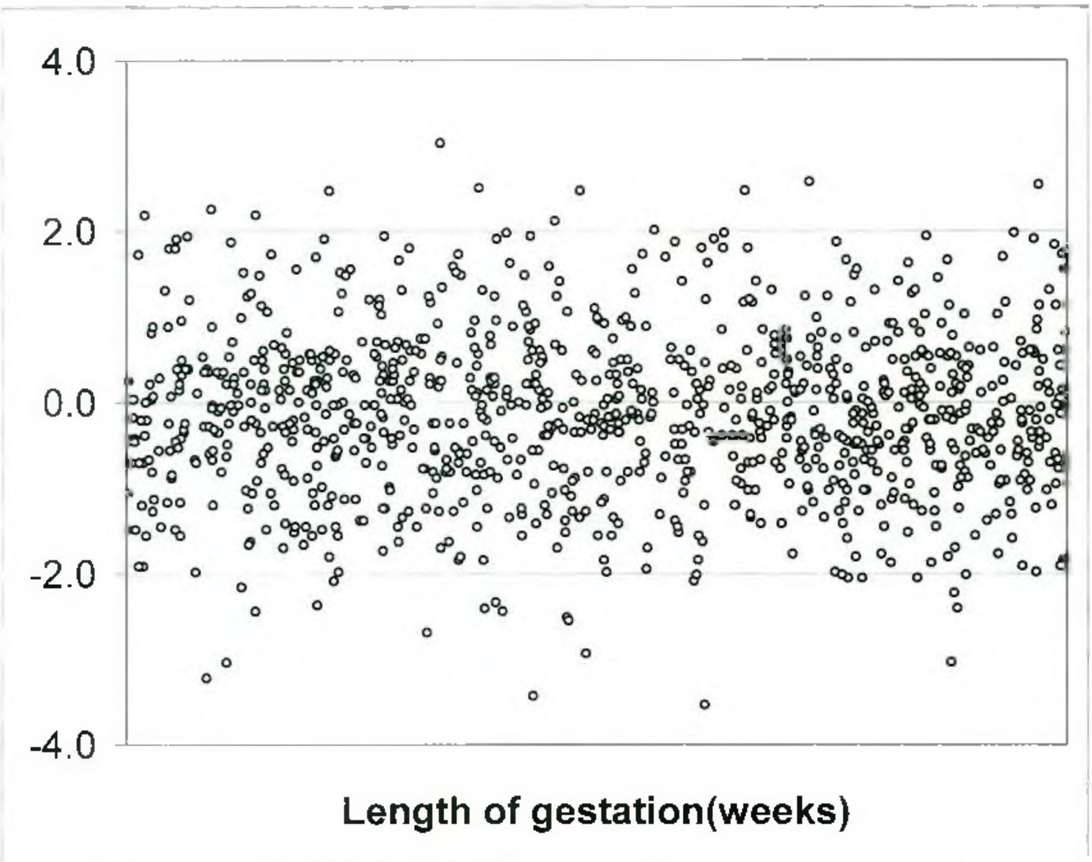


Fig 1: Assessment of fit of model for crown-rump-length plotted: Plot of standard deviation score against gestational age.

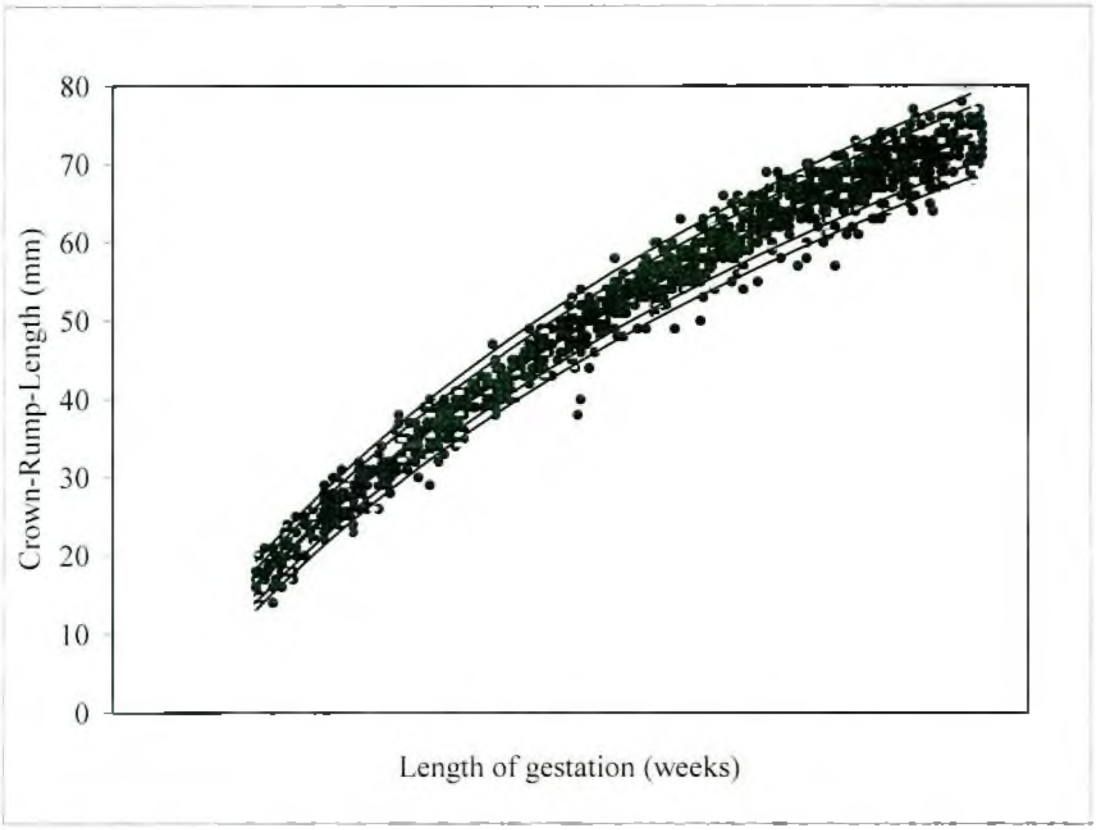


Fig 2: Raw data for crown-rump-length with fitted 5th, 10th, 50th, 90th and 95th centiles.

BIPARIETAL DIAMETER

Table 8 shows summary of measurements of biparietal diameter (BPD) (mm) as a function of gestational age. It gives the observed values. Total number of patients was 6600. The table gives the number of observation in each week, from 13 to 40 weeks gestational age and 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles of biparietal diameter at each week of gestation. It also gives the mean and ±2 standard deviations (±2SD) of the observed values. Table 9 shows the fitted 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles of fetal biparietal diameter (mm) with 95% confidence of interval (CI). It also gives estimated mean and ±2 standard deviations (±2SD) of the data. The coefficient of multiple correlation R^2=0.977 *(p<0.001)*, which indicates a good correlation between the two variables.

There was gradual increase of 2 standard deviations towards term, from 3.1 mm to 8 mm. Graph 3 shows raw data for biparietal diameter with fitted, 5th, 10th, 25th, 50th, 75th, 90th and 95th centile curves superimposed on it and in Graph 4, the values ±2 standard deviations are superimposed on the residual plot to see how well the standard deviation has been modeled. Plot of standard deviation score (standardized residuals) against gestational age for biparietal diameter, shows expected 2 standard deviations.

Table 8: Summary of measurement of Biparietal diameter (Observed)

Biparietal diameter										
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
13	200	23.3	2.3	20.6	20.9	21.8	23.3	24.8	25.7	26
14	200	25.18	2.8	23.3	23.6	24.8	25.18	28.5	29.6	29.9
15	200	29.64	3.2	26.2	26.6	27.9	29.64	32.1	33.4	33.8
16	200	33.56	4.3	28.9	29.4	31.2	33.56	36.9	38.6	39.1
17	200	37.2	3.1	33.7	34.1	35.4	37.2	39.5	40.7	41.1
18	200	40.62	3.5	36.9	37.3	38.8	40.62	43.5	44.9	45.3
19	200	44.53	3.3	40.1	40.6	41.9	44.53	46.3	47.6	48.1
20	201	47.2	3.4	43.1	43.5	44.9	47.2	49.4	50.7	51.2
21	200	50.64	3.4	45.8	46.2	47.6	50.64	52.1	53.4	53.9
22	201	53.87	3.2	48.9	49.4	50.7	53.87	55	56.2	56.7
23	200	56.91	3.4	52	52.4	53.8	56.91	58.3	59.6	60.1
24	200	59.8	4.5	53.7	54.3	56.1	59.8	62.1	63.9	64.5
25	200	62.67	3.8	57.5	58	59.6	62.67	64.7	66.2	66.7
26	201	65.24	4.1	60.2	60.7	62.4	65.24	67.9	69.5	70.1
27	200	68.13	4.6	61.8	62.4	64.3	68.13	70.4	72.2	72.8
28	200	70.54	4.5	64.8	65.4	67.2	70.54	73.2	75	75.6
29	200	73.23	4.1	68.1	68.6	70.3	73.23	75.8	77.4	78
30	200	75.84	4.3	70.5	71	72.8	75.84	78.5	80.2	80.7
31	200	78.06	5	71.6	72.2	74.3	78.06	81	83	83.6
32	200	80.62	4.7	74.1	74.8	76.7	80.62	83	.84.8	85.5
33	200	83.5	3.8	77.8	78.3	79.9	83.5	85	86.5	87
34	200	85.43	4.1	80	80.5	82.2	85.43	87.7	89.3	89.9
35	200	87.84	4.8	80.3	81	82.9	87.84	89.3	91.2	91.9
36	200	89.94	5.9	79.8	80.6	82.9	89.94	90.7	93	93.8
37	200	92.17	5.4	82.1	82.8	85	92.17	92.2	94.4	95.1
38	200	94.07	4.9	83.2	83.8	85.8	94.07	92.3	94.2	94.9
39	199	96.47	5.6	83.2	83.9	86.2	96.47	93.7	95.9	96.7
40	200	96.70	4.4	83.7	84.0	86.4	96.70	93.8	96.04	95.9

Table 9: Fitted Centiles of biparietal diameter (Estimated)

				Biparietal Diameter						
Wks	n	Mean	2SD	5^{th}	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}	95^{th}
13	200	24.2	3.1	21.5	21.8	22.7	24.2	25.7	26.6	26.9
14	200	27.2	3.9	23.9	24.2	25.4	27.2	29.1	30.2	30.5
15	200	30.3	3.8	26.5	26.9	28.2	30.3	32.4	33.7	34.1
16	200	33.8	5.0	28.7	29.2	31.0	33.8	36.7	38.4	38.9
17	200	37.5	6.7	33.8	34.2	35.5	37.5	39.6	40.8	41.2
18	200	40.3	6.6	36.1	36.5	38.0	40.3	42.7	44.1	44.5
19	200	43.7	5.8	39.7	40.2	41.5	43.7	45.9	47.2	47.7
20	201	46.6	4.0	42.6	43.0	44.4	46.6	48.9	50.2	50.7
21	200	50.2	6.2	46.2	46.6	48.0	50.2	52.5	53.8	54.3
22	201	53.3	3.6	49.4	49.9	51.2	53.3	55.5	56.7	57.2
23	200	56.7	3.5	52.7	53.1	54.5	56.7	59.0	60.3	60.8
24	200	59.6	5.6	54.2	54.8	56.6	59.6	62.6	64.4	65.0
25	200	62.6	5.8	58.0	58.5	60.1	62.6	65.2	66.7	67.2
26	201	65.6	4.8	60.7	61.2	62.9	65.6	68.4	70.0	70.6
27	200	68.2	4.5	62.7	63.3	65.2	68.2	71.3	73.1	73.7
28	200	70.9	5.8	65.5	66.1	67.9	70.9	73.9	75.7	76.3
29	200	73.7	5.5	68.8	69.3	71.0	73.7	76.5	78.1	78.7
30	200	76.3	8.0	71.2	71.7	73.5	76.3	79.2	80.9	81.4
31	200	78.5	4.8	72.5	73.1	75.2	78.5	81.9	83.9	84.5
32	200	80.8	6.5	75.1	75.8	77.7	80.8	84.0	85.8	86.5
33	200	82.7	3.4	78.1	78.6	80.2	82.7	85.3	86.8	87.3
34	200	84.9	4.1	80.0	80.5	82.2	84.9	87.7	89.3	89.9
35	200	86.6	6.2	80.8	81.5	83.4	86.6	89.8	91.7	92.4
36	200	88.1	6.1	81.1	81.9	84.2	88.1	92.0	94.3	95.1
37	200	89.4	7.0	82.9	83.6	85.8	89.4	93.0	95.2	95.9
38	200	90.5	5.0	84.7	85.3	87.3	90.5	93.8	95.7	96.4
39	199	91.5	5.2	84.8	85.5	87.8	91.5	95.3	97.5	98.3
40	200	92.3	5.7	87.1	87.7	89.4	92.3	95.2	96.9	97.5

Fitted model BPD

$$\text{Mean} = -10.183 + 1.769w + 0.089w^2 - 0.002w^3$$

$$\text{SD} = 2.4434 + 0.1271\,w$$

$$R^2 = 0.978\ (p<0.001)$$

As can be seen above, the regression of best fit is given when a=-0.002, b=0.089, c=1.769 and d=-10.183. Where a, b, c coefficient and d is constant. The form of cubic equation of regression is given by $y=aw^3+bw^2+cw+d$. Here, w=independent variable (gestational age) and y is dependent variable (Biparietal diameter). Substituting the values for a, b, c and d into this form gives the equation for the quadratic function best fitting the data set.

$$y = -10.183 + 1.769w + 0.089w^2 - 0.002w^3$$

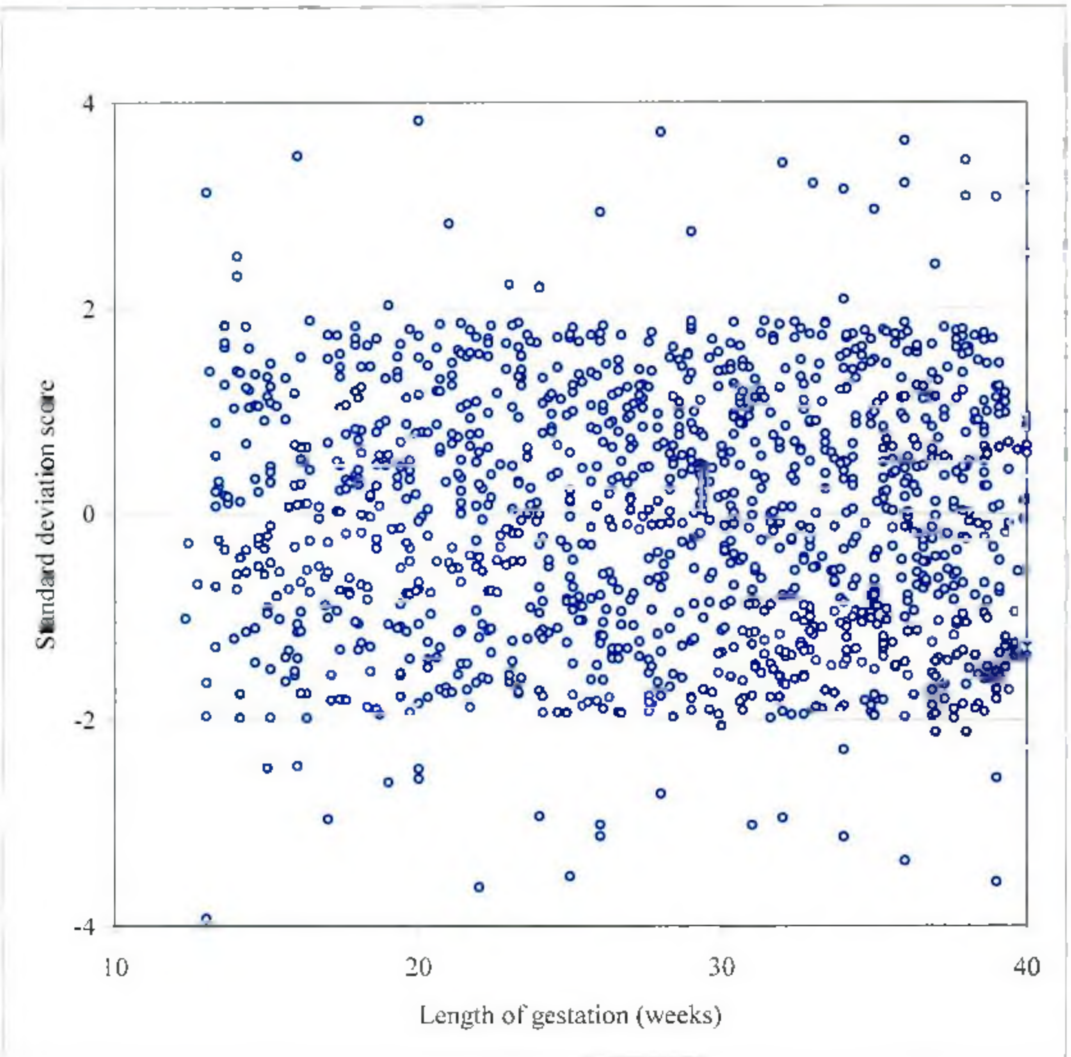


Fig 3: Assessment of fit of model for biparietal diameter plotted: Plot of standard deviation score against gestational age.

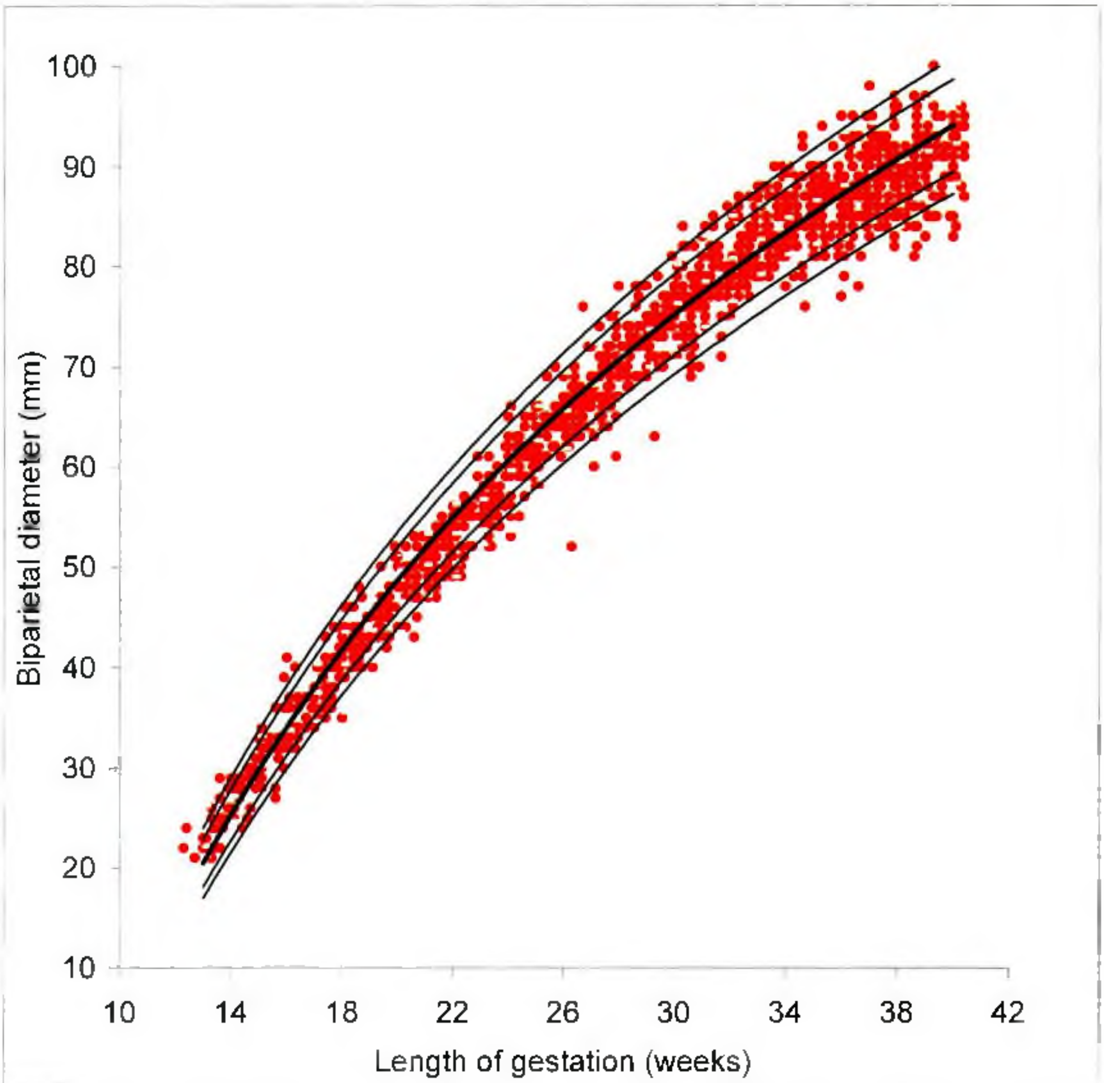


Fig 4: Raw data for Biparietal diameter with fitted 5th, 10th, 50th, 90th and 95th centiles.

Biparietal diameter (mm)	Gestational Age (weeks) Mean (w)	2SD (w)
21	13.2	0.7
22	13.4	0.7
23	13.6	0.7
24	13.8	0.7
25	14.0	0.8
26	14.2	0.8
27	14.4	0.8
28	14.7	0.8
29	14.9	0.9
30	15.2	0.9
31	15.4	0.9
32	15.7	0.9
33	15.9	1.0
34	16.2	1.0
35	16.5	1.0
36	16.8	1.1
37	17.0	1.1
38	17.3	1.1
39	17.6	1.1
40	17.9	1.2
41	18.3	1.2
42	18.6	1.2
43	18.9	1.2
44	19.2	1.3
45	19.6	1.3
46	19.9	1.3
47	20.2	1.3
48	20.6	1.4
49	21.0	1.4
50	21.3	1.4
51	21.7	1.4
52	22.1	1.5
53	22.4	1.5
54	22.8	1.5
55	23.2	1.6
56	23.6	1.6
57	24.0	1.6
58	24.4	1.6
59	24.8	1.7
60	25.2	1.7

Cont...

Biparietal diameter (mm)	Gestational Age (weeks) Mean (w)	2SD (w)
61	25.6	1.7
62	26.1	1.7
63	26.5	1.8
64	26.9	1.8
65	27.4	1.8
66	27.8	1.8
67	28.3	1.9
68	28.7	1.9
69	29.2	1.9
70	29.6	1.9
71	30.1	2.0
72	30.6	2.0
73	31.0	2.0
74	31.5	2.1
75	32.0	2.1
76	32.5	2.1
77	33.0	2.1
78	33.5	2.2
79	34.0	2.2
80	34.5	2.2
81	35.0	2.2
82	35.5	2.3
83	36.1	2.3
84	36.6	2.3
85	37.1	2.3
86	37.6	2.4
87	38.2	2.4
88	38.7	2.4
89	39.3	2.5
90	39.8	2.5
91	40.4	2.5
92	40.9	2.5

Fitted model weeks of gestation for BPD

$$\text{Mean} = 10.5966 + 0.0493 BPD + 0.0036\, BPD^2 - 0.000006\, BPD^3$$

$$SD = 0.0966 + 0.0264\, BPD$$

R^2=0.963 ($p<0.001$)

FEMUR LENGTH

Table 10 shows summary of measurements of observed of fetal femur length (FL) (mm), as a function of gestational age. Total number of patients was 6600. The table gives the number of observation in each week, from 13 to 40 weeks gestational age and 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles, of femur length at each week of gestation. It also gives the mean and ±2 standard deviations (±2SD) of the observed values. Table 11 shows the fitted 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles of femur length (mm) with 95% confidence of interval (CI). It also gives estimated mean and ±2 standard deviations (±2SD) of the data. The coefficient of multiple correlation R^2=0.982 *($p<0.001$)*, which indicates a good correlation between the two variables.

There was gradual increase of 2 standard deviations towards term, from 3.3 mm to 5.7 mm. Graph 5 shows raw data for femur length with fitted, 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} centile curves superimposed on it and in Graph 6, the values ±2 standard deviations are superimposed on the residual plot to see how well the standard deviation has been modeled. Plot of standard deviation score (standardized residuals) against gestational age for femur length, shows expected 2 standard deviations.

Table 10: Summary of measurement of femur length (Observed)

						Femur Length				
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
13	200	11.9	2.8	26.4	26.8	28.0	30.6	32.0	33.2	33.6
14	200	14.58	2.9	28.7	29.2	30.6	33.3	35.4	36.8	37.3
15	200	16.6	2.9	29.8	30.3	31.9	35.9	37.1	38.7	39.2
16	200	21.3	2.9	33.8	34.2	35.3	38.5	39.1	40.2	40.6
17	200	24.34	3.0	38.6	39.0	40.3	41.4	44.5	45.8	46.2
18	200	27.19	3.1	40.3	40.6	41.5	43.8	44.4	45.3	45.6
19	200	30.58	3.1	42.4	42.7	43.8	46.3	47.3	48.3	48.7
20	201	33.31	3.2	39.5	40.3	42.5	48.7	49.9	52.1	52.9
21	200	35.9	3.2	45.2	45.6	47.0	51.0	51.7	53.1	53.5
22	201	38.47	3.3	48.5	48.9	50.3	53.2	54.8	56.1	56.6
23	200	41.37	3.4	50.6	51.1	52.6	55.8	57.5	59.0	59.5
24	200	43.77	3.5	52.3	52.8	54.2	58.0	58.9	60.4	60.8
25	200	46.34	3.5	52.5	53.1	55.1	60.1	61.6	63.5	64.2
26	201	48.74	3.6	55.1	55.7	57.4	62.7	63.1	64.9	65.4
27	200	50.97	3.7	57.6	58.2	60.0	64.8	66.0	67.8	68.4
28	200	53.24	3.8	58.3	58.9	60.8	66.7	66.9	68.8	69.4
29	200	55.77	3.8	60.0	60.6	62.3	65.2	68.1	69.8	70.4
30	200	58.04	3.8	61.6	62.1	63.8	66.7	69.5	71.2	71.7
31	200	60.1	3.9	63.6	64.1	65.8	68.5	71.3	72.9	73.5
32	200	62.66	4.0	65.3	65.9	67.8	70.9	73.9	75.8	76.4
33	200	64.76	4.1	65.3	65.8	67.5	70.4	73.2	74.9	75.4
34	200	66.66	4.1	68.6	69.1	70.6	73.0	75.5	76.9	77.4
35	200	65.2	2.8	26.4	26.8	28.0	30.6	32.0	33.2	33.6
36	200	66.7	2.9	28.7	29.2	30.6	33.3	35.4	36.8	37.3
37	200	68.5	2.9	29.8	30.3	31.9	35.9	37.1	38.7	39.2
38	200	70.9	2.9	33.8	34.2	35.3	38.5	39.1	40.2	40.6
39	199	70.4	3.0	38.6	39.0	40.3	41.4	44.5	45.8	46.2
40	200	73.0	3.1	40.3	40.6	41.5	43.8	44.4	45.3	45.6

Table 11: Fitted Centiles of femur length (estimated)

				Femur Length						
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
13	200	10.7	3.3	7.7	8.1	9.0	10.7	12.3	13.3	13.6
14	200	13.9	3.3	10.8	11.1	12.2	13.9	15.7	16.7	17.1
15	200	17.1	3.3	13.9	14.3	15.3	17.1	18.8	19.8	20.2
16	200	20.6	3.4	17.4	17.7	18.8	20.6	22.4	23.5	23.8
17	200	24.1	3.6	20.8	21.1	22.3	24.1	26.0	27.1	27.4
18	200	26.8	3.6	23.4	23.8	24.9	26.8	28.7	29.8	30.2
19	200	29.8	3.8	26.4	26.8	27.9	29.8	31.7	32.8	33.2
20	201	32.4	3.8	28.9	29.3	30.5	32.4	34.4	35.5	35.9
21	200	35.5	4.0	31.9	32.3	33.5	35.5	37.5	38.7	39.1
22	201	38.4	3.9	34.7	35.1	36.4	38.4	40.5	41.7	42.1
23	200	41.1	4.1	37.4	37.8	39.1	41.1	43.2	44.4	44.8
24	200	43.6	4.2	39.7	40.2	41.4	43.6	45.7	47.0	47.4
25	200	46.1	4.3	42.2	42.7	43.9	46.1	48.2	49.5	49.9
26	201	48.5	4.3	44.6	45.1	46.4	48.5	50.7	51.9	52.4
27	200	50.7	4.4	46.6	47.1	48.4	50.7	52.9	54.2	54.7
28	200	52.8	4.6	48.7	49.2	50.5	52.8	55.0	56.3	56.8
29	200	55.1	4.5	51.0	51.4	52.8	55.1	57.4	58.8	59.2
30	200	57.4	4.6	53.1	53.6	55.0	57.4	59.8	61.2	61.7
31	200	59.1	4.7	54.8	55.3	56.7	59.1	61.4	62.9	63.3
32	200	61.2	4.9	56.7	57.2	58.7	61.2	63.7	65.2	65.7
33	200	62.8	4.9	58.3	58.8	60.3	62.8	65.2	66.7	67.2
34	200	64.7	5.0	60.1	60.6	62.2	64.7	67.3	68.8	69.3
35	200	66.5	5.0	61.8	62.3	63.9	66.5	69.0	70.6	71.1
36	200	68.0	5.2	63.2	63.8	65.3	68.0	70.6	72.2	72.7
37	200	69.3	5.4	64.5	65.1	66.6	69.3	71.9	73.5	74.0
38	200	70.6	5.4	65.7	66.3	67.9	70.6	73.3	74.9	75.5
39	199	71.9	5.5	67.0	67.5	69.2	71.9	74.7	76.3	76.9
40	200	73.3	5.7	68.3	68.8	70.5	73.3	76.1	77.8	78.3

Fitted model Femur Length

$$\text{Mean} = -42.083 + 4.5764w - 0.0424w^2$$

$$\text{SD} = 2.1964 + 0.09w$$

$$R^2=0.982 \ (p<0.001)$$

As can be seen above, the regression of best fit is given when a=-0.0424, b=4.576 and c=-42.083. Where a and b coefficient c is constant. The form of quadratic quation of regression is given by $y=aw^2+bw+c$. Here, w=independent variable (gestational age) and y is dependent variable (femur length). Substituting the values for a, b and c into this form gives the equation for the quadratic function best fitting the data set.

$$y = -42.083 + 4.5764w - 0.0424w^2$$

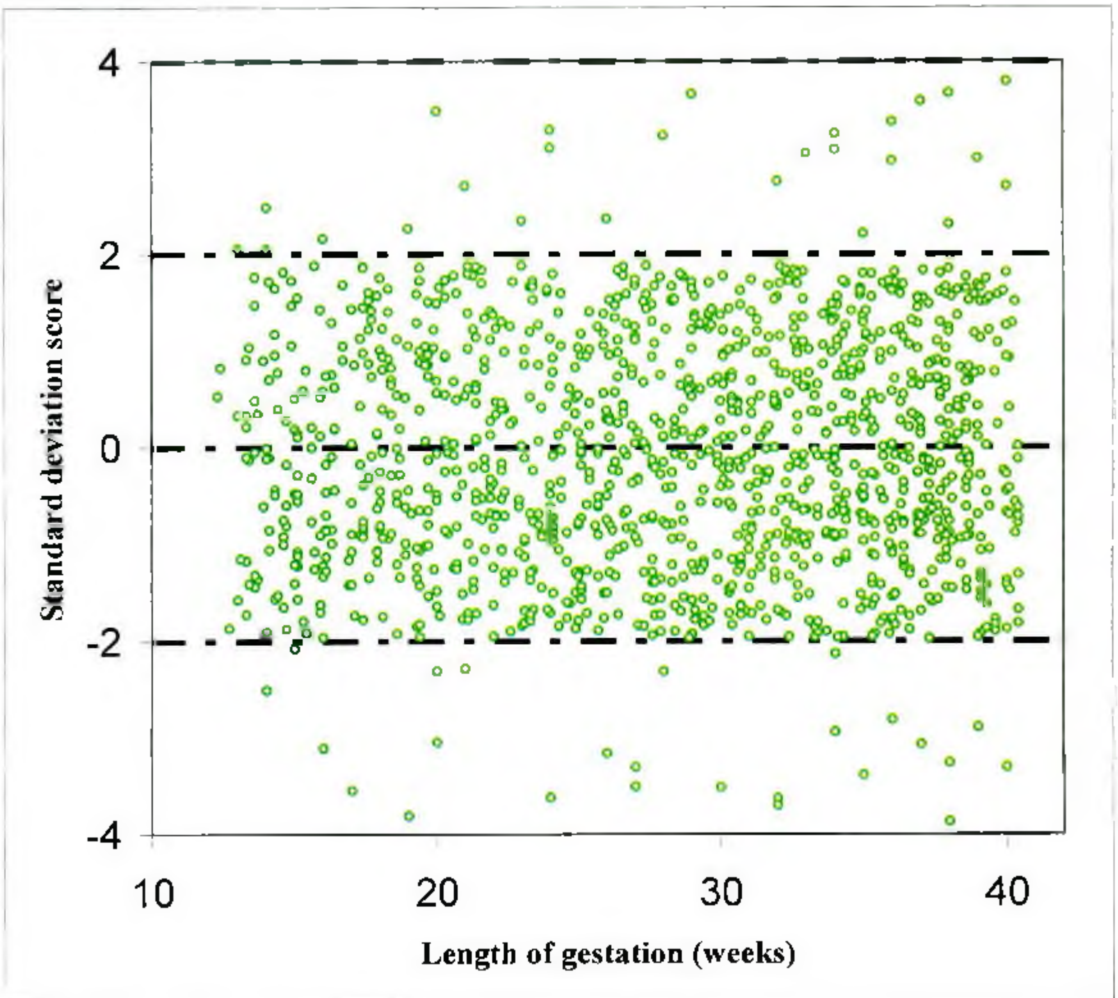


Fig 5: Assessment of fit of model for femur length: Plot of standard deviation score against gestational age.

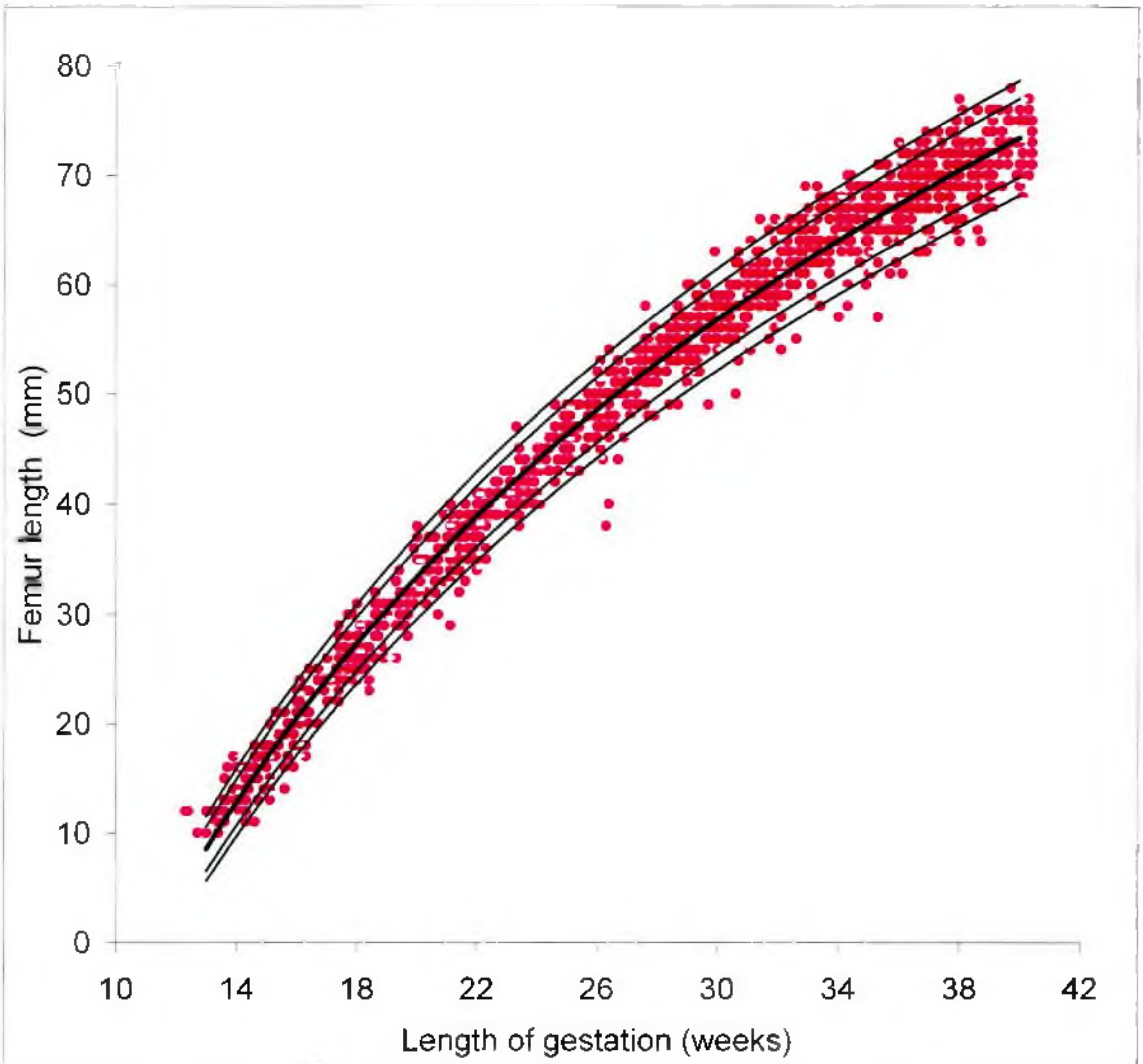


Fig 6: Raw data for femur length with fitted 5th, 10th, 50th, 90th and 95th centiles.

	Gestational age (Weeks)	
Femur length (mm)	Mean(w)	2SD (w)
10	13.2	0.75
11	13.5	0.79
12	13.7	0.83
13	14.0	0.87
14	14.3	0.91
15	14.5	0.94
16	14.8	0.98
17	15.1	1.02
18	15.4	1.06
19	15.6	1.09
20	15.9	1.13
21	16.2	1.17
22	16.5	1.21
23	16.8	1.25
24	17.2	1.28
25	17.5	1.32
26	17.8	1.36
27	18.1	1.40
28	18.5	1.43
29	18.8	1.47
30	19.2	1.51
31	19.5	1.55
32	19.9	1.59
33	20.2	1.62
34	20.6	1.66
35	21.0	1.70
36	21.3	1.74
37	21.7	1.78
38	22.1	1.81
39	22.5	1.85
40	22.9	1.89

Cont….

Femur Length (mm)	Gestational age (Weeks) Mean(w)	2SD (w)
41	23.3	1.93
42	23.7	1.96
43	24.1	2.00
44	24.5	2.04
45	25.0	2.08
46	25.4	2.12
47	25.8	2.15
48	26.3	2.19
49	26.7	2.23
50	27.2	2.27
51	27.6	2.30
52	28.1	2.34
53	28.5	2.38
54	29.0	2.42
55	29.5	2.46
56	30.0	2.49
57	30.4	2.53
58	30.9	2.57
59	31.4	2.61
60	31.9	2.64
61	32.4	2.68
62	32.9	2.72
63	33.5	2.76
64	34.0	2.80
65	34.5	2.83
66	35.0	2.87
67	35.6	2.91
68	36.1	2.95
69	36.7	2.98
70	37.2	3.02
71	37.8	3.06
72	38.4	3.10
73	38.9	3.14
74	39.5	3.17

Fitted model weeks of gestation for Femur Length

$$\text{Mean} = 11.0630 + 0.1918FL + 0.0026\,FL^2$$

$$\text{SD} = 0.3764 + 0.0378\,FL$$

$$R^2=0.975\ (p<0.001)$$

HEAD CIRCUMFERENCE

Table 12 shows summary of measurements of observed of head circumference (HC) (mm), as a function of gestational age. Total number of patients was 6600. The table gives the number of observation in each week, from 13 to 40 weeks gestational age and 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles, of head circumference at each week of gestation. It also gives the mean and ±2 standard deviations (±2SD) of the observed values. Table 13 shows the fitted 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles of head circumference (mm) with 95% confidence of interval (CI). It also gives estimated mean and ±2 standard deviations (±2SD) of the data. The coefficient of multiple correlation R^2=0.998 ($p<0.001$), which indicates a good correlation between the two variables.

There was gradual increase of ±2 standard deviations towards term, from 11.9 mm to 28.0 mm. Graph 7 shows raw data for femur length with fitted, 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} centile curves superimposed on it and in Graph 8, the values ±2 standard deviations are superimposed on the residual plot to see how well the standard deviation has been modeled. Plot of standard deviation score (standardized residuals) against gestational age for head circumference, shows expected 2 standard deviations.

Table 12: Summary of measurement of head circumference (Observed)

				Head Circumference						
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
13	200	90.00	8.6	78.3	79.6	83.5	90.0	96.4	100.3	101.6
14	200	98.10	8.8	84.5	86.0	90.6	98.1	105.7	110.2	111.7
15	200	111.20	9.1	98.4	99.8	104.1	111.2	118.3	122.6	124.0
16	200	121.00	9.6	100.3	102.6	109.5	121.0	132.5	139.4	141.7
17	200	144.60	9.9	132.4	133.7	137.8	144.6	151.3	155.4	156.7
18	200	152.00	10.2	137.6	139.2	144.0	152.0	160.0	164.8	166.4
19	200	164.50	10.5	146.1	148.1	154.3	164.5	174.8	180.9	183.0
20	201	172.00	10.8	157.6	159.2	164.0	172.0	180.0	184.8	186.4
21	200	181.50	11.2	168.5	169.9	174.3	181.5	188.8	193.1	194.6
22	201	195.50	11.6	184.3	185.5	189.3	195.5	201.8	205.5	206.8
23	200	208.00	12.0	195.4	196.8	201.0	208.0	215.0	219.2	220.6
24	200	218.50	12.3	201.9	203.7	209.3	218.5	227.8	233.3	235.2
25	200	230.00	12.6	215.6	217.2	222.0	230.0	238.0	242.8	244.4
26	201	232.50	12.9	210.5	212.9	220.3	232.5	244.8	252.1	254.6
27	200	250.00	13.3	231.1	233.2	239.5	250.0	260.5	266.8	268.9
28	200	254.50	13.6	235.2	237.3	243.8	254.5	265.3	271.7	273.9
29	200	263.00	13.9	245.0	247.0	253.0	263.0	273.0	279.0	281.0
30	200	280.00	14.4	262.9	264.8	270.5	280.0	289.5	295.2	297.1
31	200	286.50	14.7	265.4	267.7	274.8	286.5	298.3	305.3	307.7
32	200	292.00	15.0	269.5	272.0	279.5	292.0	304.5	312.0	314.5
33	200	303.00	15.3	285.9	287.8	293.5	303.0	312.5	318.2	320.1
34	200	307.50	15.7	290.0	291.9	297.8	307.5	317.3	323.1	325.1
35	200	309.00	16.0	288.3	290.6	297.5	309.0	320.5	327.4	329.7
36	200	322.50	16.4	296.9	299.7	308.3	322.5	336.8	345.3	348.2
37	200	324.00	16.7	305.1	307.2	313.5	324.0	334.5	340.8	342.9
38	200	324.00	27.1	303.3	305.6	312.5	324.0	335.5	342.4	344.7
39	199	326.00	23.4	299.0	302.0	311.0	326.0	341.0	350.0	353.0
40	200	332.00	19.8	300.4	302.8	310.0	332.0	337.0	341.2	343.6

Table 13: Fitted centiles of head circumference (estimated)

Head Circumference										
Weeks	n	Mean	2SD	5^{th}	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}	95^{th}
13	200	89.8	11.9	79.3	80.4	84.0	89.8	95.7	99.2	100.4
14	200	99.9	13.4	88.9	90.1	93.8	99.9	106.0	109.7	110.9
15	200	111.7	14.2	100.5	101.7	105.5	111.7	118.0	121.7	123.0
16	200	125.1	17.5	113.3	114.6	118.6	125.1	131.7	135.6	136.9
17	200	139.4	13.0	127.1	128.4	132.6	139.4	146.3	150.4	151.8
18	200	149.9	15.8	137.3	138.7	142.9	149.9	156.9	161.1	162.5
19	200	162.3	17.4	149.5	150.9	155.2	162.3	169.5	173.7	175.2
20	201	173.4	15.5	160.1	161.6	166.0	173.4	180.8	185.3	186.8
21	200	186.5	13.5	172.8	174.3	178.9	186.5	194.2	198.7	200.3
22	201	198.1	13.5	183.8	185.4	190.2	198.1	206.1	210.8	212.4
23	200	210.4	15.2	195.7	197.4	202.3	210.4	218.6	223.5	225.2
24	200	220.6	18.2	205.5	207.2	212.2	220.6	229.1	234.1	235.8
25	200	231.6	15.8	216.1	217.8	223.0	231.6	240.3	245.4	247.2
26	201	242.2	18.4	226.4	228.2	233.4	242.2	250.9	256.1	257.9
27	200	251.5	19.0	235.3	237.1	242.5	251.5	260.5	265.9	267.7
28	200	261.2	19.4	244.6	246.4	252.0	261.2	270.5	276.1	277.9
29	200	270.8	20.8	253.9	255.8	261.4	270.8	280.2	285.8	287.7
30	200	280.2	19.7	262.7	264.7	270.5	280.2	289.9	295.7	297.6
31	200	287.8	21.6	269.9	271.9	277.9	287.8	297.8	303.8	305.7
32	200	295.6	24.4	277.4	279.4	285.5	295.6	305.7	311.8	313.8
33	200	302.5	18.5	283.9	285.9	292.1	302.5	312.8	319.0	321.0
34	200	310.0	19.5	290.7	292.9	299.3	310.0	320.8	327.2	329.3
35	200	315.8	22.1	296.3	298.4	305.0	315.8	326.7	333.2	335.4
36	200	321.0	25.1	301.0	303.2	309.9	321.0	332.1	338.8	341.0
37	200	325.4	21.2	305.1	307.3	314.1	325.4	336.6	343.4	345.7
38	200	329.0	23.2	308.3	310.6	317.5	329.0	340.5	347.4	349.7
39	199	332.4	28.0	311.2	313.5	320.6	332.4	344.2	351.3	353.7
40	200	335.0	22.7	313.4	315.8	323.0	335.0	347.0	354.2	356.6

Fitted model Head Circumference

$$\text{Mean} = -100.39 + 9.6667\,w - 0.0499\,w^2$$

$$\text{SD} = 5.6845 + 0.4850\,w$$

$$R^2=0.998 \quad (p<0.001)$$

As can be seen above, the regression of best fit is given when a=-0.0499, b=9.667 and c=-100.39. Where a and b coefficient c is constant. The form of quadratic equation of regression is given by $y=aw^2+bw+c$. Here, w=independent variable (gestational age) and y is dependent variable (Head circumference). Substituting the values for a, b and c into this form gives the equation for the quadratic function best fitting the data set.

$$y = -100.39 + 9.6667\,w - 0.0499\,w^2$$

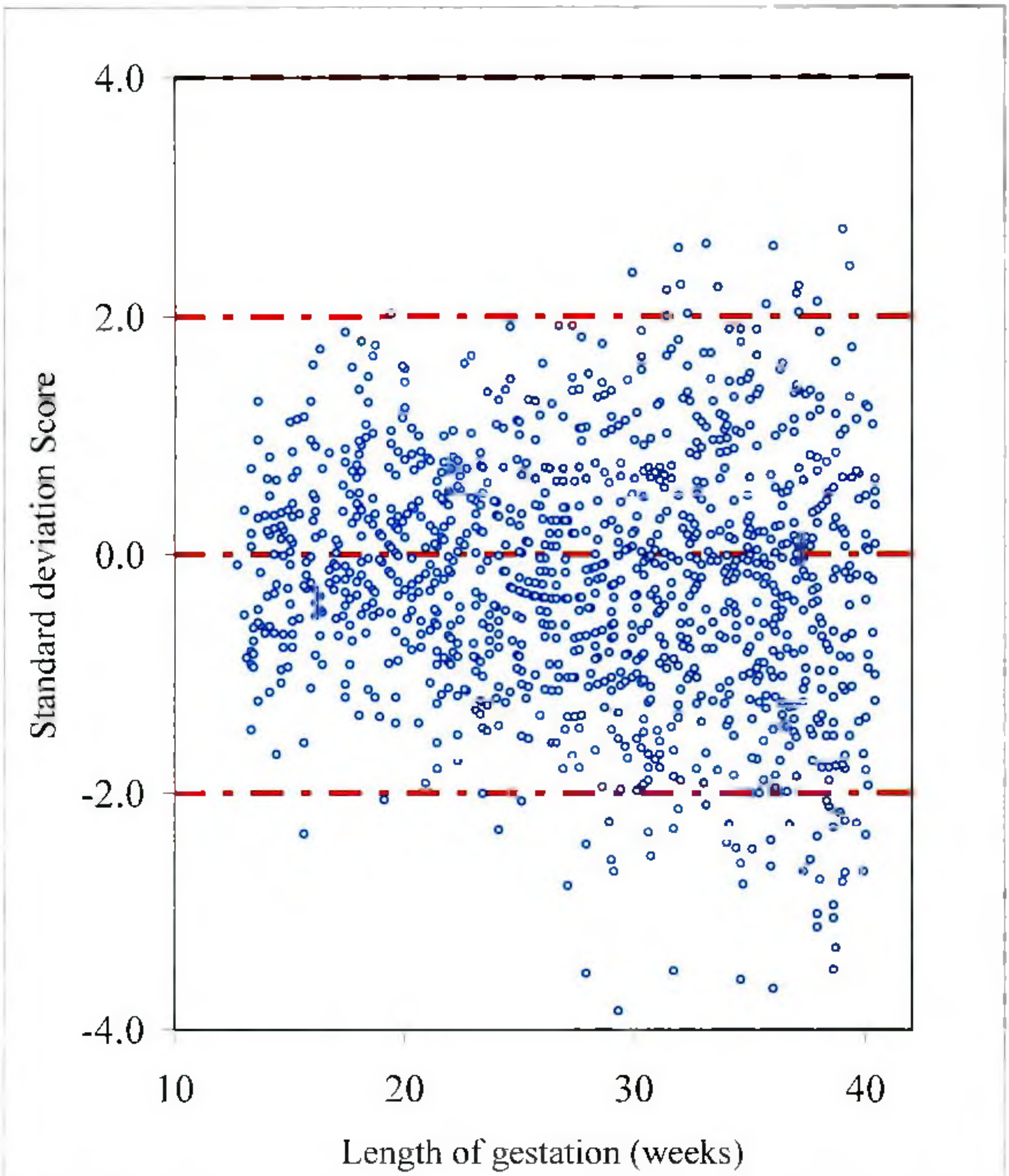


Fig 7: Assessment of fit of model for head circumference: Plot of standard deviation score against gestational age.

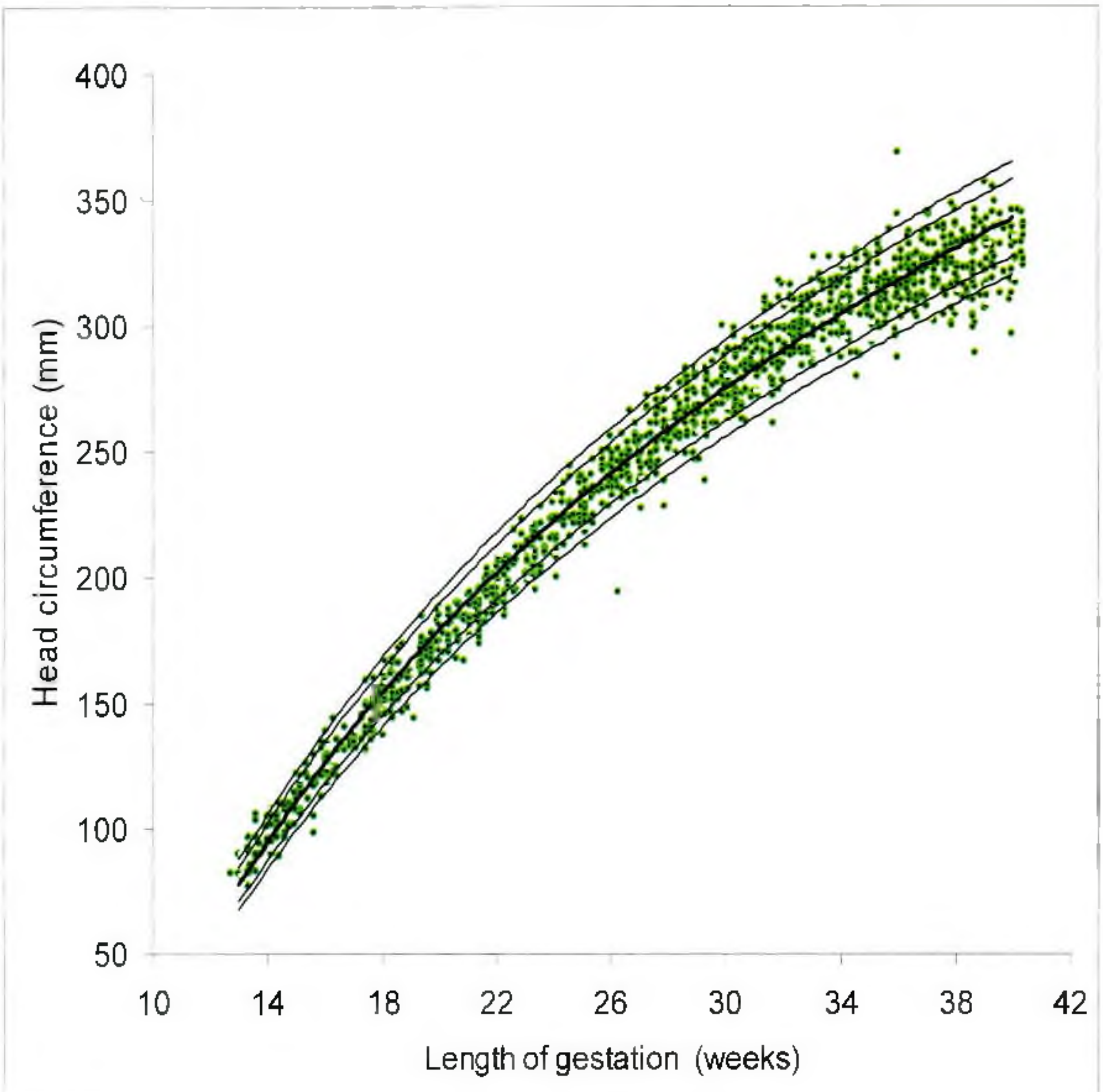


Fig 8: Raw data for head circumference with fitted 5th, 10th, 50th, 90th and 95th centiles.

Head circumference (mm)	Mean (weeks)	2SD (weeks)
85	13.5	0.4
90	13.9	0.5
95	14.1	0.5
100	14.4	0.5
105	14.8	0.6
110	15.1	0.7
115	15.4	0.7
120	15.8	0.8
125	16.1	0.8
130	16.6	0.9
135	16.9	0.9
140	17.3	1.0
145	17.7	1.0
150	18.1	1.1
155	18.5	1.2
160	19.0	1.2
165	19.3	1.3
170	19.8	1.3
175	20.4	1.4
180	20.7	1.4
185	21.4	1.5
190	21.7	1.6
195	22.2	1.6
200	22.7	1.7
205	23.2	1.7
210	23.8	1.8
215	24.3	1.8
220	24.9	1.9
225	25.4	1.9
230	26.1	2.0
235	26.6	2.1
240	27.1	2.1
245	27.7	2.2
250	28.3	2.2
255	29.0	2.3
260	29.5	2.3
265	30.1	2.4
270	30.8	2.4
275	31.5	2.5
280	32.2	2.6
285	32.8	2.6
290	33.5	2.7
295	34.1	2.7

Cont..

Head circumference (mm)	Mean (weeks)	2SD (weeks)
300	34.9	2.8
305	35.6	2.8
310	36.3	2.9
315	37.0	2.9
320	37.7	3.0
325	38.5	3.1
330	39.1	3.1
335	40.0	3.2

Fitted model weeks of gestation for Head circumference

$$\text{Mean} = 9.9894 + 0.0268\,hc + 0.00019\,hc^2$$

$$\text{SD} = -0.5367 + 0.0111\,hc$$

R^2=0.967 ($p<0.001$)

ABDOMINAL CIRCUMFERENCE

Table 14 shows summary of measurements of abdominal circumference (AC) (mm) as a function of gestational age. It gives the observed values. Total number of patients was 6600. The table gives the number of observation in each week, from 13 to 40 weeks gestational age and 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles of abdominal circumference at each week of gestation. It also gives the mean and ±2 standard deviations (±2SD) of the observed values. Table 15 shows the fitted 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles of abdominal circumference (mm) with 95% confidence of interval (CI). It also gives estimated mean and ±2 standard deviations (±2SD) of the data. The coefficient of multiple correlation R^2=0.970 ($p<0.001$), which indicates a good correlation between the two variables.

There was gradual increase of 2 standard deviations towards term, from 7.6 mm to 35.2 mm. Graph 9 shows raw data for abdominal circumference with fitted, 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} centile curves superimposed on it and in Graph 10, the values ±2 standard deviations are superimposed on the residual plot to see how well the standard deviation has been modeled. Plot of standard deviation score (standardized residuals) against gestational age for abdominal circumference, shows expected 2 standard deviations.

Table 14: Summary of measurement of abdominal circumference (observed)

Abdominal Circumference										
Weeks	n	Mean	2SD	5th	10th	25th	50th	75th	90th	95th
13	200	74.5	6.0	63.3	64.5	68.3	74.5	80.8	84.5	85.8
14	200	82.5	6.5	71.3	72.5	76.3	82.5	88.8	92.5	93.8
15	200	90.0	7.3	72.9	74.8	80.5	90.0	99.5	105.2	107.1
16	200	97.5	8.0	77.3	79.5	86.3	97.5	108.8	115.5	117.8
17	200	116.0	8.8	102.5	104.0	108.5	116.0	123.5	128.0	129.5
18	200	121.0	9.4	106.6	108.2	113.0	121.0	129.0	133.8	135.4
19	200	138.5	10.1	121.9	123.7	129.3	138.5	147.8	153.3	155.2
20	201	145.5	10.8	126.2	128.3	134.8	145.5	156.3	162.7	164.9
21	200	155.0	11.5	140.6	142.2	147.0	155.0	163.0	167.8	169.4
22	201	169.5	12.3	152.0	153.9	159.8	169.5	179.3	185.1	187.1
23	200	180.5	13.0	165.7	167.3	172.3	180.5	188.8	193.7	195.4
24	200	180.0	13.6	153.0	156.0	165.0	180.0	195.0	204.0	207.0
25	200	199.0	14.4	183.7	185.4	190.5	199.0	207.5	212.6	214.3
26	201	207.5	15.1	181.9	184.7	193.3	207.5	221.8	230.3	233.2
27	200	213.0	15.8	193.2	195.4	202.0	213.0	224.0	230.6	232.8
28	200	233.5	16.6	212.4	214.7	221.8	233.5	245.3	252.3	254.7
29	200	243.0	17.2	217.8	220.6	229.0	243.0	257.0	265.4	268.2
30	200	251.5	18.1	225.0	227.9	236.8	251.5	266.3	275.1	278.1
31	200	253.5	18.7	222.5	225.9	236.3	253.5	270.8	281.1	284.6
32	200	272.5	19.4	248.7	251.3	259.3	272.5	285.8	293.7	296.4
33	200	277.0	20.1	254.5	257.0	264.5	277.0	289.5	297.0	299.5
34	200	287.0	20.9	257.3	260.6	270.5	287.0	303.5	313.4	316.7
35	200	295.0	21.6	261.7	265.4	276.5	295.0	313.5	324.6	328.3
36	200	311.5	22.3	275.1	279.1	291.3	311.5	331.8	343.9	348.0
37	200	315.5	23.0	289.0	291.9	300.8	315.5	330.3	339.1	342.1
38	200	313.0	23.6	277.9	281.8	293.5	313.0	332.5	344.2	348.1
39	199	318.5	24.2	278.5	282.9	296.3	318.5	340.8	354.1	358.6
40	200	321.0	25.1	285.9	289.8	301.5	321.0	340.5	352.2	356.1

Table 15: Fitted Centiles of Abdominal Circumference (estimated)

Abdominal Circumference										
Weeks	n	Mean	2SD	5^{th}	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}	95^{th}
13	200	72.3	7.6	64.6	65.4	68.0	72.3	76.6	79.2	80.1
14	200	80.4	8.5	72.2	73.1	75.9	80.4	85.0	87.7	88.6
15	200	90.3	9.9	81.3	82.3	85.3	90.3	95.3	98.3	99.3
16	200	102.0	11.1	92.0	93.1	96.4	102.0	107.5	110.8	111.9
17	200	114.6	11.9	103.5	104.8	108.4	114.6	120.7	124.4	125.7
18	200	123.7	12.8	112.0	113.3	117.2	123.7	130.2	134.1	135.4
19	200	135.2	13.5	122.7	124.1	128.3	135.2	142.2	146.4	147.7
20	201	145.1	15.0	131.7	133.2	137.7	145.1	152.6	157.1	158.6
21	200	157.4	15.9	143.1	144.7	149.4	157.4	165.3	170.1	171.7
22	201	168.1	17.2	153.0	154.7	159.7	168.1	176.5	181.5	183.2
23	200	179.9	18.2	163.9	165.7	171.0	179.9	188.9	194.2	196.0
24	200	189.7	19.0	173.0	174.9	180.4	189.7	198.9	204.5	206.3
25	200	200.5	19.5	183.0	185.0	190.8	200.5	210.2	216.0	217.9
26	201	211.7	20.8	193.2	195.2	201.4	211.7	222.0	228.1	230.2
27	200	221.3	22.1	201.9	204.1	210.5	221.3	232.0	238.4	240.6
28	200	231.5	23.2	211.2	213.5	220.2	231.5	242.7	249.5	251.7
29	200	242.1	23.7	221.1	223.5	230.5	242.1	253.8	260.8	263.1
30	200	252.6	25.2	230.6	233.0	240.4	252.6	264.9	272.3	274.7
31	200	261.4	25.9	238.5	241.1	248.7	261.4	274.1	281.7	284.3
32	200	270.8	27.2	247.2	249.8	257.7	270.8	284.0	291.8	294.5
33	200	279.2	27.7	254.8	257.5	265.7	279.2	292.8	300.9	303.6
34	200	289.0	29.3	263.6	266.4	274.9	289.0	303.1	311.6	314.4
35	200	297.1	29.7	271.0	273.9	282.6	297.1	311.6	320.3	323.2
36	200	305.1	31.0	278.0	281.0	290.1	305.1	320.2	329.2	332.2
37	200	312.2	31.5	284.3	287.4	296.7	312.2	327.6	336.9	340.0
38	200	318.8	32.7	290.3	293.4	302.9	318.8	334.6	344.1	347.3
39	199	325.5	33.4	296.0	299.3	309.1	325.5	341.8	351.7	354.9
40	200	332.3	35.2	301.9	305.3	315.4	332.3	349.2	359.4	362.7

Fitted model Abdominal circumference

$$\text{Mean} = -41.694 + 5.9220w + 0.2572w^2 - 0.0043w^3$$

$$\text{SD} = -4.7877 + 1.0051w$$

$$R^2 = 0.970\ (p<0.001)$$

As can be seen above, the regression of best fit is given when a=-0.0043, b=0.2572, c=5.9220 and d=-41.694. Where a, b, c coefficient and d is constant. The form of cubic equation of regression is given by $y=aw^3+bw^2+cw+d$. Here, w=independent variable (gestational age) and y is dependent variable (abdominal circumference). Substituting the values for a, b, c and d into this form gives the equation for the quadratic function best fitting the data set.

$$y = -41.694 + 5.9220w + 0.2572w^2 - 0.0043w^3$$

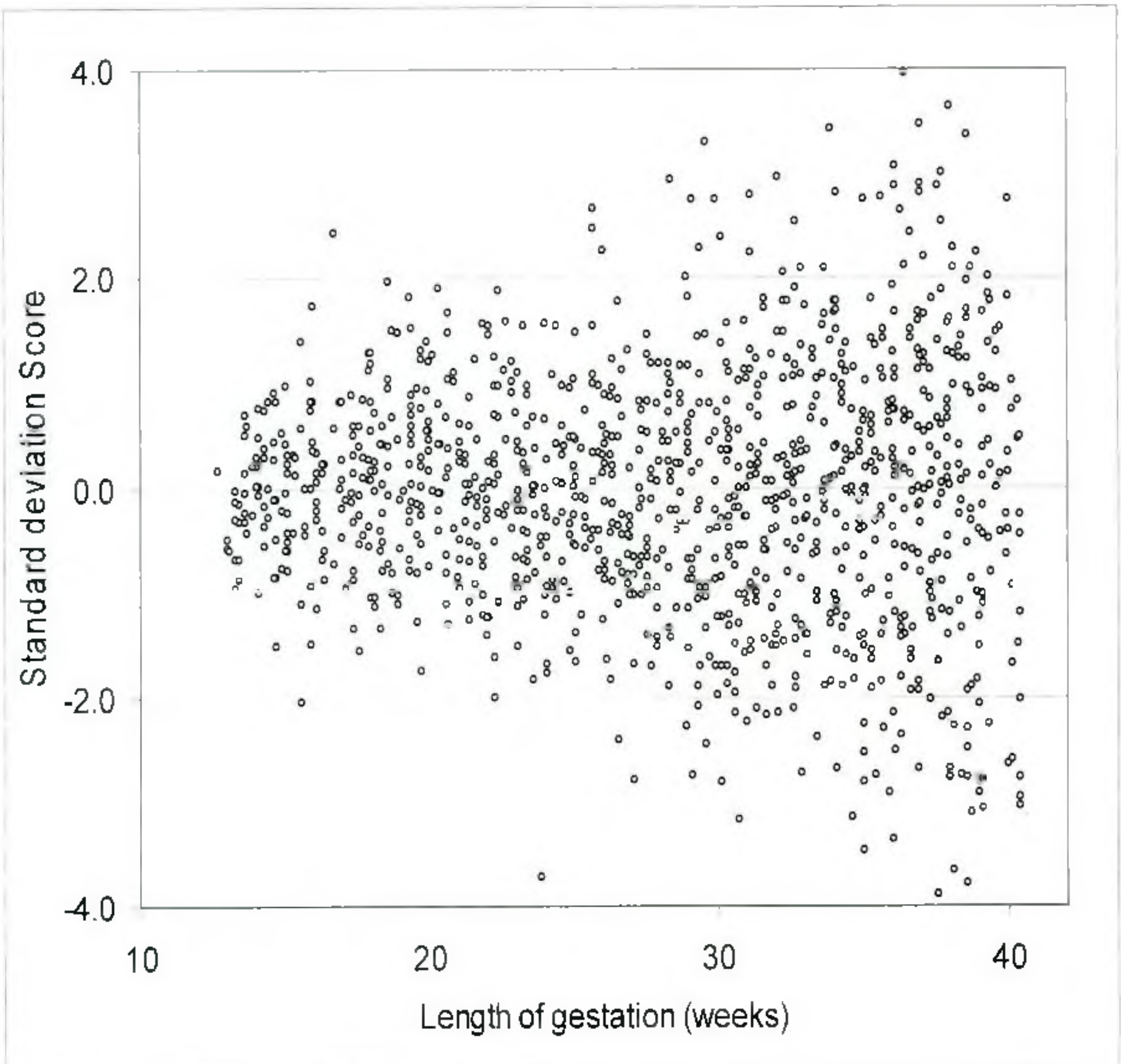


Fig 9: Assessment of fit of model for Abdominal Circumference plotted: Plot of standard deviation score gainst gestational age.

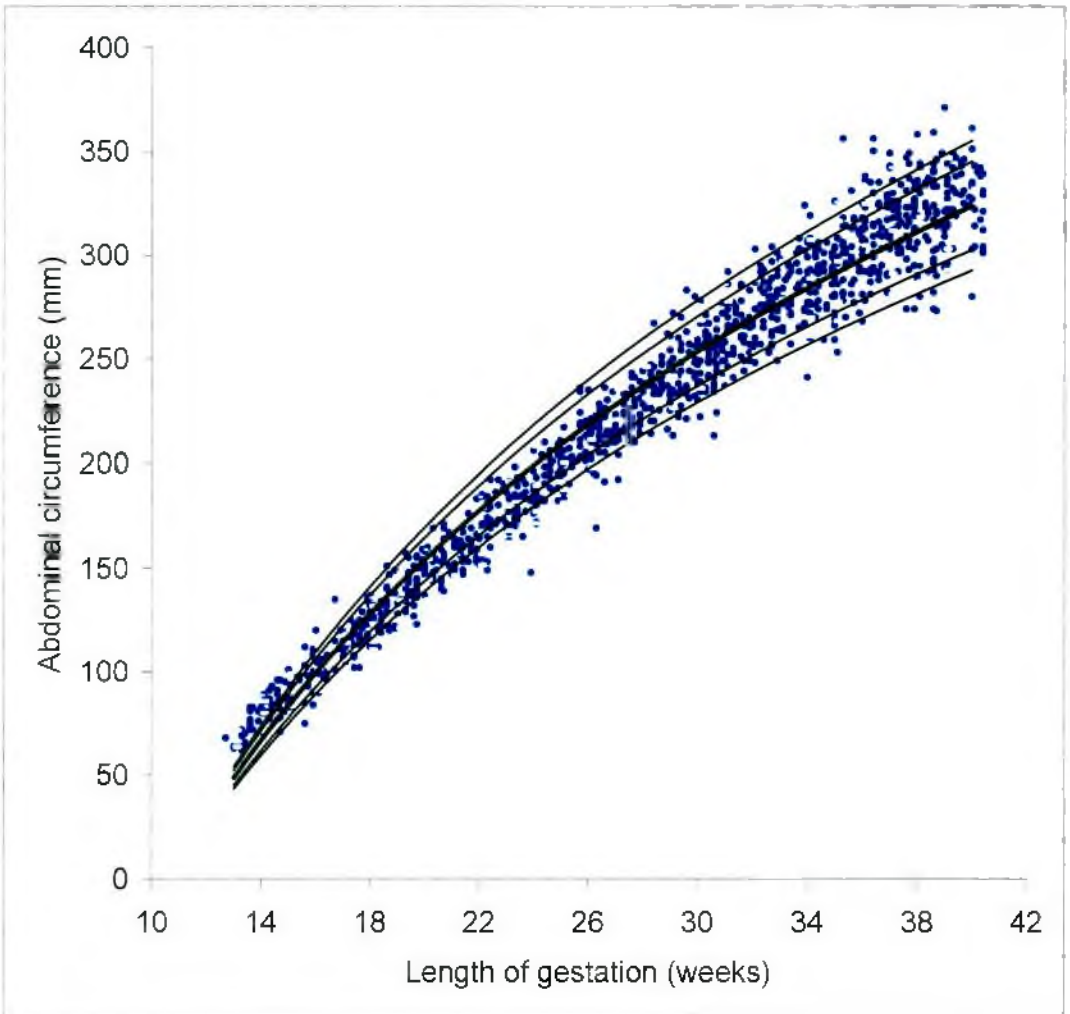


Fig 10: Raw data for abdominal circumference with fitted 5th, 10th, 50th, 90th and 95th centiles.

Abdominal circumference (mm)	Mean (weeks)	2SD (weeks)
65	13.5	0.9
70	13.8	1.0
75	14.0	1.0
80	14.4	1.1
85	14.7	1.1
90	15.0	1.2
95	15.4	1.2
100	15.8	1.2
105	16.1	1.3
110	16.5	1.3
115	17.0	1.4
120	17.5	1.4
125	17.9	1.5
130	18.3	1.5
135	18.8	1.6
140	19.3	1.6
145	19.8	1.7
150	20.2	1.7
155	20.7	1.7
160	21.3	1.8
165	21.8	1.8
170	22.3	1.9
175	22.7	1.9
180	23.4	2.0
185	23.9	2.0
190	24.5	2.1
195	25.0	2.1
200	25.6	2.1
205	26.1	2.2
210	26.7	2.2
215	27.3	2.3
220	27.8	2.3
225	28.4	2.4
230	29.0	2.4
235	29.6	2.5
240	30.0	2.5
245	30.7	2.6
250	31.2	2.6
255	31.8	2.6
260	32.4	2.7
265	32.9	2.7
270	33.5	2.8
275	34.0	2.8
280	34.6	2.9
285	35.1	2.9

Cont..

Abdominal circumference (mm)	Mean (weeks)	2SD (weeks)
290	35.7	3.0
295	36.2	3.0
300	36.7	3.0
305	37.2	3.1
310	37.7	3.1
315	38.2	3.2
320	38.7	3.2
325	39.2	3.3
330	39.7	3.3
335	40.1	3.4

Fitted model Gestational age

$$\text{Mean} = 11.7686 - 0.0002\,ac + 0.0005\,ac^2 - 0.0000074\,ac^3$$
$$\text{SD} = 0.3638 + 0.009\,ac$$
$$R^2 = 0.967\ (p<0.001)$$

ESTIMATED FETAL WEIGHT

Table 16 shows summary of measurements of estimated fetal weight (EFW) (mm) as a function of gestational age. It gives the observed values. Total number of patients was 6600. The table gives the number of observation in each week, from 13 to 40 weeks gestational age and 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles of estimated fetal weight at each week of gestation. It also gives the mean and 2 standard deviations (±2SD) of the observed values. Table 17 shows the fitted 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles of estimated fetal weight (mm) with 95% confidence of interval (CI). It also gives estimated mean and ±2 standard deviations (±2SD) of the data. The coefficient of multiple correlation R^2=0.988 ($p<0.001$), which indicates a good correlation between the two variables.

There was gradual increase of 2 standard deviations towards term, from 23.8 mm to 752.7 mm. Graph 11 Shows raw data for estimated fetal weight with fitted, 5th, 10th, 25th, 50th, 75th, 90th and 95th centile curves superimposed on it and in Graph 12, the values ±2 standard deviations are superimposed on the residual plot to see how well the standard deviation has been modeled. Plot of standard deviation score (standardized residuals) against gestational age for estimated fetal weight, shows expected 2 standard deviations.

Table 16: Summary of measurement of estimated fetal weight (Observed)

Estimated Fetal Weight										
Weeks	n	Mean	2SD	5^{th}	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}	95^{th}
13	200	78	12	69	70	73	78	83	86	87
14	200	101	11	79	82	89	101	112	119	122
15	200	111	46	84	87	96	111	126	135	138
16	200	138	51	95	100	114	138	162	176	181
17	200	197	43	149	155	171	197	224	239	245
18	200	225	35	181	186	200	225	249	263	268
19	200	277	78	222	228	246	277	307	325	331
20	201	323	91	244	253	279	323	367	393	402
21	200	389	106	318	326	350	389	429	452	460
22	201	484	122	395	405	435	484	534	563	573
23	200	597	140	492	503	538	597	655	690	701
24	200	620	132	463	481	533	620	707	759	777
25	200	759	133	638	651	692	759	827	867	881
26	201	808	230	596	619	690	808	925	996	1019
27	200	968	263	802	820	876	968	1061	1116	1135
28	200	1127	300	888	914	994	1127	1259	1339	1365
29	200	1314	305	1061	1089	1174	1314	1455	1539	1567
30	200	1490	509	1122	1163	1286	1490	1695	1817	1858
31	200	1550	461	1093	1144	1296	1550	1804	1956	2007
32	200	1826	447	1441	1484	1612	1826	2039	2168	2210
33	200	1979	452	1618	1658	1779	1979	2180	2300	2340
34	200	2154	727	1660	1715	1880	2154	2429	2593	2648
35	200	2302	805	1734	1797	1987	2302	2618	2807	2870
36	200	2628	693	2020	2087	2290	2628	2966	3169	3236
37	200	2756	626	2219	2278	2458	2756	3055	3234	3293
38	200	2798	373	2115	2191	2419	2798	3178	3405	3481
39	199	2851	602	2167	2243	2471	2851	3231	3459	3535
40	200	2981	704	2278	2356	2591	2981	3372	3606	3684

Table 17: Fitted Centiles of estimated fetal weight (estimated)

Estimated Fetal Weight										
Wks	n	Mean	2SD	5^{th}	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}	95^{th}
13	200	80	23.8	69	70	74	80	85	89	90
14	200	98	24.8	84	85	90	98	105	110	111
15	200	119	25.4	105	106	111	119	127	132	134
16	200	149	27.5	133	135	140	149	158	163	165
17	200	187	36.9	170	172	178	187	195	201	203
18	200	221	39.8	203	205	211	221	231	236	238
19	200	272	40.9	251	253	260	272	283	290	292
20	201	322	49.4	299	301	309	322	335	343	346
21	200	394	57.4	367	370	379	394	409	418	421
22	201	468	64.5	436	440	450	468	485	496	499
23	200	559	74.4	525	528	540	559	577	589	593
24	200	646	86.0	608	612	625	646	668	681	685
25	200	753	95.9	710	715	729	753	777	792	796
26	201	874	110.6	826	832	848	874	901	917	922
27	200	994	128.6	939	945	963	994	1024	1042	1048
28	200	1133	141.6	1070	1077	1098	1133	1168	1188	1195
29	200	1290	164.1	1218	1226	1250	1290	1330	1353	1361
30	200	1462	190.6	1298	1316	1371	1462	1554	1609	1627
31	200	1613	212.9	1429	1449	1511	1613	1715	1777	1797
32	200	1792	248.0	1581	1604	1675	1792	1909	1979	2003
33	200	1961	284.7	1720	1747	1827	1961	2096	2176	2203
34	200	2163	327.6	1883	1914	2007	2163	2319	2412	2443
35	200	2344	382.3	2021	2057	2165	2344	2523	2630	2666
36	200	2518	434.2	2150	2191	2314	2518	2722	2845	2885
37	200	2681	495.0	2262	2308	2448	2681	2914	3054	3100
38	200	2832	558.2	2356	2409	2568	2832	3096	3255	3307
39	199	2983	641.0	2437	2498	2680	2983	3286	3468	3529
40	200	3136	752.7	2498	2569	2782	3136	3490	3703	3773

Fitted model estimated fetal weight

$$\text{Log (weight)gm} = 0.2467 + 0.1448w - 0.00159\,w^2$$

$$SD = 0.4782 + 0.0598\,w$$

$$R^2 = 0.988 \quad (p<0.001)$$

As can be seen above, the regression of best fit is given when a=-0.0159, b=0.1448 and c=0.2467. Where a and b coefficient c is constant. The form of quadratic equation of regression is given by $y=aw^2+bw+c$. Here, w=independent variable (gestational age) and y is dependent variable (Estimated fetal weight). Substituting the values for a, b and c into this form gives the equation for the quadratic function best fitting the data set.

$$y = 0.2467 + 0.1448w - 0.00159\,w^2$$

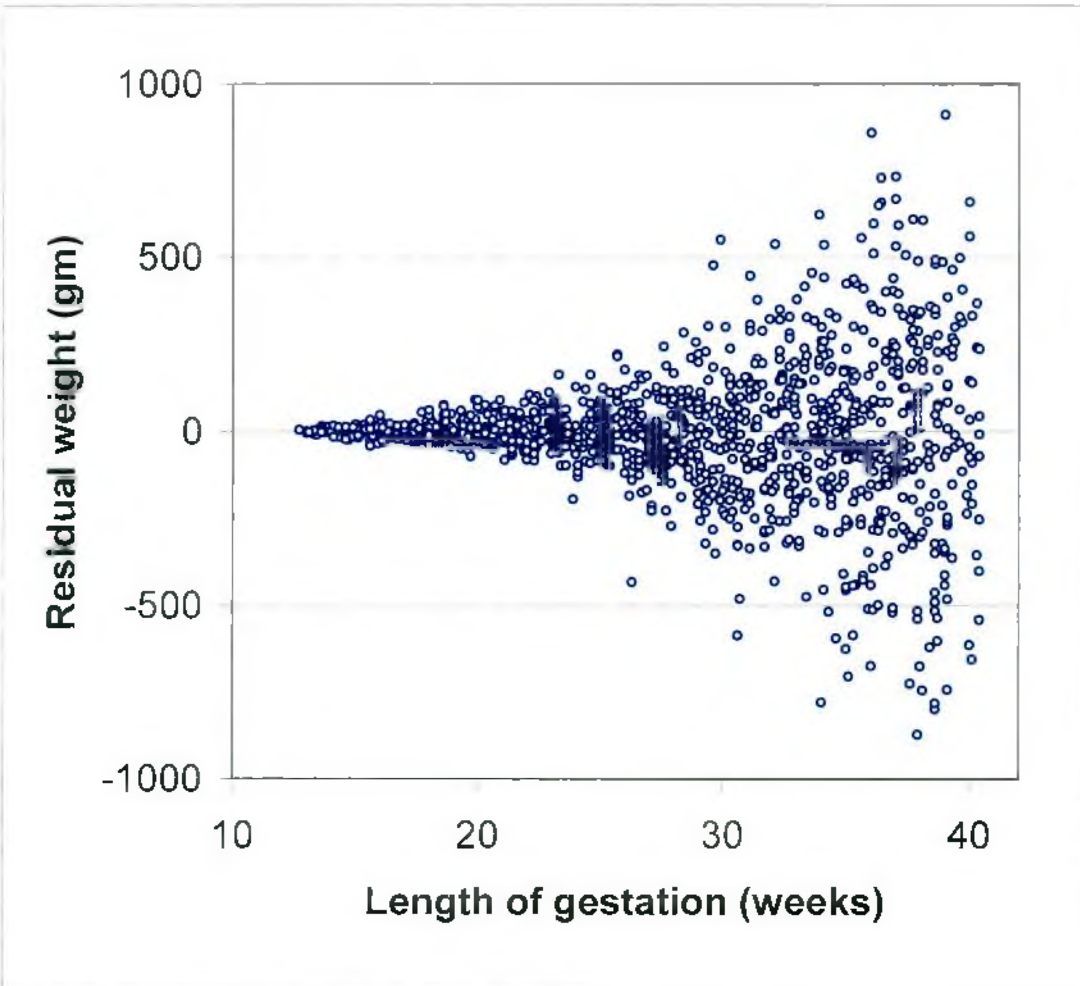


Fig 11: Assessment of fit of model for estimated fetal weight plotted: Plot of standard deviation score against gestational age

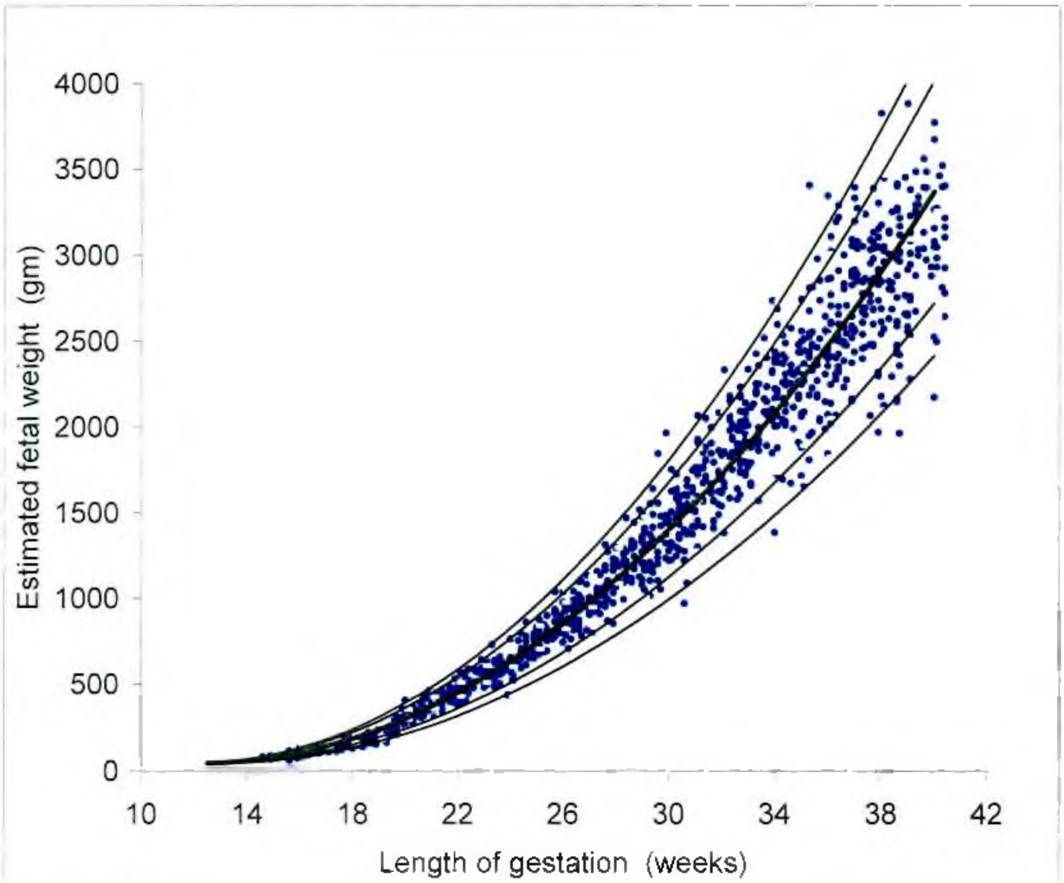


Fig 12: Raw data for estimated fetal weight with fitted 5th, 10th, 50th, 90th and 95th centiles.

Table 18: Summary of Gestational age (w) with Z Score (BPD), Z Score (FL), Z Score (HC) and Z Score (AC)

Gestational age (w)	Z Score (BPD)	Z Score (FL)	Z Score (HC)	Z Score (AC)
13.00	-1.92±0.08	-1.87±0.07	-1.98±0.09	-1.78±0.09
14.00	-1.88±0.05	-1.83±0.05	-1.96±0.07	-1.74±0.05
15.00	-1.67±0.02	-1.63±0.01	-1.72±0.02	-1.56±0.01
16.00	-1.48±0.04	-1.47±0.04	-1.53±0.05	-1.43±0.03
17.00	-1.31±0.05	-1.31±0.05	-1.33±0.05	-1.29±0.04
18.00	-1.15±0.04	-1.15±0.03	-1.14±0.04	-1.14±0.04
19.00	-0.96±0.03	-0.97±0.04	-0.93±0.04	-0.98±0.02
20.00	-0.83±0.02	-0.82±0.04	-0.81±0.04	-0.85±0.03
21.00	-0.67±0.05	-0.68±0.04	-0.64±0.04	-0.72±0.03
22.00	-0.52±0.04	-0.54±0.04	-0.48±0.04	-0.58±0.04
23.00	-0.37±0.04	-0.39±0.04	-0.34±0.04	-0.43±0.03
24.00	-0.23±0.04	-0.26±0.04	-0.19±0.04	-0.32±0.04
25.00	-0.10±0.05	-0.12±0.05	-0.05±0.04	-0.16±0.04
26.00	0.02±0.04	0.01±0.03	0.06±0.04	-0.04±0.05
27.00	0.16±0.03	0.13±0.04	0.20±0.04	0.11±0.04
28.00	0.28±0.03	0.25±0.03	0.31±0.03	0.23±0.02
29.00	0.40±0.03	0.39±0.04	0.43±0.03	0.37±0.04
30.00	0.53±0.03	0.51±0.03	0.56±0.03	0.48±0.06
31.00	0.63±0.03	0.62±0.02	0.65±0.03	0.62±0.03
32.00	0.76±0.03	0.76±0.03	0.75±0.03	0.75±0.05
33.00	0.89±0.03	0.88±0.03	0.87±0.02	0.90±0.04
34.00	0.98±0.03	0.98±0.03	0.96±0.03	0.99±0.05
35.00	1.10±0.03	1.12±0.04	1.07±0.02	1.14±0.03
36.00	1.20±0.04	1.21±0.03	1.17±0.03	1.23±0.03
37.00	1.31±0.03	1.33±0.02	1.31±0.03	1.34±0.06
38.00	1.40±0.03	1.45±0.03	1.34±0.02	1.49±0.04
39.00	1.51±0.03	1.54±0.03	1.43±0.02	1.61±0.03
40.00	1.62±0.04	1.65±0.05	1.55±0.03	1.73±0.04

Table 18 shows the summary of Gestational age (w) with Z Score (BPD), Z Score (FL), Z Score (HC) and Z Score (AC).

Table 19: Comparison between of estimated birth weight and actual birth weight (n=87).

	Mean±SD	Range (min – max)	p value
Estimated birth weight (kg)	2.74±0.73	2.49 – 3.85	0.433^{ns}
Actual birth weight (kg)	2.83±0.78	2.5 – 3.37	

Paired t-test

p>0.05 in paired t-test (not significant)

In order to compare the estimated fetal weight and actual birth weight, the study set the hypothesis that the average estimated fetal weight is equal to the average actual birth weight. The paired t-test was performed.

The calculated paired t value was 0.433 and hence the test is not significant, i.e. the hypothesis may be accepted at 95% level of confidence interval. In other words, there is no statistically significance difference between estimated fetal weight and actual birth weight.

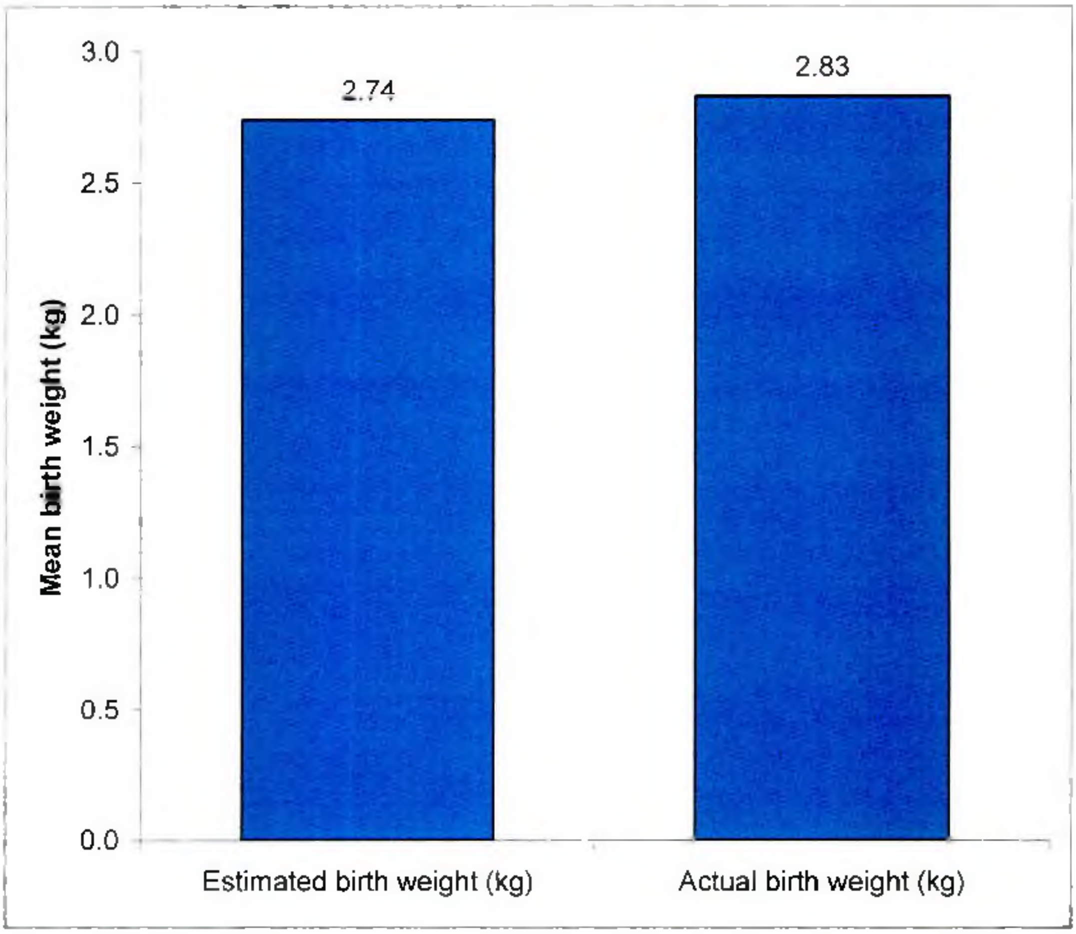


Figure 13: Bar diagram showing the comparison between of estimated birth weight and actual birth weight.

Table 20: The quartile distribution of estimated birth weight and the actual birth weight (n=87).

Estimated birth weight		Actual birth weight							
		1st Quartile (n=14)		2nd Quartile (n=29)		3rd Quartile (n=23)		4th Quartile (n=21)	
	N	n	%	n	%	n	%	n	%
1st Quartile	16	14	87.5	2	12.5	0	0.0	0	0.0
2nd Quartile	27	0	0.0	26	96.3	1	3.7	0	0.0
3rd Quartile	24	0	0.0	1	4.2	22	91.6	1	4.2
4th Quartile	20	0	0.0	0	0.0	0	0.0	20	100

According to quartile of estimated birth weight and the actual birth weight, it was observed 16 patients in 1st quartile according to estimated birth weight, out of which 14 cases in 1st quartile according to actual birth weight.

According to estimated birth weight 27 cases was found in 2nd quartile, out of which 26 cases was 2nd quartile in actual birth weight.

According to estimated birth weight 24 cases was found in 3rd quartile, out of which 22 cases was 3rd quartile in actual birth weight.

According to estimated birth weight 20 cases was found in 4th quartile, out of which 20 cases was 4th quartile in actual birth weight.

Kappa=0.953, p value =0.001

A more complete list of how Kappa might be interpreted (Landis & Koch. 1977) is given in the following table

Kappa	**Interpretation**
< 0	Poor agreement
0.0 – 0.20	Slight agreement
0.21 – 0.40	Fair agreement
0.41 – 0.60	Moderate agreement
0.61 – 0.80	Substantial agreement
0.81 – 1.00	Almost perfect agreement

Estimated birth weight was evaluated by ultrasonograpgy. The results of the interpreter analysis are Kappa = 0.953 with $p < 0.001$. This measure of agreement, while statistically significant, is almost perfect agreement.

5. DISCUSSION

This study was undertaken to provide Bangladeshi clinicians with new reference charts and equations for fetal biometry that would be useful in their practice. The need to develop a new reference chart for the Bangladeshi population was derived from the small published data for Bangladeshi fetal biometry and a number of ethnic differences in fetal biometry. A total of 6600 patients who came in Maternal and Child health Training Institute (MCTI) and the Institute of Nuclear Medicine & Ultrasound, Bangabandhu Sheikh Mujib Medical University, Dhaka (BSMMU) during the period of July 2008 to June 2010 were included in this study. Several authors have emphasized the value of using customized fetal biometry charts that consider variables such as maternal weight, parity and race (Pang et al., 2003). Cross-sectional and longitudinal ultrasound studies have demonstrated racial variations in fetal growth (Drooger et al., 2005; Jacquemyn et al., 2000; Salomon et al., 2006). It was reported that the fetus of Turkish and Moroccan women had a shorter femur, smaller abdominal and HCs than Belgian Women, and in Africa, Nigerian AC and biparietal diameter were found to be smaller than those of the British population (Jacquemyn et al., 2000; Okonofua et al., 1988). One group demonstrated that Cape Verdian, Surinamese- Creole and Surinamese-Hindustani women had, on average, smaller fetuses than the native Dutch women after adjustment for maternal weight, height, age and parity (Drooger et al., 2005). In general, studies involving Asian populations have found that biometric parameters are smaller during pregnancy than in Caucasian populations (Beigi and ZarrinKoub, 2000; Siwadune et al., 2000; Sunsaneevithayakul et al., 2000; Titapant et al., 2000).

This is a cross-sectional study in which each fetus was measured once in contrast to longitudinal studies in which measurements of each fetus were made at different gestational ages. It should be noted that reference charts in this study are cross-sectional standards for fetal size. This study selected a cross-sectional design to avoid biased estimation through a highly complex statistical model of longitudinal study, and to easily compare with other cross-sectional data. This current study paid particular attention to the methodology used to construct new charts, doing best to follow the methodology of previous reviews (Altman and Chitty, 1994; Royston and Wright, 1998).

In this current study it was observed that almost a half (47.9%) of the respondents were in the age group of ≤25 years and the mean (±SD) of age of the respondents was 25.75±4.79 years with a range of 18 to 38 years.

The mean (±SD) height of the respondents was 155.5(±8.94) cm with a range of 147-164 cm, weight was 53.5(±9.52) kg with a range 41-66 kg, haemoglobin was 10.04(±1.14) gm/dl with a range of 8.30-13.00 gm/dl, monthly family income of the respondents was 4519.28(±1512.52) BDT with a range of 2500-10000 BDT, age at marriage was 19.71 (±2.47) years with a range of 15 to 25 years and duration of marital life was 6.04±3.7 years with a range of 2 to 16 years.

More than a half (54.1%) of the respondents were primi gravida and 45.9% were multi gravida. More than eighty (81.7%) were vaginal delivery and rest 18.3% had history of underwent cesarean section.

Razaee and Baradaran. (2006-2007) mentioned in their study that the Crown-rump length (CRL) is the most accurate parameter for first trimester dating between 6 and 12 weeks of gestation. In the present study Crown-rump length (CRL) determine between 8 weeks to 12 weeks of gestation and then 5th, 10th, 25th, 50th, 75th, 90th, 95th percentile curves derived by fitting a model were superimposed on the raw data of 1000 normal singleton fetuses. During 8 weeks of gestational age, mean Crown-rump length (CRL) was observed 19.2(±2.9) mm (2SD), at 10w it was 35.5(±5.5) mm and at 12w it was 59.2(±8.9) mm.

Then estimated values were derived after fitting the model, and at 8w gestational age, mean CRL was found to be mean Crown-rump length (CRL) was observed 21.5(±3.4) mm (2SD), at 10w it was 37.1(±5.6) mm and at 12w it was 59.8(±6.9) mm, with a 95% CI of 53 to 67 mm. The coefficient of multiple correlation R2= 0.982, indicated a strong correlation between gestational age and CRL. There was gradual increase of 2SD to wards, from 3mm to 9mm, showing increasing of CRL towards. The CRL measurements observed before 13 weeks of gestation were smaller than those reported by Robinson and Fleming (1975). This might be due to use of improved high-resolution ultrasound equipment and standardization of technique. This suggests that gestational age may be underestimated if pregnancies are dated before 13 weeks of gestation according to the CRL curve of Robinson and Fleming. The magnitude of this error is up to 4 days with a CRL of 10 mm, and this may be clinically important.

Early ultrasound examination is commonly recognized to provide a more valid estimate of gestational age than does LMP dating, which is consistent with the results from the current study (Barr and Pecci 2004; Tunon, Eik-Nes and Grottum 1996). In a substantial proportion of pregnancies, LMP cannot be used because the date is incorrect or not known, women have only recently stopped using oral contraceptives, or report having irregular or prolonged menstrual cycles. Even when the LMP is known and the cycle was reported to be regular, there may be subtle variations in gestational age due to early or delayed ovulation, fertilization or nidation; in addition, early pregnancy bleeding may be misinterpreted as the LMP (Morin et al. 2005). A disadvantage of dating based on ultrasound measurements is that biological variation in early fetal growth is reduced to zero. Embryological studies have observed uniform development of the human embryo with small differences in size and age at different stages, and support the use of ultrasound imaging alone in preference to menstrual history for pregnancy dating (Blaas et al 1998). However, disparities in growth may occur at an early stage of pregnancy owing to chromosomal or structural abnormalities, early placental maladaptation or environmental factors including nutrition (Smith 2004). In clinical practice, substantial differences between gestational age based on ultrasound measurements and LMP, if reliable, should be considered as an indicator of possible pathology and an increased risk of fetal growth restriction (Nguyen et al. 2000).

Accurate pregnancy dating is important to establish gestational age for evaluation of fetal growth and prediction of the date of delivery. The increasing variation in fetal size as pregnancy proceeds implies increasing uncertainty in prediction. The present study found that early ultrasound assessment, preferably between 10 and 12 weeks, provides a better prediction of gestational age, which has important implications for the timing of the first antenatal visit. An additional advantage is that some major structural defects can be detected by ultrasound examination in early pregnancy after 10 weeks of gestation (Becker and Wegner 2006). Increasing fetal size and variability with gestation makes ultrasound estimates of gestational age less accurate in later pregnancy.

Razaee and Baradaran, (2006-2007) determined the relationship between gestational age and measurement of mean diameter of gestational sac, volume of sac, and crown-rump length in a group of pregnant women who had regular cycles and certain dates. Charts and predictive equations were constructed from data obtained from pregnancies in which the CRL was between 6 and 60 mm and for which the outcome was normal. CRL showed correlation with gestational age ($r=0.935$, $p<0.0001$). The best fit regression equation was the quadratic model. Age (week) = $5.822+1.610$ CRL (cm) - $0.080(\text{CRL})^2$ (cm), which is consistent with the current study quadratic regression equation model. A chart for CRL derived from the regression equation are presented and compared with those obtained by Robinson & Fleming and Hadlock. They concluded that there were no significant differences between the Iranian and European parameters for the CRL and mean gestational sac curves.

In the current study biparietal diameter (BPD) was determined between 13 weeks to 40 weeks of gestation on 5600 normal singleton fetuses. At 13 weeks (w) gestational age, mean biparietal diameter (BPD) was 23.3(±2.3mm) (2SD), at 28w it was 73.23(±4.1mm) and at 40w it was 96.7(±4.4mm). Then estimated values were derived after fitting the model, and at 13w gestational age, mean BPD was found to be 24.2 (±3.1mm), at 28w it was 70.9(±5.8mm) and at 40w it was 92.3(±5.7mm), with a 95% CI of 87 to 98 mm. The coefficient of multiple correlation R^2= 0.977, indicated a strong correlation between gestational age and BPD. The head exhibited a greater increase in variability after approximately 29 weeks. There was gradual increase of 2SD to wards term, from 3mm to 8mm, showing increasing dispersion of BPD towards term.

The values ±2SD were superimposed on the residual plot and the plot of standard deviation scores (standardized residuals) against gestational age for BPD, showed expected 2SD. Linear model was fitted for the SD. It was similar to Chitty and co-worker's study (1994). The fitting of the curves selected for the single variables is consistent with that reported by Chitty et al. (1994) with a cubic polynomial equation expressing the relationship between all distance variables (BPD with gestational age. There was a gradual increase of BPD centiles up to 37th week of gestation; there after a slower growth rate was noted. The polynomial regression linear- cubic model showed a good fit to the mean. It also showed that there was increased dispersion of data and the centile curves as the pregnancy progressed. This was not found in the studies which did not follow the proper methodology (Chitty et al, 1994).

Lower growth rates were found in BPD measurements after 38w of gestation reported by Ashrafunnessa, et al, (2003), where the authors found that at 18w mean BPD was 41mm (±3 mm) and at 40w it was 90mm (±4mm). Biswas et al, (2006) observed the mean BPD were 72mm and 95mm at 28w and 40w weeks of gestational age. In another study, Quddus, (2005) considered gestational age as the dependent, where 23mm indicated 13w (±7d) (2SD) and 92mm indicated 40w (±21d). Campbell and Newman (1971) reported BPD 96mm at 38w however, Moslem et al, (1996) showed 93mm (±11 mm). Bala, (1991) found that the fetal BPD was 1 to 2w smaller for the date in comparison to fetus from developed countries. In our country, Quddus and Chowdhury, (2004) found that BPD measurements increased gradually from 13 to 28w at the rate of 3mm/w, then from 28 to 33 weeks it increased by about 2mm/w, thereafter up to 40w the increase was about 1mm/w. It was 92mm at 40 and 41w. Similar, rate of increase observed in this study.

Rajan, et al, (2001) done a study in India and showed observed values at 13w gestational age mean BPD was 23mm (±3mm) and at 40w it was 90mm (±3mm) and after fitting a model, at 13w gestational age mean BPD was 23mm and at 40w it was 95mm (Estimated values), which is consistent with the current study.

In Osaka University a group of investigators showed at 12w mean BPD was 21mm (±4mm) (2SD) and at 40 w it was 94mm (±8mm) and in the other study 20mm indicated 12w (±7d) (2SD) and 95mm indicated 40w (±25d) (Tokyo University), which is a little higher by 2 to 3 mm with the current study.

In London, Chitty et al, (1994) found at 13w gestation mean BPD was 22mm (±3mm) (2SD) and at 40w it was 95mm (±9mm) (Observed values), and by fitting model, at 13w BPD was 22mm (±4mm) and at 40w it was 95mm (±8mm) (Estimated values). In another study, Hansmann et al, (1985) showed 24mm predicted 13w (±8d) (2SD) and 99mm predicted 40w (±30d), that is higher with the present study by 4 to 8 mm.

Hadlock et al, (1982) found that at 14w gestational age mean BPD was 27mm and at 40w it was 95mm (Observed values) and by taking gestational age as dependent variable 20mm predicted 12w (±6d) (2SD) and 96mm predicted 40w (±25d). In Shepard and Filly's study (1982) at 14w gestational age mean BPD was 28mm and at 40w it was 97mm, and Kurtz et al, (1980) found at 14w mean

BPD was 26mm and at 40w it was 95mm. In 1977, Campbell et al. reported that 24mm indicated 13w (±7d) (2SD) and 100mm indicated 4y, (±21d).

In the early 2nd trimester Bangladeshi, Indian, Japanese, Korean and Western measurements were the same but as pregnancy progressed there was discrepancy between different races. Humphrey and Holzheimer, (2000) did not show any statistical or clinically important difference in BPD, AC and FL of Aboriginal and Caucasian fetuses in Australia. They concluded that there is no reason to use separate fetal growth charts when examining Aboriginal fetal growth. Bernstein et al., (1996); Chung et al., (2003); Jacquemyn et al., (2000) studies demonstrated that significant ethnicity variations in fetal size and growth. Beigi and Zarrin, (2000) showed that Iranian fetuses had smaller BPD and shorter FL measurements in comparison with Western studies. Gutknecht, (1998) documented that tables from industrialized countries relating gestational age to sonographically measured BPD are not applicable for pregnancies in developing countries.

In this present series it was observed at 13 weeks (w) gestational age, mean femur length (FL) was 11.9(±2.8mm) (2SD), at 28w it was 53.24(±3.8mm) and at 40w it was 73.0(±3.1mm). Then estimated values were derived after fitting the model, and at 13w gestational age, mean FL was found to be 10.7 (±3.3mm), at 28w it was 52.8(±4.6mm) and at 40w it was 73.3(±5.7mm), with a 95% CI of 68 to 78mm and R2 = 0.982. There was a gradual increase of the FL measurements up to 37th week of gestation, and then there was a slower increase till term. There was also gradual increase of 2SD towards term, from 3.4 to 5.8mm.

The values ±2SD were superimposed on the residual plot and the plot of standard deviation scores (standardized residuals) against gestational age for BPD, showed expected 2SD. Linear model was fitted for the SD. It was similar to Chitty and co-worker's study (1994). The fitting of the curves selected for the single variables is consistent with that reported by Chitty et al. (1994) with a cubic polynomial equation expressing the relationship between all distance variables (BPD with gestational age. There was a gradual increase of BPD centiles up to 37^{th} week of gestation; there after a slower growth rate was noted. The polynomial regression linear- cubic model showed a good fit to the mean. It also showed that there was increased dispersion of data and the centile curves as the pregnancy progressed. This was not found in the studies which did not follow the proper methodology (Chitty et al, 1994).

Standard deviation scores plot against gestational age, showed expected 2SD, which is consistent with western study performed by Chitty et al, (1994). The polynomial regression quadratic model showed a best fit of the data. It also showed that there was increased dispersion of data and the fitted curves as the pregnancy progressed.

In Bangladesh, Biswas et al, (2006) showed at 28w FL was 52mm and at 40w it was 75mm. By taking gestational age as dependent variable Quddus and Begum, (2004) showed 18mm predicated 15w (±7d) (2SD) and 73mm indicated 40w (±2Id). Ashrafunnessa et al, (2003) obtained at 18w FL was 26mm (±3mm) and at 40w it was 71mm (±3mm). In another study Quddus, (2002) showed at 16w, FL was 19mm (±2.6mm) and at 40w it was 72mm (±3.2mm).

In India, Rajan et al, (2001) documented at 13 w gestational age that FL was 11mm (±2mm) and at 40w it was 72mm (±4mm) (Observed values), and after fitting model, at 13w FL was 11mm and at 40w it was 76mm (Estimated values), which is closely resembled with the current study. In two Japanese university studies, at 13w mean FL was 9mm (±2mm) and at 40w it was 71mm (±3mm) (Osaka University), and in the other study with gestational age as dependent variable 32mm predicted 20w (±17d) (2SD) and 70mm predicted 40w (±64d) (Tokyo University), which is 2 to 3mm smaller than the current study.

Chitty's et al. (1994) series included British women, at 13w gestational age FL was 11mm (±2mm) and at 40w it was 75mm (±4mm) (Observed values) and after fitting model, at 13w FL was 11mm (±2mm) and at 40w it was 74mm (±3mm). (Hansmann et al, (1985) considered gestational age as dependent variable, 10mm predicted 13w (±7d) (2SD) and 75mm predicted 40w (±23d). Hadlock et al. (1984) obtained at 14w FL was 14mm (±1mm) and at 40w it was 77mm (±2mm); at 13w FL was 12mm (±7mm) (2SD) and at 40w it was 75mm (±9mm) reported by Jeanty, (1983); at 14w FL was 17mm (±3mm) (2SD) and at 40w it was 75mm (±6mm) documented by O'Brien et al, (1981). Hadlock et al. (1982) recognized that 10mm predicted 13w (±10d) (2SD) and 78mm predicted 40w (±22d) when gestational age considered as dependent variable. In 1977, Campbell et al, (1977) acknowledge that 18mm indicated 15w (±6d) (2SD) and 75mm indicated 40w (±22d), which are higher by 2 to 5mm with the current study.

In case of FL also, as in BPD and HC, all studies showed that in the early second trimester Bangladeshi, Indian, Japanese and Western measurements were similar but as pregnancy progressed there was discrepancy between different races.

Kurtz and Goldberg (1988) evaluated the measurement of the femur for the prediction of gestational age and fetal size and in the detection of fetal abnormalities. Leopold, (1986) suggested that FL should be measured routinely and recorded after the 14^{th} w of gestation. As with BPD considerable biological variation is present late in pregnancy.

Honarvar et al, (2001) mentioned that previous normal ultrasonic fetal FL curves for another population may underestimate or overestimate normal fetal weight for the Iranian population. In general, studies involving Asian populations have found that biometric parameters are smaller during pregnancy than in Caucasian populations documented by Beigi and ZarrinKoub, 2000; Siwadune et al., 2000; Sunsaneevithayakul et al., 2000; Titapant et al., 2000). Shohat and Romano, (2001) pointed out that new fetal measurement charts were prepared for FL and BPD from the Israeli population and those were found to be similar to those published for other Caucasian populations.

In this current study it was observed at 13 weeks (w) gestational age, mean head circumference (HC) was 90.0(±8.6mm) (2SD), at 28w it was 254.50(±13.6mm) and at 40w it was 332.0(±19.8mm). Then estimated values were derived after fitting the model, and at 13w gestational age, mean HC was found to be 89.8 (±11.9mm), at 28w it was 261.2(±19.4mm) and at 40w it was 335.0(±22.7mm), with a 95% CI of 313 to 357mm and $R^2 = 0.998$. There was a gradual increase of the HC measurements up to 37th week of gestation, and then there was a slower increase till term. There was also gradual increase of 2SD towards term, from 3.4 to 5.8mm.

Assessment of goodness of fit of the model for SD of fetal HC was shown in a graph. which is consistent with Chitty et al. (1994). Polynomial regression quadratic model showed a good fit to the data. There was a gradual increase of the HC measurements up to 37th w of gestation thereafter the growth was slower. It also showed that there was increased dispersion of data and the outer centiles as the pregnancy advanced. This was not found in the studies which did not follow the proper methodology and study design (Chitty et al. 1994).

Quddus, (2006) observed at 14w gestation HC was found to be 98mm (±5mm) and at 40w it was 333mm (±13mm). In another study, Quddus and Rashid, (2006) found at 13w HC was 87mm (±13mm) (2SD) and at 40w it was 330 mm (±23mm) (Estimated values), R2= 0.980. In the same study with gestational age as dependent variable 85mm predicted 14w (±0.4w) (2SD) and 340mm predicted 40w (±3w) (Estimated values), R2 = 0.966. Quddus, (2004) observed at 13w HC was 86mm (±5mm) and at 40w it was 333mm (±13mm). In addition, the author mentioned that the HC gradually increased with menstrual age at the rate of 13mm/w to 3mm/w at term. The 2SD also increased from ±10mm to ±26mm at term. At 13w the HC was 86mm (±10mm), at 20w it was 175mm (±15mm), at 38w it was 327mm (±26mm) and at 40w it was 333mm (±26mm). A Western study also found that the growth rate of HC tapered off as the gestational age increased. At 12-13w it is 1.6 (±0.2) (2SD) cm/w and at 39- 40w it is 0.4 (±0.3) cm/w (Deter et al, 1982). This shows that the rate of increase in both Bangladeshi and Western studies declines as the pregnancy advances. In an Indian study, Rajan et al, (2001) showed at 13w gestational age HC was 91mm (±8mm) and at 40w it was 329mm (±20mm) (Observed values) and after fitting model, at 13w HC was 84mm and at 40w it was 343mm (Estimated values).

Chitty et al, (1994) series included British women found, at 13w HC was 84mm (±14mm) (2SD) and at 40w it was 342 mm (±38mm) (Observed values) and by estimating values, at 13w mean HC was 82mm (± 14mm) and at 40w it was 344mm (±26mm)). In another series, Hadlock et al, (1984) showed at 14w mean HC was 97mm (±6mm) and at 40w it was 346mm (±20mm). In a study with gestational age as dependent variable considered by Hansmann et al, (1985) observed 106mm predicted 14w (±8d) (2SD) and 349mm predicted 40w (±35d).

At 13w gestational age HC was 89mm f±19mm) (2SD) and at 40w it was 345mm (±19mm), and by estimated values and considered gestational age as dependent variable, 80mm predicted 12w.3d (±9d) (2SD) and 350mm indicated 40w (±24d) (Hadlock et al, 1982). In Deter (1982) study, at 13w HC was 87mrn (±15mm) (2SD) and at 40w it was 359mm (±25mm) and in a very early study 115mm predicted 14w (±10d) (2SD) and 345mm indicated 40w(±35d) (Campbell et al, 1977).

Here also like BPD, all studies showed that at in the early 2nd trimester all the local, Indian, and western measurements were similar but as pregnancy progressed there was discrepancy between different races. The observed values of the other Bangladeshi and Indian studies were similar to this study at term but western values of HC were much bigger than ours with a difference of 16 to 24mm at term. This was because of the difference in size and stature between the sub-continental people and the western people. The socio-economic conditions of these groups are also very different to make an impact on the fetal size.

The technique is important in the measurement of HC. The measurements obtained by direct measurement around the circumference were consistently (by about 1%) more than those obtained by derivation from the BPD (outer-outer) and occipito-frontal diameters (Chitty et al, 1994). When using a nomogram same method should be used as the author did.

Predicted reduction in birth weight at an increase of exposure to fine particles from 10-50 microg/m3 was 140.3g. The corresponding predicted reduction of birth length would be 10mm, and of HC, 5mm. The study provides new and convincing epidemiologic evidence that high personal exposure to fine particles is associated with adverse effects on developing fetus (Jedrychowski et al, 2004). Three years of growth hormone treatment induced a growth resulting in a normalization of height and other anthropometric measurements, including HC, in contrast to untreated SFD control subjects (Arends et al. 2004).

The measurement of fetal AC was first described in 1975 as a useful measure for estimating fetal weight (Campbell and Wilkin 1975). It is now widely used to monitor normal fetal growth, to detect IUGR (Campbell and Thomas 1977) or macrosomia, and in the estimation of fetal weight (Hadlock et al, 1985).

Regarding the abdominal circumference (AC) it was observed in this current study, at 13 weeks (w) gestational age, mean AC was 74.5(±6.0mm) (2SD), at 28w it was 233.50(±16.6mm) and at 40w it was 321.0(±25.1mm). Then estimated values were derived after fitting the model, and at 13w gestational age, mean HC was found to be 72.3 (±7.6mm), at 28w it was 231.5(±23.2mm) and at 40w it was 332.3(±35.2mm), with a 95% CI of 302 to 363mm and R^2 = 0.970 ($p<0.001$). Polynomial regression cubic model showed a good fit to the data. It also showed that there was increased dispersion of data as the pregnancy advanced. This was not found in the studies which did not follow the proper methodology (Chitty et al, 1994).

Ashrafunnessa et al, (2003) and Quddus, (2002) showed at 40w it were 330mm (±19mm) and 328mm (±22mm) respectively. In an Indian study, Rajan et al, (2001) at 40w gestational age AC was 334mm (±25mm) (Observed values). The above mentioned studies are closely resembled with the current study at 40w gestational age. On the other hand, Ashrafunnessa et al, (2003) observed at 18w gestational age AC was 133mm (±13mm); Quddus, (2002) obtained at 16w AC was 110mm (±11mm), which are comparable with the present study. Rajan et al, (2001) obtained at 13w gestational age AC was 74mm (±16mm) (Observed values), and after estimating values at 13w AC was 69mm in their Indian population, which is consistent with the current study.

Chitty et al, (1994) done a study on British population and found at 13w gestational age mean AC was 69mm (±6mm) (2SD) and at 40w it was 344mm (±23mm) (Observed values) and after fitting a model at I3w AC was 67mm (±5mm) and at 40w it was 340mm (±21mm) (Estimated values). In another study, at 14w AC was 73mm (±6mm) (2SD) and at 40w 353mm (±29mm) (Hadlock et al, 1984), and with gestational age as dependent variable 63 mm indicated 13w gestational age and 320mm predicated 40w (Hansmann et al, 1985). At 13w AC was 69mm (±3mm) (2SD) and at 40w it was 354mm (±3mm) and in the same study with gestational age as dependent variable and fitting model, 100mm indicated 15w.4d (±13d) gestational age and 360mm predicated 40w (±18d) (Hadlock et al, 1982). Deter et al, (1982) observed at 13w gestational age AC was 74mm (±1mm) (2SD) and at 40w it was 370mm (±5mm). In one of the earliest studies 90mm indicated 14w (±14d) (2SD) gestational age and 350mm predicated 40w(±30d) (Campbell et al, 1977), which are higher by 21 to 28mm with the current study.

In the evaluation of AC also, like BPD, HC and FL, all studies showed that in the early second trimester the local, Indian, and western measurements were similar but as pregnancy advanced there was variation between different races.

In a study here, in cases of BPD and AC, after 38w of gestation the percentiles showed a slower growth rate. So the new charts constructed for these parameters are different after 38w from those published for Caucasian populations. This may be a characteristic of the fetal size chart for our population (Ashrafunnesa et al, 2003). Fetal abdominal size charts were constructed which should have several applications in clinical practice. Comparison of this cross sectional data with that of other authors might be explained by difference of study population. In this study after 37w of gestation the percentiles showed a slower growth rate in case of AC but in western studies the AC continued to grow linearly till term.

In Bangladesh, Quddus (2000) obtained gestational age by ultrasonography from the measurement of AC and using Hadlock et al. (1982) table, was found to be constantly smaller after 24w of gestation. At 40w the AC age was 37w (±3w) by using the Western table. At 40w AC was 359mm by Hadlock's table but 332mm by Bangladeshi table. Therefore a table was prepared to give the mean AC measurements of our fetuses, so that in one glance the obstetricians can get an accurate idea of the fetal nourishment at a particular gestational age (Quddus, 2000). Hadlock et al (1982) did not model the SD to take into account the increasing variation with gestation. So their centiles were much wider apart in early pregnancy and narrower at term. Difference in sampling may have been more influential. Vangeenderhuysen and Nono, (1998) established reference charts for the population of Nigeria and showed transverse abdominal fetal diameter to be below normal.

Growth restriction was diagnosed when there was no growth in fetal AC between two consecutive examinations. There was a dramatic increase in false-positive rates as the time interval between exams was reduced. There was a significant increase in the false-positive rate as the gestational age of initial ultrasound was increased. Mongelli et al, (1998) obtained at 28w, the false-positive rate with a 2w interval was 11.8%, increasing to 24.1% at 38w.

Reduced AC was the best single parameter in discriminating between IUGR and non-IUGR fetuses with the highest sensitivity among the proposed parameters in the both Iranian and Australian sample. Its positive predictive value is low. The parameters obtained to evaluate their diagnostic accuracy in predicting IUGR babies, were BPD, FL, HC, AC, API and Doppler from umbilical arteries (Systolic/Diastolic ratio) (Niknafs and Sibbald, 2001). Other published nomograms indicated that the false-negative rates for classifying our population as <10th centile or >90th centile with ranged from 11.3% to 90.5% and from 0 to 66.4%, respectively (Smulian et al. 2001).

Reliable information on gestational age is important for assessment of fetal size and fetal growth. Accurate information on gestational age is also important to avoid unnecessary obstetric interventions at the time of delivery (Fang 2005). The results of the ultrasound biometry, expressed as estimated fetal weight (EFW), plotted on the customised growth chart to assess relative size-for gestation or growth. Reference curves for normal fetal growth from 13 weeks of gestational age onwards were derived. At 13w gestational age mean estimated fetal weight (EFW) was 78g (±12g) (2SD), at 28w it was 1127g (±300g) and at 40w it was 2981g (±704g). The estimated values was constructed after fitting a model, at 13w gestational age mean EFW was 80g (±23.8g) (2SD), at 28w it was 1133g (±141.6g) and at 40w it was 3136g (±749g), with 95% CI of 2498 to 3773g. The coefficient of multiple correlation, R2 = 0.988, ($p<0.001$), indicated a strong correlation between gestational age with fetal weight.

Assessment of goodness of fit of model for SD of EFW was done. Plot of standard deviation score against gestational age showed expected 2SD. The graph demonstrated the raw residuals across gestational ages. It was similar to a study on Caucasian population (Hadlock et al, 1991). The 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile curves derived by fitting a model were superimposed on the observed raw data. Polynomial regression quadratic model showed best fit to the data, as shown in the graph. It also showed that there was increased dispersion of data and percentile curves as the gestational age increased. This was also found in a Caucasian study which followed the same methodology obtained by Hadlock et al. (1991). In this study the growth was slow up to 26w and then it increased linearly up to 40w of gestation, that is consistent with Hadlock et al. (1991) study.

Rajan et al, (2001) showed at 24w gestational age EFW was 595g (±180)g and at 40w it was 3076g (±565)g (Observed values) and after fitting a model, at 24w gestational age EFW was found to be 640g and at 40w it was found to be 3280g (Estimated values) in Indian population.

In Japanese population, a study done in Osaka University, at 16w gestational age mean EFW was 137g (±29)g and at 40w it was 3220g (±387)g. In a Brazilian study, at 20w gestational age mean EFW was 368g and at 42w it was 3417g. There was a mean increase of 200g/w from 27 to 38th week, when the gain decreased reported by Cecatti et al, (2000).

In Western countries, Doubilet et al, (1997) showed at 26w mean EFW was 860g and at 40w it was 3280g, at 13w gestational age mean EFW was 73g with 95%CI 55 – 91g and at 40w it was 3619 (2714-4524)g (Hadlock et al, 1991), at 14w mean EFW was 93g and at 40w it was 3788g (Ott et al, 1988), at 21w gestational age mean EFW was 0.41kg (0.28-0.86)kg and at 40w it was 3.28kg (2.75-3.87)kg (Hadlock et al, 1983), at 14w mean EFW was 82g and at 40w it was 3863g (Deter et al. 1982), at 21w gestational age mean EFW was 410g and at 40w it was 3280g (Brenner et al, 1976).

In Bangladesh Quddus (2002) observed at 16w gestational age EFW was 0.2 (±0) kg and at 40w it was 3 (±0.4) kg. The EFW were found to be less than the Caucasian population (Hadlock et al, 1991) at the same gestational ages in the third trimester. From 29w the difference increased regularly from 0.1 kg to 0.6

kg at 40w. This was most likely due to racial factor influenced the fetal weight, as very poor and malnourished patients were not included in their study and majority of patients belonged to the middle class documented by Quddus, (2002).

In another series in Bangladesh, Quddus and Khatun, (2001) obtained mean (SD) were 2.86 (±0.34) kg at 38w, which increased to 3.1 (±0.4) kg at 40w but did not increase following gestational age. The curve showed a linear trend upwards from 22w, with the increase of fetal age, but with a pulling down from 40 to 42w gestational age. At 22w gestational age EFW was 0.47 (±0.065) kg. The mean EFW reported in one study here at 38w was 2998g, but they used Hansmann's formula that is based on BPD and antero-posterior body diameter and not AC (Miah et al, 1998).

At term different Bangladeshi studies were 0.2 to 0.8kg smaller than Western studies, but similar to Indian and Japanese studies. In early second trimester all studies were comparable. In Postnatal weight studies, at 22w gestational age mean EFW was 513 (±30)g and at term it was 3462 (±13)g (Williams et al, 1982), and in Benson et al, (1970) study at 28w mean EFW was 1118 (±30)g, and at 40w it was 3448 (±13)g.

Kurtz and Goldberg, (1988) reported that extremes in fetal weight are associated with poor perinatal outcomes. For this reason, reliable estimates of fetal weight can be valuable in the management of pregnancy. De Jong et al, (1998) documented that fetal weight gain as measured by ultrasound is subject to pathological deviation, as well as physiological variations due to maternal height, weight, ethnic group and parity. Sex, race and parity differences have also been found. These results document the need for selecting a set of normal ranges, which is appropriate for the specific population being studied (Deter et al, 1983).

Nahum and Stanislaw (2004) mentioned that birth weight correlates negatively with maternal hemoglobin concentration. This is consistent with well-known effect of high-altitude exposure during pregnancy, which increases both hematocrit and blood viscosity and lowers birth weight. Term birth weight was reduced by 89g for each 1.0g/dL increase in hemoglobin concentration ($P<0.01$) (Nahum and Stanislaw, 2004).

Fanaroff et al, (1995) documented in their study that perinatal mortality is inversely related to gestational age and birth weight. Whereas gestational age is generally known, fetal weight can only be estimated. Clinical variables including fundal height measurements are rather inaccurate predictors of fetal weight, especially in preterm and small-for-gestational-age fetuses in which weight estimates are the most relevant (Guidetti et al, 1990).

Numerous studies have been conducted to derive reference charts for fetal size. Many, however, had a suboptimal design, using a hospital-based population or having an inappropriate sample size. Additionally, substantial differences in reference charts exist depending on the population and the method of pregnancy dating (Altman and Chitty 1994; Altman and Chitty 1993). Reference charts are often based on measurements taken from 12 or more weeks of gestation onwards (Altman and Chitty 1993; Salomon et al. 2006; Snijders and Nicolaides 1994). Hadlock and colleagues method is based on longitudinally measured normal fetuses. The reported standard deviation of their method is 7.3%, which implies that 95% of infants have a measured birth weight within 15.0% of the EFW (Hadlock et al, 1985). In another of his study 95% confidence range was ±16% (Hadlock et al, 1985). In Vintzileo's study 95% confidence range was ±17.6% (Vintzileo et al, 1987). In Shepard's study it was ±18.2% (Shepard et al, 1982) and in Warsofs study it was±17.4% (Warsof et al, 1977).

In a post-natal weight study, there was a uniform variance of approximately ±16% at the 10^{th} and 90^{th} percentiles (Secher et al, 1986), which is very similar to the variance observed in Hadlock's pre-natal weight study, ±17% (Hadlock et al, 1991) and this study. Recent studies have documented increased perinatal morbidity and mortality rates in the growth restricted post-term fetus.

Ultrasonographic estimation of fetal weight is a useful test for predicting fetal growth restriction in prolonged pregnancies (O'Reilly-Green and Divon, 1999).

Sonographic determination of fetal growth from 20w of gestation onwards correlated with birth weight deviation, and this emphasized the clinical value of evaluating fetal growth during the later half of pregnancy in Japanese population mentioned by Youshida et al, (2001). The Osaka University determined mean fetal weight to be 2.9kg at 38w and 3.2kg at 40w.

The ultrasonography-based growth curve generated in China provided an additional tool for the evaluation of fetal growth obtained by Lei and Wen, (1998). In a study on Arabian mothers it was suggested that a nomogram of "fetal growth" is of less variance than absolute measurements and could be more useful in the early identification of growth abnormalities than absolute fetal measurements (Nasrat, 1997). In a population of small fetuses, Hadlock's estimates of fetal weight correlated well with measured birth weight, whereas Scott's method tended to overestimate (Kaaij et al, 1999).

Fetal BPD, HC, AC, FL and fetal thigh soft tissue thickness (FTSTT) were measured by ultrasonography and found that there was significant correlation between FTSTT and birthweight, $R^2 = 0.988$. They concluded that, FTSTT is a simple, accurate and valuable index in estimation of fetal weight (Han et al, 1998).

Mean clinical estimate of fetal weight was equal to ultrasound for the estimation of fetal weight in their population. This has important implications for developing countries where there is a lack of technologically advanced ultrasound machines capable of performing sophisticated functions like fetal weight estimation (Mehdizadeh et al, 2000).

Several models for sonographic foetal weight estimations have been generated by various investigators using different combination of foetal biometric measurements. (Campbell and Wilkin (1975); Higginbottom (1975); Khalil, Rana and Goraya (2002); Hadlock et al. (1985); Shepard et al. (1982); Warsof et al. (1977); Woo et al. (1985) and Shahida et al. (2009). No consensus has been drafted so far to which model gives a better validity for predicting foetal weight in obstetric sonographic practice. The use of particular model is mainly based on preference of the individual obstetrician or radiologist.

Almost all sonographic foetal weight estimation models have been derived from data of western populations (Campbell and Wilkin 1975; Higginbottom et al. 1975) and only Woo et al. (1985) used Chinese data for foetal weight estimation model within Hong Kong. In published resources it has not been identified if any sonographic birth weight estimation model is established for Bangladeshi population as well as for other South East Asian region.

Population differences, ethnicity and secular changes are known to affect birth weight (Shehzad et al. 2006; Woo, Li, Ma 1986 and Wohlfahrt et al. 1998). Anthropological variation of the selected population may change the equation form of published sonographic foetal weight estimation models derived from western population data. Birth weight estimation models derived from other ethnic population applied in our locality might result in systemic erroneous estimations.

In the current study fetal weight estimation was done by Hadlock et al. (1985) formula based on HC, FL and AC. The mean gestational age at delivery was 37.7 (±2) weeks and the mean time interval between ultrasound examination and delivery was 1.67 (±1.07) days. The mean percentage error (PE) of EFW using this formula was -1.4± 7.4%. This was close to the PE of the better examiners of the study mentioned below (Kurmanavicius et al. 2004). Meyer found that predicted fetal weights were significantly underestimated with each of the formulas (Meyer et al, 1995), which support the current study. In the present study mean EFW was 2740 (±730)g and the mean actual birth weight was 2830 (±780)g, which was not statistically significant between EFW and actual birth weight and SD was 7.6% nearly same as reported by Hadlock, on normal population, 7.3% (Hadlock et al, 1985).

In this current study EFW and actual birth weight was classified according to quartile and showed the results of the interpreter analysis Kappa = 0.953 with $p < 0.001$, which indicates that the measure of agreement, was statistically significant and is almost perfect agreement between EFW and actual birth weight. More than eighty percent (83.9%) of the patients belonged to 2nd to 4th quartile in EFW and actual birth weight. The EFW value is coincides with the birth weight. This indicates that the EFW is most accurate at 3.0 kg or the 50th centile weight in our population. In another study here mean EFW was 3.07 (±0.47) kg by BPD and AC formula of Shepard. Birth weights ranged from 2.2kg to 4.1kg and mean was 3.15 (±0.43) kg. The mean EFW was 0.08kg less than mean birth weight. The percentage error was -2.5%, which concluded that USG is a reliable tool to estimate fetal weight (Quddus and Khatun, 2001). With Hadlock and Campbell's formulae and Shepard and Merz formulae the percent errors of EFW varied from 4.0± 8.5% to 1.3± 8.5% between examiners (Kurmanavicius et al, 2004).

To compare the accuracy of eight sonographic formulae for predicting fetal birth weight at term in a multiethnic population, pregnant women at term were included. Patients were from the Indian subcontinent, from Africa, from the Arabian Peninsula and from other ethnic groups. The mean absolute error ranged from a minimum of 0.3% (±11.3) for Hadlock (BPD, HC, AC, FL) to a maximum of 37.5% (±10.0) for Wars of (FL only). The combination of AC with BPD measurements rather than FL achieves a high level of accuracy (Mirghani et al, 2005).

Clinical estimation of birth weight in early labor is as accurate as routine ultrasonic estimation obtained in the preceding week. In the lower range of birth-weight (<2500g), ultrasonic estimation is more accurate; in the 2500-

4000g range, clinical estimation is more accurate. In the higher range of birth weight (>4000g), both methods have similar accuracy (Sherman et al, 1998).

The accuracy of intrapartum ultrasonographic fetal weight estimation was similar among diabetic and non-diabetic women. Birth weights >4500gm rather than maternal diabetes seem to be associated with less accurate ultrasonographic fetal weight estimates. The mean (SD) absolute percent error of fetal weight estimates among subjects with macrosomic fetuses (birth weight >4500 gm) was significantly greater than that observed in fetuses with birth weights <4500gm (12.6 ± 8.4% vs 8.4 ±6.5% p= 0.001) (Alsulyman et al. 1997). Retrospective analysis was undertaken of ultrasound data of all fetuses who underwent an examination within one week of delivery. It was concluded that EFW is as accurate in twins and triplets as it is in singletons (Lynch et al, 1995). When more than one ultrasound estimation of fetal weight are available, prediction of birth weight in relation of gestational age should be based on the last ultrasound examination only (Larsen et al, 1995). The accuracy of sonographic fetal weight estimation was independent of amniotic fluid index (API) across all gestational ages and birth weights. Each of the five formulas had similar error percentages, and no significant differences were detected. Predicted fetal weight was significantly underestimated with each of the formulas, a finding that was also independent of birth weight and AFI. Ultrasonography can be therefore used reliably to estimate fetal weight in patients with altered amniotic fluid volumes (Meyer et al, 1995). In a study in Thailand, the accuracy of clinical and US estimation of fetal weight was compared. It was found that accuracy of clinical estimation of fetal weight by second year resident physicians was comparable to that of US estimation. However, when the clinical estimate of fetal weight is less than 2500g, ultrasound examination should be performed for more accurate results. Careful attention should be paid to infants with birth weight of more than 4000g since no method can correctly estimate the weight (Titapant et al, 2001). Thigh volume measurement using three cross-sectional images of femur by 3D ultrasound was simple, and there was better accuracy (R^2 = 0.921, $p < .001$) with this method than with 2D ultrasound methods (BPD, FL and AC), for predicting fetal weight during the third trimester of pregnancy (Song et al. 2000).

Ultrasound fetal weight estimation is a key element of obstetric management in pregnancy complicated with diabetes. Ultrasound estimates based on formulae utilizing AC measurements only, appear more accurate in this group of women. However they are still associated with errors of up to 25% of true birth weight (Farrell et al. 2004). Gender-related fetal weight calculation allows optimized prediction of fetal weight at birth. Inclusion criteria were a singleton live fetus, gestational age above 25 weeks, birth weight between 1000g and 4500g and fetal biometry within 8 days of delivery (Schild et al, 2004).

Reference curves for fetal growth for BPD, HC, AC and FL demonstrated a similar pattern of increase with gestation and no large inconsistencies with other frequently used curves (Snijders and Nicolaides 1994; Chitty and Altman 1994). The distributions and SD of the growth characteristics are similar to those of the curves developed by Chitty *et al.* (1994). Snijders and Nicolaides (1994) found a greater increase in SD and different distributions of SD for BPD, HC and AC as pregnancy proceeded compared with those in this study. Before 16 weeks of gestation, the mean of BPD, HC, AC and FL was significantly smaller in the current study than was found by Snijders and Nicolaides (1994). These differences are likely to arise from different statistical methods and the way in which pregnancy was dated. Another explanation may be different population characteristics. Improving ultrasound resolution and standardization of technique in this study might also have some influence.

Comparison of fetal weight models from different studies has shown that the use of multiple parameters, and in particular the combination of head, abdomen and femur length measurements, provide the most adequate estimations of fetal weight with 95% confidence interval in the range of 15-16% (Hadlock, 1990). Studying the weight estimation for fetuses small and large for their gestational age, it was observed that only formulae dependent on femur length (FL) fitted both groups well (Miller et al, 1988). Abdominal diameter measurement has been found to be less accurate in cases of oligohydramnios because the fetal skin edge may be difficult to identify when liquor volume is diminished (Valea et al, 1990).

The accuracy of a given model in predicting birthweight decreases further as the population deviates further from that used to generate such a model (Hirata et al. 1990). It is therefore important that each institution should determine which formula best suits its cases, especially when no model has yet been generated locally.

In the present study, EFW(Shepard) showed the least bias overall. This finding is at variance with reports from some other studies which concluded that Shepard's model, which combined AC and BPD, was less accurate than other formulae which used AC and FL (Miller, 1988).

Although it has been claimed in the past that there is cessation of fetal growth at 38 weeks gestation (Rossavik et al, 1989), results from the current series did not support this observation and showed that fetal growth continued until term. When the two new equations were subjected to the same statistical analysis as the four equations under review, the newly generated equations gave more accurate results.

This study is larger than most other studies of fetal growth. It is a large, population-based study with cross sectional fetal growth measurements, allowing normal ranges for fetal measurements with gestational age to be established. Pregnancies were essentially normal, resulting in a healthy singleton birth. Fetuses were followed from early fetal life onwards, which enabled us to create fetal growth curves from 8 weeks of gestation until birth. an important advantage compared with previously published charts. The use of reference curves covering the whole range of gestational age, as in this study, prevents confusion or inconsistency that may arise from the use of different reference curves in clinical practice.

6. CONCLUSION:

This study was undertaken to develop charts for ultrasound dating of pregnancy based on crown–rump length from 8 weeks to 12 weeks of gestational age, biparietal diameter, head circumference, abdominal circumference, femur length from 13 of gestational age onwards and second, to derive reference curves for normal fetal growth based on biparietal diameter, head circumference, abdominal circumference and femur length from 14 weeks of gestational age onwards. Fetal weight was estimated from HC, FL and AC by using Hadlock et al's formula (1985). Growth profile tables and graphs of fetal BPD, HC, FL, AC and estimated fetal weight (EFW) showing 5th, 10th, 25th 50th, 75th, 90th and 95th percentiles were obtained from a cross-sectional study sample of 6600 subjects. Mean, two standard deviations (2SD) and 95% confidence interval were derived after fitting models. Accuracy chart and graph of the EFW were prepared from the birth weights of 73 neonates included in the study for this purpose.

The rate of growth of BPD and FL were approximately 2-4 mm per week from 13 to 23 weeks, 4-5 mm per week from 24 weeks to 36 weeks and thereafter it was 5-6 mm per week till 40 weeks. Whereas the rate of growth of HC and AC were approximately 9-11 mm per week from 13 weeks to 36 weeks and thereafter it was 3-4 mm per week till 40 weeks.

The form of quadratic equation of regression is best fit for femur length (FL) and head circumference (HC), whereas the cubic equation of regression is best fit for biparietal diameter and abdominal circumference (AC). The quadratic equation of regression is best fit for estimated fetal weight. This thesis model signify the estimated gestational age & fetal weight can be calculate from derived equation in our population.

Reference curves for normal fetal growth were developed from 13 weeks of gestation onwards for BPD, HC, AC and FL. The CRL was derived from 8 to

12 weeks of gestation. Early ultrasound dating of pregnancy and the use of reliable growth curves can improve obstetric management in pregnancy.

This study was taken to provide new reference equations for fetal size in Bangladesh, based on a very large sample of fetuses. It is important to establish the reference equations for the mean and SD because researchers can calculate any percentile chart and compare with other equations derived from the same methodology. It can be employed in screening obstetric ultrasound in the Bangladeshi population.

7. STUDY LIMITATION

This study was conducted in two Hospital in capital city of Dhaka and fetal biometry was measured by researcher, which may cause of intraobserver error.

The percentages of mothers with lower socioeconomic status were slightly lower than expected from population statistics in Bangladesh. This selection possibly resulted in a more healthy study population, which may have affected the generalizibility of the results.

This study constructs new reference charts for fetal growth parameters, including CRL, BPD, HC, AC and FL but other fetal growth parameters could not be observed due to time limit of the study. Fetal growth parameters were also not differentiated between male & female fetus.

In Western countries. fetal biometric studies and nomograms were prepared about two decades before, so most of the references in this study are of that time. More comparisons of fetal biometry, with regional studies could not be made as those could not be obtained by browsing Medline search at the time of this research. Reason being either the neighboring countries have not conducted research in this field yet or those were not published in international journals.

8. RECOMMENDATIONS

A multi-centre based study can be conducted with data from all over Bangladesh, to prepare a National standard of fetal nomograms.

Normal predicted values and 95% confidence limits for fetal parameters, BPD, HC, FL, AC and EFW, were given in this study.

In view of the distribution of the normal data on these curves, 5th and 95th percentile boundaries can be used as confidence limits for normal growth, as these cover 95% of the population.

Proper use of these data will lead to earlier recognition of abnormal growth patterns such as growth restriction and growth acceleration, as well as fetal skeletal anomalies from the nomograms.

These growth curves presented herein may also be applicable to populations of nearby regions of similar racial and socioeconomic origins, till they prepare their own nomograms.

The growth percentile of different parameters can be acquired and accurate report based on these population specific nomograms can be given to the patient, to improve the growth rate of fetus with growth deviation.

The nomograms database derived in this study may be installed into the ultrasound machine's in the clinics and hospitals. This way the tables and graphs can promptly be used while scanning the patients.

These nomograms should be published in the Medline and internet so that these can be accessed easily in different research and clinical works. Doctors in western countries can also avail it when needed for their south Asian patients. This will then be of benefit to the maximum number of people, which is the aim of all research work.

Further prospective research is required to evaluate the diagnostic value and effectiveness (both clinical and cost-effectiveness) of predicting small-for-gestational-age babies using: customised fetal growth charts to plot symphysis–fundal height measurements and routine ultrasound in the third trimester.

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Appendix-I
Data Collection Sheet

DETERMINATION OF GESTATIONAL AGE BY ULTRASOUND

General characteristics

1. Patient's name... Reg. No ....
2. Address.. Ph : ....
3. Current age .... in Years. /..................../
4. Age at marriage .... in years /.................... /
5. Occupation (mother)
   1= Service 2= Farmer 3= Business
   4= House wife 5 = Others (Specify) ....
6. Occupation (husband).
   1 = Service 2 = Farmer 3 = Business
   4= Labour (industry) 5= Labour (Non-industry)
   6 = Others (Specify). ....
7. Monthly expenditure in Taka .... / ..../
8. Level of education (husband) : /...............
   1 = Illiterate. 2 = Non-formal education.
   3 = Class 1-V. 4 = Class V1-X 5 = SSC
   6 = HSC 7 = Graduate 8 = Master and above
9. Level of education (mother): / ....
   1 = Illiterate 2 = Non-formal education.
   3 = Class 1-V 4 = Class V1-X 5 = SSC
   6 = HSC 7 = Graduate 8 = Master and above
10. Date of sonography : ..../.........../.......

Reproductive History :

11. LMP ..../.........../.........
12. EDD .... / .... / ....
13. No. of pregnancies .... / ....
14. Para .... / ....
15. Age of last child (If present) .... months / ..../
16. Whether current pregnancy planned. 1 = Yes 2= No / ..../
17. Antenatal care received ? 1 = Yes 2 = No /..................../
18. If yes, when started ? .... weeks / .... /
19. How many visited completed ? ....no / .... /

20 No. of Tetanus toxoid (TT) received ...... no / .... /

21. Past obstetric complications (Multiple answer allowed) / .... /

1= None 2= Diabetes. 3= Hypertension

4= PET 5= Twin 6= APH.

7 = UTI. 8= Others (Specify) .....

22. Iron / vitamin supplementation received ? 1= Yes 2= No / ..../

Physical Examination :

23. Pulse ..../ min / .... /

24. Blood pressure (systolic) .... mmHg / .... /

25. Blood pressure (diastolic) .... mmHg / .... /

26. Height .... cm. /.............../

27. Weight .... kgs. / .... /

28. Hemoglobin .... gm/dl. / .... /

29. Fetal heart sound .... / min. / .... /

30. Height of uterus .... wks / .... /

31. Fetal presentation

1= Head 2 = Breech 3= Transverse

4= Oblique

32. Fetal position

1= Longitudinal 2= Oblique

Fetal Biometry by USG

33. Gestational sac (GS) .... mm / ..../

34. Crown ramp length (CRL) .... mm / .... /

35. Bi-parietal diameter (BPD) .... mm / ..../

36. Femoral length (FL) .... mm / .... /

37. Abdominal circumference (AC) .... mm / .... /

38. Expected fetal weight (EFW) ....gm / .... /

39. Anterior- posterior trunk diameter (APTD) .... mm / .... /

40. Transverse trunk diameter (TTD) .... mm / ..../

Ultrasound Machines:

41. Model : volison 730proV . 2= GE. 3=Others / ..../

42. Probe : 1= Curve linear. 2= Linear. / .... /

43. MHz : 1= 3.5 MHz. 2= 5MHz (Early pregnancy) /................. /

3= Transvaginal USG

Fetal outcome and anthropometry

Reg. No : ....

44. Date of delivery : / .... / ....

45. Fetal outcome :

1= Normal vaginal delivery (Live) 2= LUCS

3= Stillbirth. 4 = abortion. 5= Others (Specify) ....

46. Sex : 1 = Boy. 2= Girl. / ..../

47. Length ....mm / .... /

48. Bi-parietal diameter (BPD) .... mm / .... /

49. Abdominal Circumference (AC) .... mm / .... /

50. Head Circumference (HC) .... mm / .... /

51. Estimated fetal birth weight (EFBW) ....gm / .... /

52. AFGAR Score in one minute .... / .... /

Signature and Date : Checked by :

Appendix-II

CONSENT FORM

I Mr./Mrs...hereby give my well informed free consent for the participation in the study conducted by Dr. Aleya Ferdousi, I fully understand that my participation in the study will bring fruitful medical information useful for myself and for many others in future. I am convinced that during participation in the study I will not be exposed to any physical, psychological and legal risks. My privacy and confidentiality will be safeguarded and my anonymity will be protected. I would not like to be monetarily compensated because of my loss of work time.

Signature/Thumb-print Signature of Researcher

Date:

সম্মতিপত্র

আমি .... জানতে পারলাম যে, ডাঃ আলেয়া ফেরদৌসি, বি.এস.এম.এম.ইউ এবং এমসিএইচটিআই হাসপাতালে গর্ভবতী মায়েদের বাচ্চার বয়স আল্টাসনোগ্রামের মাধ্যমে নির্ণয়ের একটি গবেষণার কাজ করছেন। তিনি আমাকে গবেষণার কাজটির উদ্দেশ্য, পদ্ধতি ও সময়কাল অংশগ্রহণের ফলে আমার সুবিধা-অসুবিধা এবং আমার দেয়া তথ্যাদির প্রয়োজনীয়তা সম্পর্কে অবহিত করেছেন। তিনি আমাকে আশ্বস্ত করেছেন যে, এই গবেষনায় অংশগ্রহণ সম্পূর্ণভাবে আমার ইচ্ছাধীন। আমি অবগত যে, গবেষণার প্রয়োজনে আমার দেয়া তথ্যাদির গোপনীয়তা রক্ষা করা হবে এবং গবেষণায় অংশগ্রহণ না করলে আমার চিকিৎসা সেবা ব্যহত হবে না। আমাকে আরও জানানো হয়েছে যে, এই গবেষণালব্ধ জ্ঞান ভবিষ্যতে চিকিৎসার ক্ষেত্রে গুরুত্বপূর্ণ ভূমিকা রাখতে পারে। আমি আরও জানাচ্ছি যে, এই গবেষণা কাজ অংশগ্রহণের জন্য কোন আর্থিক সুবিধা গ্রহনে ইচ্ছুক নই।

উপরিল্লিখিত বিষয়াদি জেনে আমি স্বজ্ঞানে ও স্বেচ্ছায় ই গবেষণায় অংশগ্রহণের সম্মতি প্রদান করলাম।

স্বাক্ষর/বৃদ্ধাঙ্গুলের ছাপঃ

গবেষকের স্বাক্ষরঃ

তারিখঃ

Appendix-III

Government of the People's Republic of Bangladesh
Directorate General of Family Planning

Maternal and Child Health Training Institute (MCHTI)

Azimpur, Dhaka-1205

Ultrasound Unit

Ultrasound Report

Patient's Name : Age:

USG of Pregnancy Profile Ref. No:

Referred by:

Thank you for your referral

No. of foetus:

Presentation :

Foetal Cardiac Pulsaton: FHR : bpm

Parameters are

GS	mm	BPD	mm	APTD	mm
CRL	mm	FL	mm	TDD	mm
EFBW	gm (± 10%)			AC	mm

Corresponds to weeks days (± weeks) of pregnancy

Placental position : Grade

Amount of Amniotic Fluid

AFI cm Largest pocket cm

EDD :

Others :

IMPRESSION :

(Because of Hospital policy, we will not tell the foetal sex)

Signature : --

Name : --

Date : --