ULTRASONIC FETAL BIOMETRY IN JOS, NIGERIA

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CERTIFICATION

This is to certify that this thesis has been examined and approved for the award of the degree of **DOCTOR OF PHILOSOPHY in ANATOMY.**

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DEDICATION

This work is dedicated to all lovers of truth and excellence in academics

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Abstract

Fetal biometry has been studied using large sample sizes in the developed countries and reference values created for their population but the sample sizes that have been used in Nigerian studies are very small to provide statistically significant data for the relationship between gestational age and fetal parameters. The purpose of this study was to find out the mean values of biparietal diameter, head circumference, occipitofrontal diameter, abdominal circumference, femur length and weight of fetuses in Jos from 12 weeks to 42 weeks of gestation and also to determine the relationship of the aforementioned fetal parameters to gestational age and symphysio-fundal height. Reference values for fetal biometric parameters are important because the study of normal and abnormal growth of fetuses has become an increasingly important part of the practice and research in all fields related to child health. In a cross-sectional study conducted on 13,740 Nigerian fetuses in Jos ranging from 12 weeks to 42 weeks at the Centre for Reproductive Health Research Jos; fetal biometric parameters were measured using ultrasound machine and mean values determined after analyzing the data statistically. The relationship between the derived mean values of the various fetal biometric parameters and gestational age were studied.

Mathematical modeling of data demonstrated that the best-fitted regression model to describe the relationship between biparietal diameter and gestational age is a positive polynomial correlation with a correlation of determination of $R^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the second order polynomial regression equation $y = -0.0511x^2 + 5.3221x - 35.511$ where y is the biparietal diameter in millimeters and x is the gestational age in weeks. A similar correlation was found between gestational age and occipitofrontal diameter with a correlation of determination of $R^2 = 0.9996$ ($P < 0.0001$) which is described by the third order polynomial regression equation $y = -0.001x^3 + 0.0137x^2 + 4.671x - 27.99$ where y is the occipitofrontal diameter in millimeters and x is the gestational age in weeks. Again, a positive polynomial correlation between gestational age and abdominal circumference with a correlation of determination of $R^2 = 0.9995$ ($P < 0.0001$) was found in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = -0.0004x^4 + 0.0349x^3 - 1.2485x^2 + 30.598x - 172.02$ where y is the abdominal circumference in millimeters and x is the gestational age in weeks. Furthermore, mathematical modeling of data demonstrated that the best-fitted regression model to describe the relationship between femur length and gestational age was the second order polynomial regression equation $y = -0.017x^2 + 3.2794x - 25.282$ with a correlation of determination of $R^2 = 0.999$ ($P < 0.0001$) where y is the femur length in millimeters and x is the gestational age in weeks. Mathematical modeling of data demonstrated that the best-fitted regression model to describe the relationship between weight and gestational age was the power regression equation $y = 0.038x^3$ where y is the fetal weight in grams and x is the fetal age in weeks with a correlation of determination of $R^2 = 0.9951$ ($P< 0.0001$) in Nigerian fetuses in Jos. When fetal weight was plotted against symphysio-fundal height, it was found out that there is a positive correlation between fetal weight and symphysio-fundal height with a correlation of determination of $R^2 = 0.9951$ ($P< 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.0409x^3$ where y is the fetal weight in grams and x is the symphysio-fundal height in centimeters. Growth of the fetal biometric parameters in the study population showed a curve similar to that of Europeans. The study identified a 19th week gestation problem (characterized by decrease in growth rate of fetal parameters measured with concomitant weight loss) which will require to be pursued by future investigators. It is concluded that biometric parameters in Nigerian fetuses in Jos correlated well with gestational age and symphysio-fundal height.

CHAPTER ONE
INTRODUCTION

Fetal biometry is an important part of the regular examinations performed during the second and third trimesters of pregnancy. This type of examination during pregnancy became popular with the introduction of ultrasound technology in clinical practice and today, the use of ultrasound in the measurement of fetal parts is referred to as ultrasonic fetal biometry. Before the introduction of ultrasound in medicine, radiological imaging was used in the assessment of the status of the fetus *in utero* though in a limited way because of its risk factors (Mahony *et al*., 1985).

1.0 STATEMENT OF PROBLEM

One of the major objectives of Nigeria's development policy is the quality of life of its population. The well-being of the fetus is an important determinant of the quality of life of the population in the future. This is very much significant in two important respects. Firstly, it is strongly conditioned by the health and nutrition of the mother, in the sense that maternal malnutrition, ill-health and other deprivation are the most common causes of retarded fetal growth and prematurity, as manifested in low birth weight. Secondly, it is one of the most important factors that decide the chance of a newborn to survive and grow in a healthy way. For these reasons, increasing attention is now given to the study of the anatomy of the fetus as a general indicator of the health status of the population. At the same time it reflects, in a simple and easily comprehensible manner, the survival and health prospects of the youngest generation both of which are important determinants of the quality of human life in the future.

1.1 BACKGROUND AND JUSTIFICATION FOR THE RESEARCH

The structural aspects of Anatomy are now well documented but the variables are treated as if they are homogeneous while they are not. Even though structural variations are described in Anatomy, in most cases the anatomists do not provide statistical values for the structures which are well established. They consider these structures to be rigid in their topography whereas they tend to vary from individual to individual and even from race to race. Variations in the anatomical structures of the fetus include variation in head length (distance between the occipital bone and the frontal bone or occipitofrontal diameter), variation in head width (distance between the left and right parietal bones or the biparietal diameter) and variation in the distance round the head (head circumference). The modern Anatomist must be able to unravel this in order to provide superior information that is utilizable in various spheres of life and scientific investigations. He must apply statistical methods in analyzing his data and take mean values for such variable structures and accept them as the central tendency without discarding the scatter. In the developed world, this has been done and now they have normal mean values with their concomitant standard deviations and standard errors of mean which they use in their own community for the diagnosis and treatment of diseases but the sample sizes that have been used in Nigerian studies are very small to provide statistically significant mean values.

Arguments for the use of anthropological information in the diagnosis and treatment of diseases in the western setting were advanced by Kleinman in a series of writings (Kleinman, 1982). Kleinman described this as a clinically applied medical anthropology. Medical anthropology which was popularized by Rivers suggested that medicine is part of culture. Rivers model represents a first attempt at scientific systematics in medical anthropology. Today, medical anthropology is defined as that discipline which recognizes variations in human measurable parameters in relation to medicine and medical systems and the human confrontation with disease and illness. It therefore examines variations in medical systems and medicine in different cultures. It is very strongly linked to cultural modes of diagnosis and treatment of diseases. When such information on cultural beliefs and attitudes towards sickness and the state of being unwell or indeed disease taxonomy, is applied to the treatment of a patient from similar cultural extraction under the western system, the technique may be labeled as clinical anthropology. Ogunranti, following the lead of Morley began to popularize the use of biological anthropology with its sister subdivision anthropometry to classify populations in relation to medical practice. Since Morley said “weight charts…form the most convenient estimate of a fetus/child’s nutrition and health…” it follows that Morley’s approach forms a basis for implicating anthropometry in modern medical practice. It goes to prove that physical anthropological characteristics like head circumference can be highly valuable as health indicants or concomitants. Morley’s approach to the study and utility of weight in clinical practice has been examined and found to be a pioneering effort in clinical anthropology (Nwokoro *et al*., 2006). Clinical anthropology can be recognized as an applied branch of medical anthropology that has direct relationship with clinic situation for diagnosis and treatment of patients.

Although the erstwhile approach to clinical anthropology is highly culturally oriented, Ogunranti formulated a revised form of clinical anthropology which includes biological data especially as it affects the developing world (Didia and Ogunranti 1986). In view of this factor, one is therefore justified to relate the approach of Morley to obtaining fetal biometric parameters such as weight for clinical utility as a pioneering effort in clinical anthropology in general and that the effort in procuring normal values for growing fetuses is continued effort in biologically oriented clinical anthropology.

Thus if the weight of a fetus from Jos in Northern Nigeria at a particular gestational age is lower than the normal average value for his counterpart at the same gestational age obtained at Edinburgh, one can look at the normal values of the Jos fetuses in order to determine whether such a fetus is abnormal or not. In this study, anthropometric parameters of contemporary growing fetuses in Jos were examined as a prelude to prescribing normal values for fetal weight, biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference and femur length for the present generation of Nigerian fetuses in Jos during normal pregnancy. A research that will include sonographic measurement of fetal parameters and the statistical treatment of these quantities is expected to solve the problems of measurements in biomedicine and specifically problems for ultrasound measurement of growing fetuses in this environment. It will also provide better understanding of the growth pattern of fetuses during normal pregnancy and create database for fetuses in this environment which will be utilizable in clinical anthropological practice in this environment. It will also provide scientific understanding of the nature of human growth at the level of the fetus.

1.2 OVERVIEW OF BIOMETRY

Biometrics is the mathematical study of variation between individuals of a certain species in a population. To the anthropologist, biometrics refers to body measurements and the statistical treatment of those quantities. Biometrics can produce valid, objective information when applied to people. It is non-invasive and its instruments are relatively inexpensive. Information derived from the study of biometrics can give clues to variability, such as whether it is due to heredity or to environment. Ultrasonic fetal biometry is a technique in sonographic embryology devoted to the measurement of several parts of fetal anatomy and their growth (Hohler, 1984). Modern embryology takes into consideration new horizons in molecular embryology and a new modality of fetal study is sonographic or ultrasonic embryology. Sonographic embryology is an emerging field of study which allows detailed examination of the fetal anatomy and measurement of the unborn *in utero* using real time ultrasound technology. Since ultrasonography was first introduced in the 1950s as a diagnostic tool, its use has turn out to be commonplace in many obstetric practices such that the use of ultrasound technology has been the province of clinicians. Of recent, some modern anatomists have broken away from this notion and have acquired skills in modern sonographic imaging techniques which they utilized in describing processes of development by the examination of the developing embryo (Hill, 2000). Armed with these skills, they survey fetal anatomy for gross malformations in addition to descriptive human embryology which would have been impossible giving the paucity or indeed non existence of data (Huang *et* *al*., 2008). Congenital malformations are responsible for 20% - 25% of perinatal deaths and even higher percentage of perinatal morbidity. Some of these anomalies are difficult to diagnose than others, whether because of technical factors such as cardiac defects, or lesion size such as small facial clefts. The detection of other anomalies such as choroid plexus cysts is dependent on the gestational age of the fetus. The accuracy of sonography in detecting certain lesions prenatally is difficult to assess because of differences in the extent of the malformation, quality of the equipment, and the skill of the sonographer.

Fetal biometry can be carried out by cross-sectional or longitudinal studies. For cross-sectional study, fetuses are examined only once during gestation. This type of study can be performed in a small period of time and the data is easier to collect and analyze statistically.

A longitudinal study, on the other hand, is one in which a small number of fetuses are investigated serially, at least thrice during the course of pregnancy. In this type of study, fetal age is established in early pregnancy, abnormal growth curves are easily diagnosed; and the statistics provide more relevant and stronger information. These studies necessitate that same fetuses be scanned during the whole gestation, which considerably increases the time to collect the data and calls for a high motivation on the part of both the mother and investigator.

Data collected from either cross-sectional or longitudinal studies are usually analyzed statistically. In analyzing the data, mean value, standard deviation, standard error of mean, scattergrams, correlation and regression analysis are usually done. When a person uses the word “average”, he usually has in mind the arithmetic mean. The arithmetic mean is the most common type of average. An average is a *measure of central tendency*. This simply states that the average is a point around which the numbers group. With the average, we have some idea of the kind of numbers it represents, but the whole story still remains incomprehensible at the stage of average. To clear up the mystery of the hidden numbers that make up an average, another measure is necessary. It is called the *standard deviation from the mean.* The two measures go together like star and satellite. If we know the mean and the standard deviation of a group of numbers, no matter how large, this is what we know about them:

1. The mean + 1 standard deviation and – 1 standard deviation will include about 2 out of 3 numbers in the group
2. The mean + 2 standard deviations and – 2 standard deviations will include about 95 out of 100 numbers in the group
3. The mean + 3 standard deviations and – 3 standard deviations will include 997 numbers out of 1,000, if there are enough numbers, or 99.7 per cent of the numbers in the group.

As one might expect, the larger the group of numbers from which our mean and standard deviation are calculated, the more accurate will be the information they give. There can be no doubt that the mystery of hidden numbers is cleared by the standard deviation.

1.3 BASIC PHYSICS IN ULTRASOUND

Sound is the orderly transmission of mechanical vibrations through a medium. Sound above 20 KHz is described as ultrasound. Audible sound spreads out from its source in a fashion similar to waves on a pond. Ultrasound can be made to be more directional and can therefore be used diagnostically (Denis 1982). Ultrasound waves are produced by applying a short pulse of electricity to a piezo-electric crystal. This causes the crystal to change its width. The change in width causes the particles of the adjacent medium to vibrate. These vibrations are propagated through the medium as a pulsed, sinusoidal wave. Diagnosis by ultrasound is made by interpretation of echoes produced from reflection or scattering of ultrasound at tissue interfaces or from scattering from heterogeneous structures within tissue.

1.4 ULTRASOUND SCHEDULE

There is no hard and fast rule as to the number of scans a woman should have during her pregnancy (Chen *et al*., 2008). A scan is ordered when an abnormality is suspected on clinical grounds. Otherwise a scan is generally booked at about 7 weeks to confirm pregnancy, exclude ectopic or molar pregnancies, confirm cardiac pulsation and measure the crown-rump length for dating (Margaret and John 1999).

1.5 SAFETY CONCERNS OF ULTRASOUND

The safety of ultrasonography in pregnancy is well documented (Tu *et al.*, 2008; Rasmussen *et al.*, 2009; Ho *et al.*, 2009; Yap *et al*; Bani *et al.*, 2009; Imbergamo *et al.*, 2008; Chen *et al.*, 2008; Doné *et al.*, 2008; Reddy *et al.*, 2008; Miller, 2008; Fowlkes, 2008; Sheiner and Abramowicz 2008). 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 for its wide usage (Nyborg, 2002). Ultrasound is safe for the patient, the fetus and the sonologist (Stark *et al.*, 1984). There is no reported risk of ionizing radiations as in X-rays (Mahony *et al.*, 1985), or any other known biological or embryotoxic effect. It does not require the injections such as radio-opaque dyes as sometimes needed in X-ray radiology (Miller *et al.*, 1998).

1.6 FREQUENCTLY USED PARAMETERS IN ULTRASOUND STUDIES:

1.6.1 Biparietal Diameter (BPD): This parameter is used in the second trimester, from 12th week onwards. It measures the maximum distance between the two parietal bones taken from the leading edge of the skull to the outer to inner leading edge (Hadlock *et al.*, 1982). It can also be measured from outer to outer table of the skull. This axial plane passes through the widest portion of skull where the continuous midline echo of falx cerebri is broken by cavum septum pellucidum with both the thalami enclosing the slit like opening of the 3rd ventricle of brain.

Studies report the growth of the BPD in the mid trimester is linear and rapid and biological variation at each week of gestation is small. The measurement of BPD from 14 – 26 weeks predicts the correct duration of gestation to the extent of ± 9 days in 95% of cases, however, the measurement of the parameter in second trimester (16 – 20weeks) routine scan is performed in all good antenatal care centers.

At times, when the fetal head may be short and wide (brachycephaly) or long and flattened (dolicephaly), the assessment of age from BPD will be under or over estimated. Therefore, if the shape of head appears brachycephalic or dolicephalic; the cephalic index is calculated; and if found to be outside the normal range, the head circumference should be used to estimate age.

1.6.2 Head Circumference (HC): This parameter is used in the third trimester along with other parameters such as femur length (Ott, 1994; Warda *et al*., 1985; Exacoustos *et al*., 1991). It is measured at the same level at which the BPD is taken by using the ellipsoid mode of the machine and adjusting the elliptical calipers to the outer margin of the skull table. The accuracy of this parameter is ±2 – 3 weeks with 95% confidence interval.

1.6.3 Abdominal Circumference (AC): This ultrasonic fetal anthropometric parameter is less used for the assessment of gestational age. It is however, more used for monitoring fetal growth, especially in the third trimester and for estimation of fetal weight (Campbell and Wilkin, 1975). The abdominal circumference is taken at the level where the umbilical vein enters the left branch of portal vein; alternatively, a scan at a slightly lower level showing a short segment of the umbilical vein may be taken. The outline of the abdomen should be as circular as possible. Until 36 weeks of pregnancy, the head circumference is larger than the abdominal circumference, the HC: AC ratio is therefore more than 1, but after 36 weeks, the AC catches up with the HC, and then continues to grow at a faster rate, so that the ratio of HC to AC near term becomes less than one (Campbell and Thoms, 1977).

1.6.4 Femur Length (FL): Femur length is a very useful anthropometric parameter in the second and third trimesters of pregnancy. It grows linear throughout and is best measured after 14 weeks of gestation (Deter *et al*., 1987; Chitty *et al*., 1994; Kurmanavicius *et al*., 1999).

The diaphysis is measured from the greater trochanter above to the lateral condyle below. The outer border of femur is straight and the inner border is curved normally (Sharlon and Filly, 1985). The accuracy of gestational age calculation by FL is within 6 – 7 days of menstrual age at 95% confidence level (Brien *et al.*, 1981). These four parameters are most frequently used for the estimation of gestational age and sometimes considered as the ‘gold standard’ and they collectively assess the gestational age to the highest degree of accuracy (Brien *et al.*, 1981).

1.7 LESS FREQUENTLY USED PARAMETERS

Parameters, less frequently used in the discipline of fetal anthropometry, include the fetal transverse thoracic diameter, thoracic circumference, and measurement of long bones, orbit and lens dimensions and fetal binocular distance.

1.8 RATIOS OF BODY PARAMETERS

Limitation of growth potential in the fetus is called intrauterine growth retardation (IUGR) and this can either be symmetrical or asymmetrical. Symmetrical growth retardation implies a fetus whose entire body is proportionally small while asymmetrical growth retardation implies a fetus that is undernourished and is directing most of its energy to maintaining growth of vital organs such as the brain and heart, at the expense of the liver, muscle and fat. Ratios of biometric parameters can be useful in screening for IUGR (Deter *et al* 1993) especially when it is asymmetrical. Ratios not involving head measurements tend to be relatively constant after 20 weeks of gestation and so can be useful in evaluating fetuses where the dates are uncertain. The ratios of body parameters commonly used for assessing fetal development include biparietal diameter to occipitofrontal diameter ratio, head circumference to abdominal circumference ratio, biparietal diameter to femur length ratio, thoracic circumference to abdominal circumference ratio, femur length to head circumference ratio and femur length to abdominal circumference ratio. These ratios can be used in the diagnosis of congenital anomalies.

1.8.1 Biparietal diameter to occipitofrontal diameter ratio (Cephalic index)

Cephalic index is the ratio of the biparietal diameter of the skull to the occipitofrontal diameter and can detect asymmetry in the skull during development (Abuhamad, 1996). Normal range is 74% to 83%, <74.9% =dolichocephalic skull, from 75% - 79.9% = mesocephalic skull, from 80% - 84.9% = brachycephalic

1.8.2 Head circumference to abdominal circumference ratio

This ratio is useful in detecting asymmetrical growth retardation (Abuhamad, 1996; Deter, 1986; Deter and Harrist 1993).

1.8.3 Biparietal diameter to femur length ratio

The ratio of BPD to FL at 15 to 23 weeks of gestation can be used to identify fetuses at risk for Down syndrome. Infants with Down syndrome have shortening of the femur which contributes to an increase in the above normal.

Interpretation

- i. the ratio decreases with gestational age
- ii. infants with Down syndrome have a ratio greater than 1.5 standard deviations above the mean for the control population.

1.8.4 Femur length to head circumference ratio

Since the biparietal diameter can be affected by different fetal head shapes, the head circumference can be useful for providing a comparison with femur length.

Interpretation (Hadlock, 1984):

1. A normal ratio exclude dwarfism
2. A low ratio suggest possible dwarfism
3. A high ratio suggests possible microcephaly

Limitations:

The ratio will not be affected by growth abnormalities that do not affect the head or long bones

(Deter and Harrist, 1993)

1.8.5 Femur length to abdominal circumference ratio

FL/AC ratio is constant in the normally growing fetus from 21 weeks of gestation to term being independent of menstrual age. An increase in the ratio above normal can be seen in fetuses that are small for gestational age (Divon *et al.*, 1986). FL/AC ratio = FL in cm/AC in cm*100

Interpretation

1. Infants who are small for gestational age have a ratio > or = 23.5; however, due to low prevalence of growth retardation in a general population only 25% of infants with a ratio of 23.5 will be growth retarded (Ott, 1985)
2. Large for gestational age infants have a ratio around 21
3. Once an infant has been identified as being at risk for growth retardation by the FL/AC ratio then other criteria for growth should be monitored rather than the ratio as the ratio can return to normal in infants who are growth retarded (Hadlock *et al.*, 1983).

1.9 PURPOSE OF THE STUDY

This study set out to determine the mean values of biparietal diameter, head circumference, occipitofrontal diameter, abdominal circumference, femur length and weight of fetuses in Jos from 12 weeks to 42 weeks of gestation. Correlation and regression analysis was then carried out between the obtained mean values of the fetal parameters and gestational age. Correlation and regression analysis was also carried out between the mean values of theses parameters and mean values of symphysio-fundal height. Fetal biometric mean values obtained from this study will provide standards against which to compare growth in individual fetuses in this environment. Such comparisons will provide the means for detecting and characterizing abnormal fetal growths. The findings of this study will be of benefit to obstetricians, embryologist, perinatologist, forensic pathologist, clinical anthropologist, scientific investigators and auxiologist. As therapeutic methods are developed, these standards will also be important in assessing the response to treatment because such standards will focus on the population from which the sample studied was drawn and therefore to which the results can be referred. The scope of the study was limited to fetuses in Jos from 12 to 42 weeks of age.

1.10 AIMS AND OBJECTIVES

This study was aimed at achieving the following objectives:

1. To determine reference charts and equations for biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight of Nigerian fetuses in Jos from 12 to 42 weeks of gestation.
2. To determine the growth rate of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference and femur length from Nigerian fetuses in Jos between 12 and 42 weeks of gestation.
3. To determine rate of weight gain in fetuses in Jos from 17 to 42 weeks
4. To determine the best fetal parameter to use in dating pregnancy in this environment
5. To explore the relationship between maternal symphysio-fundal height and fetal biometric parameters in an obstetric population dated by sonography.

1.11 RESEARCH QUESTIONS

The following research questions guided the study.

1. What are the mean values of fetal biometric parameters in this environment at gestational age ranging from 12 to 42 weeks?
2. Is there any correlation between fetal biometric parameters and gestational age? If yes, then what are the regression equations for such relationships?
3. Is there any correlation between the different fetal biometric parameters? If yes, then what are the regression equations between these fetal biometric parameters?

4. Can ratios of fetal biometric parameters be used to diagnose malformed fetuses in this environment? If yes, then what are these ratios?
5. Can one predict the weight of a fetus by the measurement of the symphysio-fundal height? If yes, then what is the regression equation for such predictions?
6. Can one predict the weight of a fetus by just measuring any of its biometric parameters? If yes, then what is the regression equation for such prediction?
7. Is there any significant difference between mean biometric parameters of fetuses in this environment and other well known standards?
8. At what gestational age do these fetal biometric parameters have their greatest growth rate and what is the growth velocity at that age?
9. Are there new relationships previously unknown for growth patterns in this study when compared to others in the past with less population sizes?

1.12 HYPOTHESES

The following null hypotheses were tested at alpha level of 0.0001:

1. Ho_1: There is no significant difference in the mean values of fetal biometric parameters in this environment and other well known standards.
2. Ho_2: There is no correlation between fetal biometric parameters and gestational age.
3. Ho_3: There is no correlation between the different fetal biometric parameters.
4. Ho_4: The weight of a fetus cannot be predicted from symphysio-fundal height measurement.
5. Ho_5: The weight of a fetus cannot be predicted from any of its biometric parameters.
6. $Ho_{6:}$ Data presented in this study for the parameters of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight from Nigerian fetuses in Jos between 12 and 42 weeks of gestation cannot be used to predict gestational age in the fetus.

7. Ho_7: There is no new pattern of human fetal growth expected from the study despite its large sample size of over 13,000.

CHAPTER TWO
LITERATURE REVIEW

2.0 GENERAL REVIEW

An assessment of the publications on fetal biometric parameters revealed that the relationship between these parameters and fetal age has been studied by a large number of investigators in different parts of the world, particularly North America and Europe. Also it has been noted that there is nothing in the literature to show that maternal biometric parameters such as symphysio-fundal height (SFH) have been studied in relation to fetal biometric parameters. This kind of relationship is worth studying because a fetus grows in the womb of its mother.

Of all the publications on fetal biometric parameters, there appear to be a systematic difference in the data sets collected before and after 1974 (Kurtz *et al*., 1980; Hadlock *et al*., 1982). The basis for this difference though not known has been suggested to be as a result of the introduction of gray scale imaging which was made possible by the use of convertors (Kossoff, 1972). A scan convertor is a device for storing and processing images before display. The development of scan convertors was a major advance in ultrasound because of their ability to display echo amplitudes as shades of gray. Prior to the advent of scan convertors a storage oscilloscope was used and this produced an all or nothing, black and white, bi-stable picture (Kossoff, 1972). With the storage oscilloscope, very strong echoes such as those obtained from bone/soft tissue interfaces saturate the display such that weak echoes from soft tissue interfaces are lost. For example, there is a complete loss of the echoes from the fetal brain because of the strong echoes from the fetal skull/brain interface. In gray scale imaging, however, the range of echo magnitudes are presented as shades of grey. The human eye can only appreciate about 15 shades of gray so the signal range has to be compressed in such a way as to preserve the weaker echoes, so that the reduction in the signal range does not result in a loss of information. Since all current ultrasound machines employ gray scale imaging, the literature review will focus on studies published after 1974.

2.1 BIPARIETAL DIAMETER

Biparietal diameter studies available after 1974 showed that two studies (Hassani 1978; Hobbins and Winsberg 1977) were simply tables relating BPD values to gestation age with no information pertaining to the sample studied, the measurement procedures used, or the analysis performed to ascertain the biparietal diameter-gestational age. Except for the most current investigations very little information concerning the demographics of the samples studied was available. The data available indicates that fetuses of Latin Americans (Fescina *et al.*, 1982), Polynesians (Jung *et al.*, 2007; Kankeow, 2007; Walton 1982) and black Africans (Okupe *et al.*, 1984; Vialet *et al.*, 1988; Munjanja *et al.*, 1988; Kouam *et al.*, 2000; Cisse *et al.*, 2000; Gutknecht 1998; and Okonofua and Atoyebi 1989) have been reported. The limited information on the effect of race and sex (Sabbagha *et al.*, 1976; Walton 1982; Fescina *et al.*, 1980; Deter *et al.*, 1984; Okupe *et al.*, 1984; Parker *et al.*, 1984) indicates that in general, these variables are not significant factors except in special cases (Walton 1982). However, one recent publication has reported a sex difference after 24weeks (Parker *et al.*, 1984). In these studies measurement procedures have generally been good, although some authors have not provided independent confirmation of dates, (Issel *et al.*, 1975; Levi and Erbsman 1975; Wladimiroff *et al.*, 1978; Walton 1982; Hern 1984) have not given their measurement procedures (Hoffbauer *et al.*, 1979; Aantaa and Forss 1980; Hern 1984) or have utilized nonstandard methods (Hoffbauer *et al.*, 1979; Aantaa and Forss 1980; Hern 1984; Okupe *et al.*, 1984). In a number of investigations, the data collected were partially longitudinal (Wittman *et al.*, 1979; Queenan *et al.*, 1976; Persson *et al.*, 1978; Hoffbauer *et al.*, 1979; Weinraub *et al.*, 1979; Okupe *et al.*, 1984) or completely (Sabbagha *et al.*, 1976; Fescina *et al.*, 1982), but were analyzed as if they were cross-sectional. This “mixed model” approach does not provide valid variability estimates although the determination of regression functions is not impaired. The method of analysis was not defined in four cases (Issel *et al.*, 1975; Levi *et al.*, 1975; Aantaa and Forss 1980; Hern 1984). Appropriately analyzed cross-sectional (Jung *et al.*, 2007; Kankeow, 2007; Salomon *et al.*, 2006; Nasrat and Bondagji, 2005; Paladini *et al.*, 2005; Jacquemyn *et al.*, 2000; Kurmanavicius *et al.*, 1999; Chitty *et al.*, 1994b; Figueras *et al.*, 2002; Hadlock *et al.*, 1982; Wladimiroff *et al.*, 1978; Walton 1982) and longitudinal (Deter *et al.*, 1982a; Deter *et al.*, 1984) studies have been reported in a few instances. Two (Wladimiroff *et al.*, 1978; Walton 1982) of the cross sectional studies did not cover the entire range over which BPD measurements can be made. One (Wladimiroff *et al.*, 1978) had poor documentation of dates and measurement methods and the other (Walton 1982) was carried out on an inadequate sample. The cross-sectional study of Hadlock *et al* (1982) and the longitudinal studies of Deter *et al* (1982b, 1984) appear to be free of major methodological problems.

Of the studies giving results appreciably different from those of Hadlock *et al.*, three (Wladimiroff *et al.*, 1978; Hoffbauer *et al.*, 1979; Deter *et al.*, 1982a) used anatomical planes chosen on the basis of other criteria, and two (Fescina *et al.*, 1982; Okupe *et al* (1984) used outside-to-outside rather than outside-to-inside measurements.

2.2 HEAD CIRCUMFERENCE

Growth of the fetal head circumference, a measure of head size (Deter *et al.*, 1983), has been evaluated in many investigations (Jung *et al.*, 2007; Kankeow, 2007; Salomon et l., 2006; Paladini *et al.*, 2005; Nasrat and Bondagji, 2005; Figueras *et al.*, 2002; Jacquemyn *et al.*, 2000; Kurmanavicius *et al.*, 1999; Chitty *et al.*, 1994; Levi and Erbsman, 1975; Hoffbauer *et al.*, 1979; Weinraub *et al.*, 1979; Aantaa and Foss, 1980; Fescina and Ucieda, 1980; Fescina *et al.*, 1982; Deter *et al.*, 1983; Deter *et al.*, 1982b; Hern, 1984; Campbell, 1976; Hadlock *et al.*, 1982; Deter *et al.*, 1982b). As with other parameters, the demographics of the sample studied have been only in the later studies, (Jung *et al.*, 2007; Kankeow, 2007; Salomon et l., 2006; Paladini *et al.*, 2005;

Nasrat and Bondagji, 2005; Figueras *et al.*, 2002; Jacquemyn *et al.*, 2000; Kurmanavicius *et al.*, 1999; Chitty *et al.*, 1994) these data indicating that fetuses of white, middle-class women have been evaluated primarily. Racial differences have been investigated (Jacquemyn, 2000) and only four cases (Fescina *et al.*, 1982; Deter *et al.*, 1982a; Deter *et al.*, 1984; Parker *et al.*, 1984) has the effect of sex been examined – sex differences could be demonstrated in only one case (Parker *et al.*, 1984) .

Measurement procedures have generally been good, but in some cases the measurement method was not given (Hoffbauer *et al.*, 1979) or was questionable (Weinraub *et al.*, 1979). Other investigations have not given the method used to date the pregnancy at the time of measurement (Hoffbauer *et al.*, 1979; Campbell, 1976), or the dates used were not independently confirmed (Levi and Erbsman, 1975). There have been very few evaluations of measurement errors (Fescina and Uceida, 1980; Hadlock *et al.*, 1982; Deter *et al.*, 1982b).

Data analysis has also been a major problem. Three investigators (Hoffbauer *et al.*, 1979; Weinraub *et al.*, 1979; Fescina *et al.*, 1982) have used the mixed model, which does not give valid variability estimates, while in two cases (Levi and Erbsman, 1975; Campbell, 1976) insufficient information was given to determine the study type used. The cross-sectional studies of Jung *et al* (2007), Kankeow (2007), Salomon et l (2006), Paladini *et al* (2005), Nasrat and Bondagji (2005), Figueras *et al* (2002), Jacquemyn *et al* (2000), Kurmanavicius *et al* (1999), Chitty *et al* (1994), Deter *et al* (1982b) and Hadlock *et al* (1982), as well as the longitudinal studies of Deter *et al* (1982a, 1984) appear to be free of major methodological problems. The cross-sectional and longitudinal studies of Deter *et al* (1982a, 1982b) have given very similar results.

2.3 OCCIPITOFRONTAL DIAMETER

The occipitofrontal diameter has been used as an indicator of head growth in many investigations. (Deter *et al.*, 1982a; Levi and Erbsman, 1975; Hoffbauer *et al.*, 1979; Fescina *et* *al.*, 1982). The demographics of the sample studied were given in only one case, a study of a Latin American population (Fescina *et al.*, 1982). This study is also the only one to consider an effect of sex, but the method of evaluation used was not given.

Evaluation of the measurement procedures used in these investigations indicates a number of significant problems. Dating methods was either not given (Hoffbauer *et al.*, 1979) or independent confirmation of the dates was not obtained (Deter *et al.*, 1982b; Levi and Erbsman, 1975). The head profile used for measurement was not given in one case (Hoffbauer *et al.*, 1979), and the conventional BPD profile was not used in another (Levi and Erbsman, 1975). There have been no assessments of measurement errors.

Evaluation of the analytical methods used in these investigations reveal further problems. The study type could not be determined (Levi and Erbsman, 1975) or the mixed type was used (Hoffbauer *et al.*, 1979; Fescina *et al.*, 1982). The one appropriately analyzed cross-sectional study (Deter *et al.*, 1982a) was compromised by inadequate dating, absence of data before 20 weeks, and lack of documentation of the representativeness of the sample distribution over time. Since there has been no evaluation of measurement errors, it is difficult to assess the differences seen in these data sets. Differences in the plane used for measurement are the most likely explanation for differences between the data of Levi *et al* (1975) and Hoffbauer *et al* (1979) and those of Deter *et al* (1982b). However, this is not likely for the differences with the data of Fescina *et al* (1982). Other possibilities are absence of measurements before 20 weeks and the distribution of measurements as a function of time (not given) in the study of Deter *et al*. Both of these factors could affect the regression function and thus the predicted values. However, in none of the studies was the method of measurement precisely described, and differences at this step may be sufficient to account for most of the differences seen. In view of these results, the occipitofrontal diameter/gestational age relationship cannot be considered well defined at this time.

2.4 ABDOMINAL CIRCUMFERENCE

Growth of abdominal circumference, a measure of trunk growth and a sensitive indicator of liver size (Deter *et al.*, 1983) has been studied in many investigations (Jung *et al.*, 2007; Kankeow, 2007; Salomon et l., 2006; Paladini *et al.*, 2005; Nasrat and Bondagji, 2005; Figueras *et al.*, 2002; Jacquemyn *et al.*, 2000; Kurmanavicius *et al.*, 1999; Chitty *et al.*, 1994; Levi and Erbsman, 1975; Hoffbauer *et al.*, 1979; Weinraub *et al.*, 1979; Hoffbauer *et al*, 1979; Weinraub *et al.*, 1979; Feiscina *et al.*, 1982; Deter *et al.*, 1982a; Deter *et al.*, 1984; Campbell, 1976; Deter *et al.*, 1982b; Warsof, 1977; Tamura and Sabbagha, 1980; Meire *et al.*, 1981; Woo *et al.*, 1984; Hadlock *et al.*, 1982). Compared to other parameters, considerably more demographic data on the sample studied have been presented, but sex differences have been evaluated only by Fescina *et al,* (1982), Deter *et al* (1982b) and Parker *et al* (1984) and racial differences by Tamura and Sabbagha (1980) and Meire and Farrant (1981). A statistically significant (but probably not clinically significant) sex difference was found by both Deter *et al* (1984) and Parker *et al* (1984) in their longitudinal studies. No differences between blacks, whites and Hispanics were found by Tamura and Sabbagha, while Meire and Farrant observed systematically smaller mean values in Indians as compared to European whites. Tamura and Sabbagha did not describe how the different ethnic groups were compared.

Evaluation of the measurement procedures used in these investigations revealed a number of problems. Among these were failures to give the method of dating the pregnancy at the time of measurement (Hoffbauer *et al.*, 1979; Campbell, 1976; Warsof, 1977) or to give the measurement method itself (Hoffbauer *et al.*, 1979; Meire and Farrant, 1981). The AC was determined from diameters rather than by direct measurement in one case (Fescina *et al.*, 1982). There was an assessment of measurement errors by several investigators (Fescina and Ucieda, 1980; Deter *et al.*, 1982a; Warsof, 1977; Woo *et al.*, 1984; Hadlock *et al.*, 1982).

The analyses used in these investigations also raise serious questions. Studies of mixed type were used (Hoffbauer *et al.*, 1979; Weinraub *et al.*, 1979; Fescina *et al.*, 1980; Tamura and Sabbagha 1980; Meire and Farrant, 1981), or there were insufficient data to determine the study type (Meire and Farrant, 1981). Two of the appropriately designed and analyzed cross-sectional studies are limited by poor sample representativeness with respect to time or inadequate range (Woo *et al*., 1984). The cross-sectional studies of Deter *et al* (1982a) and Hadlock *et al* (1982), as well as the longitudinal studies of Deter *et al* (1982b, 1984) appear to be free of significant problems. The cross-sectional studies of Jung *et al* (2007), Kankeow (2007), Salomon et l (2006), Paladini *et al.,* (2005), Nasrat and Bondagji (2005), Figueras *et al* (2002), Jacquemyn *et al* (2000), Kurmanavicius *et al* (1999), Chitty *et al* (1994), and longitudinal studies of Deter *et al* (1984) have given very similar results.

Comparing the mean values obtained by the different investigator, it can be seen that these results indicate an amazing consistency in AC – Gestational age relationship, at least up to 38 weeks (the differences seen are well within measurement error). The two exceptions to this pattern are the data of Hoffbauer *et al* (1979) and Warsof (1977) before 17 – 18 weeks. The former show unusually small values, but in view of the absence of information on the dating and measurement procedures, sample distribution with respect to time, and the analytic methods used, such values cannot be considered reliable. The values of Warsof are unusually high for this period and may be due to sampling problems. The sample used by Warsof to obtain the regression equation contained only 23 points before 23 weeks.

After 38 weeks there are more significant differences between the studies. The basis for these differences may be in sampling or in AC growth curve heterogeneity. Longitudinal studies, though somewhat compromised by limited data beyond 38 weeks, indicate that some individuals show linear AC growth after 37 weeks, while others reach a plateau. Differences in the relative proportions of these two growth patterns in a given sample, as well as sample size, could account for the observed differences in these growth curves late in pregnancy.

2.5 FEMUR LENGTH

The growth of the femur (FL) has been studied in several investigations (Jung *et al*., 2007; Kankeow, 2007; Salomon *et al*., 2006; Paladini *et al*., 2005; Nasrat and Bondagji, 2005; Figueras *et al*., 2002; Jacquemyn *et al*., 2000; Kurmanavicius *et al*., 1999; Chitty *et al*., 1994; Levi and Erbsman, 1975; Hoffbauer *et al*., 1979; Weinraub *et al*., 1979; Hoffbauer *et al*, 1979; Weinraub *et al*., 1979; Feiscina *et al*., 1982; Deter *et al*., 1982a; Deter *et al*., 1984; Campbell, 1976; Deter *et al*., 1982b; Warsof, 1977; Tamura and Sabbagha, 1980; Meire *et al*., 1981; Woo *et al*., 1984; Hadlock *et al*., 1982). As seen repeatedly, very few demographic data on the samples used have been given. The available information indicates that white and black fetuses have been studied (Jacquemyn *et al*., 2000; Kurmanavicius *et al*., 1999; Chitty *et al*., 1994; Osinusi, 1990; Marinho and Bamgboye, 1987).

No significant problems in the measurement procedures have been noted, but very little information on measurement error is available. One interesting finding is that measurements along the bone curvature, which frequently is seen in the third trimester, differ significantly from straight-line bone measurements. It should be pointed out that these measurements are of the bone shaft, since the head and condyles are not calcified before birth and thus do not appear echogenic (Mahony and Filly, 1984).

In contrast to measurement procedures, an evaluation of the analytical procedures used revealed significant problems. Either the mixed study type was used (Queenan *et al*., 1980; O.Brien and Queenan, 1981); Seeds and Cefalo, 1982) or insufficient information was given to determine the study type (Jeanty *et al*., 1981; Hadlock *et al*., 1982). Of the three valid cross-sectional, those of Yeh *et al* (1982) and Hobbins *et al* (1982) used significantly smaller sample, did not evaluate more than one model, and assumed no change in variability during pregnancy without documentation. The data of Jung *et al* (2007), Kankeow (2007), Salomon et l (2006), Paladini *et al* (2005), Nasrat and Bondagji (2005), Figueras *et al* (2002), Jacquemyn *et al*

(2000), Kurmanavicius *et al* (1999), Chitty *et al* (1994) appear to be free of significant problems.

2.6 WEIGHT

Although weight has always been recognized as a sensitive nutritional growth parameter but in scientific study of growth, height is more useful (Collis *et al*., 1962 a-b; Didia and Ogunranti, 1986). Measurements of fetal abdominal diameter and circumference were first used to estimate fetal weight by Campbell and Wilkin (1975). Since then abdominal circumference (AC) has become the main fetal parameter used to estimate fetal weight before birth (Higginbottom *et al*., 1975; Schillinger *et al*., 1975; Campogrande *et al*., 1977; Poll and Kasby, 1979). Fetal weight is widely used to detect and monitor fetal intrauterine growth retardation (Campbell and Thoms, 1977; Sabbagha, 1978; Little and Campbell, 1982; De Vore and Platt, 1987) or fetal macrosomia in diabetic pregnancy (Tamura *et al*., 1985; Tamura *et al*., 1986; Hill *et al*., 1990). Reference ranges for fetal weight have been reported by a number of investigators but there is no comparable information from developing countries. We only rely on values derived from Europeans.

2.7 HEAD CIRCUMFERENCE/ABDOMINAL CIRCUMFERENCE RATIO

The ratio of HC to AC has been used as an indicator of body proportionality since its introduction by Campbell and Thomas (1977) as a means for assessing growth retardation. There have been five investigations of the relationship of HC/AC to gestational age (Fescina *et al*., 1982; Deter *et al*., 1983; Deter *et al*., 1982a). With the exception of the study of Fescina *et al* (1982) on a Latin American population, these investigations have been limited to middle-class Caucasians.

Measurement procedures have generally been good, but no direct assessment of measurement errors has been made. Evaluation of the analytical procedures used has revealed some problems. There have been three appropriately designed cross-sectional studies (Deter *et al*., 19821 1983;

Campbell and Thomas, 1977) one similarly designed longitudinal study (Deter *et al.*, 1982b; Campbell and Thomas, 1977), and one study of mixed type (Fescina *et al.*, 1982). Constant variability with time is claimed in one study (Campbell and Thomas, 1977), while it is assumed without documentation in two others (Deter *et al.*, 1983; Deter *et al.*, 1982a).

2.8 BIPARIETAL DIAMETER/ OCCIPITOFRONTAL DIAMETER RATIO

The cephalic index is the ratio of the biparietal diameter of the skull to the occipitofrontal diameter and can detect asymmetry in the skull during development. Normal range is 0.74 to 0.83 (Abuhamad, 1996). When the cephalic index is 0.749 and below, the skull is described as dolichocephalic; when it is between 0.75 and 0.799 it is described as mesocephalic but when it is between 0.80 and 0.849 it is described as brachycephalic. Ancient man was thought to be dolichocephalic whereas modern man is tending towards brachycephalisation (Abuhamad, 1996; Deter, 1993)

2.9 BIPARIETAL DIAMETER/ FEMUR LENGTH RATIO

The ratio of biparietal diameter to femur length at 15 to 23 weeks of gestation can be used to identify fetuses at risk for Down syndrome. Infants with Down syndrome have shortening of the femur which contributes to an increase in the ratio above normal. The ratio decreases with gestational age. Infants with Down syndrome have a ratio greater than 1.5 standard deviations above the mean for the control population (Lockwood, 1987)

2.10 FEMUR LENGTH /HEAD CIRCUMFERENCE RATIO

Since the biparietal diameter can be affected by different fetal head shapes, the head circumference can be useful for providing a comparison with femur length. The normal ratio predicted from the menstrual age (in weeks) for Caucasian fetuses is 0.138 + 0.00216 x gestational age. A normal ratio exclude dwarfism while a low ratio suggests possible dwarfism and a high ratio suggests possible microcephaly. The limitation to the use of this ratio is that the ratio will not be affected by growth abnormalities that do not affect the head or long bones (Deter, 1993; Hadlock *et al*., 1984).

2.11 FEMUR LENGTH/ABDOMINAL CIRCUMFERENCE RATIO

The ratio of the femur to abdominal circumference is constant in the normally growing fetus from 21 weeks of gestation to term being independent of menstrual age. An increase in the ratio above normal can be seen in fetuses that are small for gestational age. Infants who are small for gestational age have a ratio that is greater or equal to 23.5; however due to the low prevalence of growth retardation in a general population only 25% of infants with a ratio greater or equal to 23.5 will be growth retarded (Divon *et al*, 1986). Infants who show appropriate development for gestational age have a ratio less than 23.5 with values around 22. Large for gestational age infants have a ratio around 21. Once an infant has been identified as being at risk for growth retardation by the femur length to abdominal circumference ratio then other criteria for growth should be monitored rather than the ratio as the ratio can return to normal in infants who are growth retarded (Divon *et al*, 1986; Hadlock *et al*., 1983; Ott, 1985).

2.12 SYMPYSIO-FUNDAL HEIGHT

Symphysio-fundal height (SFH) measurement is one of the methods used in assessing gestational age at antenatal follow up visits. This method (SFH measurement) has gained its fame in the assessment of fetal growth, especially in centres where other more precise measurements such as those from ultrasound cephalometry are not available routinely. A number of investigators have alleged that symphysio-fundal height measurement has high degree of sensitivity and specificity in the detection of the growth-retarded fetus (Belizan *et al*., 1978; Calvert *et al*., 1982; Galbraith *et al*., 1979; Pschera H and Soderbert G, 1984; Quaranta *et al* 1981; Taylor *et al*., 1984; Tian, 1982; Westin, 1977; Zhuo *et al*., 1980). Other researchers (Beazley *et al*., 1970; Loeffler, 1967; Rosenberg *et al*., 1982), have however, expressed fear over the use of this measurement. Before growth deviation can be assessed it is important that an accurate nomogram of this parameter against gestational age should be constructed for a given population. Calvert *et al* (1982) have opined that it may not be necessary to have individual nomogram for each institution for the Caucasian population in general, as they have found that the measurements at each gestation were comparable in these populations. The use of such a Caucasian nomogram in the Nigerian population however may not be appropriate

CHAPTER THREE
MATERIALS AND METHODS

3.0 DESIGN OF THE STUDY

This was a prospective cross-sectional study carried out in Jos, the capital of Plateau state of Nigeria. The study involved a population of pregnant women with fetuses from 12 – 42 weeks of gestation undergoing ultrasound examination. The sample used in the research consisted of all women with uncomplicated pregnancy who presented for routine ultrasound at Centre for Reproductive Health Research Jos, a division of Tadam limited (Plate 1). The study was approved by the Ethics Committee of Jos University Teaching Hospital and before inclusion of the patients, informed consent was obtained. In seeking the informed consent, the following information was provided to each subject:

a) A description of the procedure to be followed

b) A description of any reasonably foreseeable risks or discomfort

c) A description of benefits to the subjects or to others which may reasonably be expected from the research

d) A disclosure of appropriate procedure that might be advantageous to the subject

e) A statement describing the extent to which confidentiality of records identifying the subject will be maintained.

f) An explanation of whom to contact for answers to pertinent questions about the research and research subjects’ rights, and whom to contact in the event of a research related injury to the subject; and

g) A statement that participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and that the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Figure 1. Picture of Centre for Reproductive Health Research Jos – A division of Tadam Ltd

3.1 EXCLUSION CRITERIA

Only singleton pregnancies were included. Pregnant women with concomitant disease possibly affecting fetal growth (e.g. diabetes mellitus, asthma, hypertension, renal disease, thyroid disease) were not included as were those with complications of pregnancy known at the moment of the ultrasound scan (e.g. bleeding, pre-eclampsia). If a fetal malformation was detected during the examination the patient was excluded. Patients with a history of obstetric complications, intrauterine growth retardation or macrosomia were also excluded. The investigator did not take into account complications or diagnosis that occurred later in the pregnancy, after the ultrasound measurements were performed.

Every fetus was measured and included only once so that a pure cross-sectional set of data was constructed. For each patient the gestational age was recorded, as were last menstrual period, maternal age and parity. Maternal age was calculated in completed years at the moment of the ultrasound. Symphysio-fundal height measurements (tape measurement of the distance from the pubic symphysis to the uterine fundus) were taken using a non-stretch tape measure in centimeter (Plates 2). Plate 3 is a diagrammatic representation of size of uterus at different gestational ages.

3.2 AREA OF THE STUDY

The area of study was Jos. Jos is a city in the middle belt of Nigeria and the capital of Plateau State (Plate 4). It is located near the center of the Jos Plateau on the Dilimi River and it is about 1250 meters (about 4100 ft) above sea level. Plateau State derives its name from the geographical landscape that predominates in this part of the country. It has a population of 3,178,712 (2006 estimate). The state lies between latitude 7 and 11 degrees north of the Equator and longitude 7 degrees east. Although located in the tropical zone, the climate of plateau state is the nearest equivalent of a temperate climate in Europe and United States of America.

Figure 2. Picture of the investigator measuring symphysio-fundal height of a pregnant woman

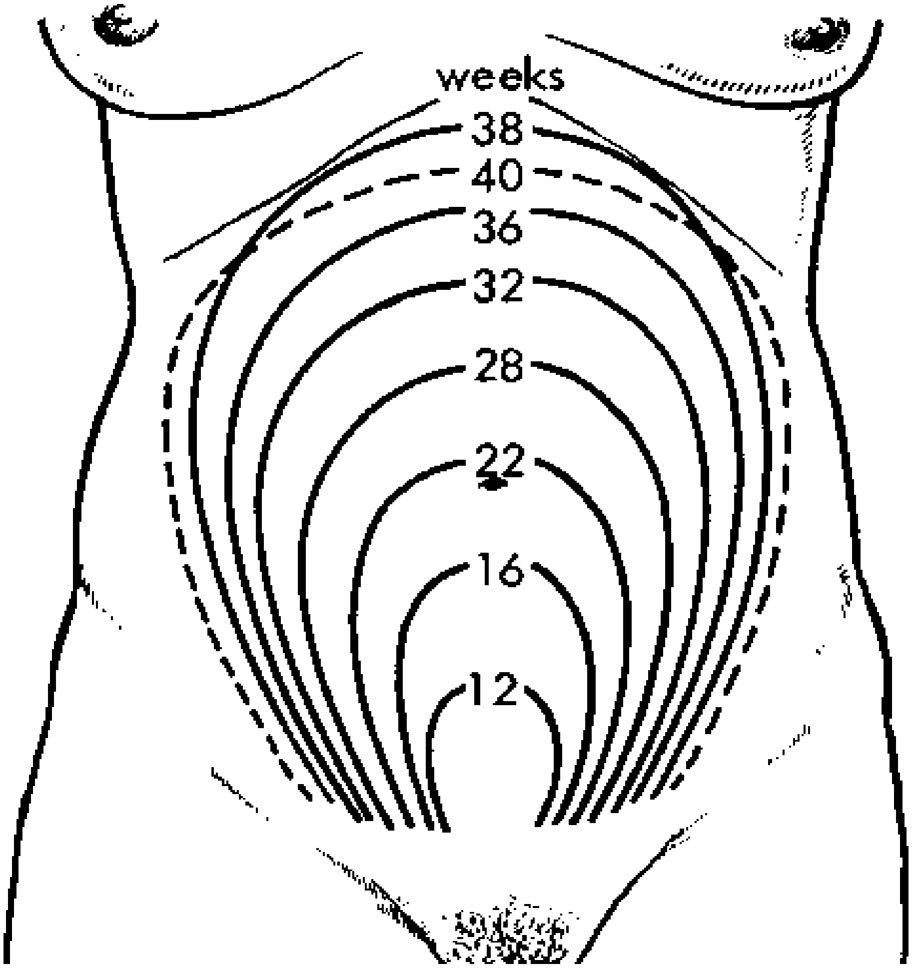

Plate 3. A Diagrammatic representation of size of uterus at different gestational ages

Figure 4. Map of Nigeria showing Jos, the capital of Plateau state

The state has over 50 ethnic groups each with a proud cultural heritage with no single group large enough to claim majority position. Nature has richly endowed this State with scenic beauty making it a tourist haven. Coupled with the invigorating climate, people from all over the country love staying in Jos that is why the state has been rightly described as a miniature Nigeria because it contains within itself almost, if not all the various ethnic groups of Nigeria.

3.3 SAMPLE SIZE

The sample size in this study was estimated from pilot study findings. From simple statistics, it is known that the standard error of the mean is equal to the standard deviation of the characteristic divided by the square root of the number in the sample i.e. $SE = SD/\sqrt{n}$ where *SE* is standard error of mean, *SD* is standard deviation and *n* is sample size. From the pilot study that was carried out, the standard deviation of fetal biparietal diameter at 23 weeks was 2.1. Since the size of the sample is the denominator of the fraction in the equation above, the standard error of mean in the study was set at 0.1 so as to get a larger random sample. Hence, by substituting the values of SD and SE into the equation, the sample size at 23 weeks gestation was obtained as below:

$$SE = SD/\sqrt{n}$$

or $$0.1 = 2.1/\sqrt{n}$$

$$0.1\sqrt{n} = 2.1$$

$$\sqrt{n} = 2.1/0.1$$

$$\sqrt{n} = 21$$

$$n = 441$$

So, the sample size for each week of gestation from 12 – 42 weeks was found to be approximately 441 fetuses. When 441 is multiplied by 31 (12 – 42 weeks), that will give the approximate number of fetuses to form the sample size which is roughly 13,671 fetuses.

Although this figure served as a guide during the course of study, the actual number of singleton fetuses that were scanned was 13,740 and their biometric parameters documented for analysis.

3.4 ULTRASOUND AND THE PATIENT

The patient to be scanned had to lie on the examination couch such that she is able to see the screen easily. Most scans were performed with the patient supine (Plate 5). However, in later pregnancy many patients feel dizzy in this position and it was necessary for such patients to be tilted to one side. This is easily achieved by placing a pillow under one of the buttocks. The patient had to be uncovered just sufficiently to allow the examination to be performed. This will include the first inch of the area covered by the pubic hairs and will extend far enough upwards to allow the fundus of the uterus to be visualized. A full bladder was the only prerequisite for an ultrasound examination.

3.5 FETAL BIOMETRIC MEASUREMENTS

All the fetal biometric measurements were performed by the investigator using Philips Real time ultrasound machine equipped with 3.5MHz transducer and an electronic caliper system set at a velocity of 1540m/s (Plates 6, 7). Fetal head measurements were made in an axial plane at the level where the continuous midline echo is broken by the cavum septum pellucidum in the anterior third and that includes the thalamus (Plate 8). This transverse section should demonstrate an oval symmetrical shape. Measurement of BPD was from the outer edge of the closest temporomandibular bone to the outer edge of the opposite temporomandibular bone (Plate 9). Measurement of OFD was from the outer edge of the frontal bone to the outer edge of the occipital bone (Plate 10). The HC was measured around the calvarium from the same axial image as for the BPD (Plate 11). The abdominal circumference was measured through the transverse section of the fetal abdomen at the level of the stomach and bifurcation of the main portal vein into its right and left branches (Plates 12 and 13). The femur length (Plates 14 and 15) was measured from the greater trochanter to the lateral condyle, with both ends clearly visible and at a horizontal angle <45^0. All measurements were expressed in millimeters. Estimated fetal weight was calculated in grams by the formulae described by Shepard and by Hadlock, as these are included in the software of most commercially available ultrasound scanners (Shepard *et al.*, 1982). To enable appropriate statistical comparison of data, only studies with the number of examined fetuses indicated were included since many studies do not indicate the number of fetuses and are reported in graphic rather than tabular forms.

Plate 5. A Picture of a pregnant woman about to be scanned

Plate 6. The Investigator together with a staff nurse during an ultrasound examination session.

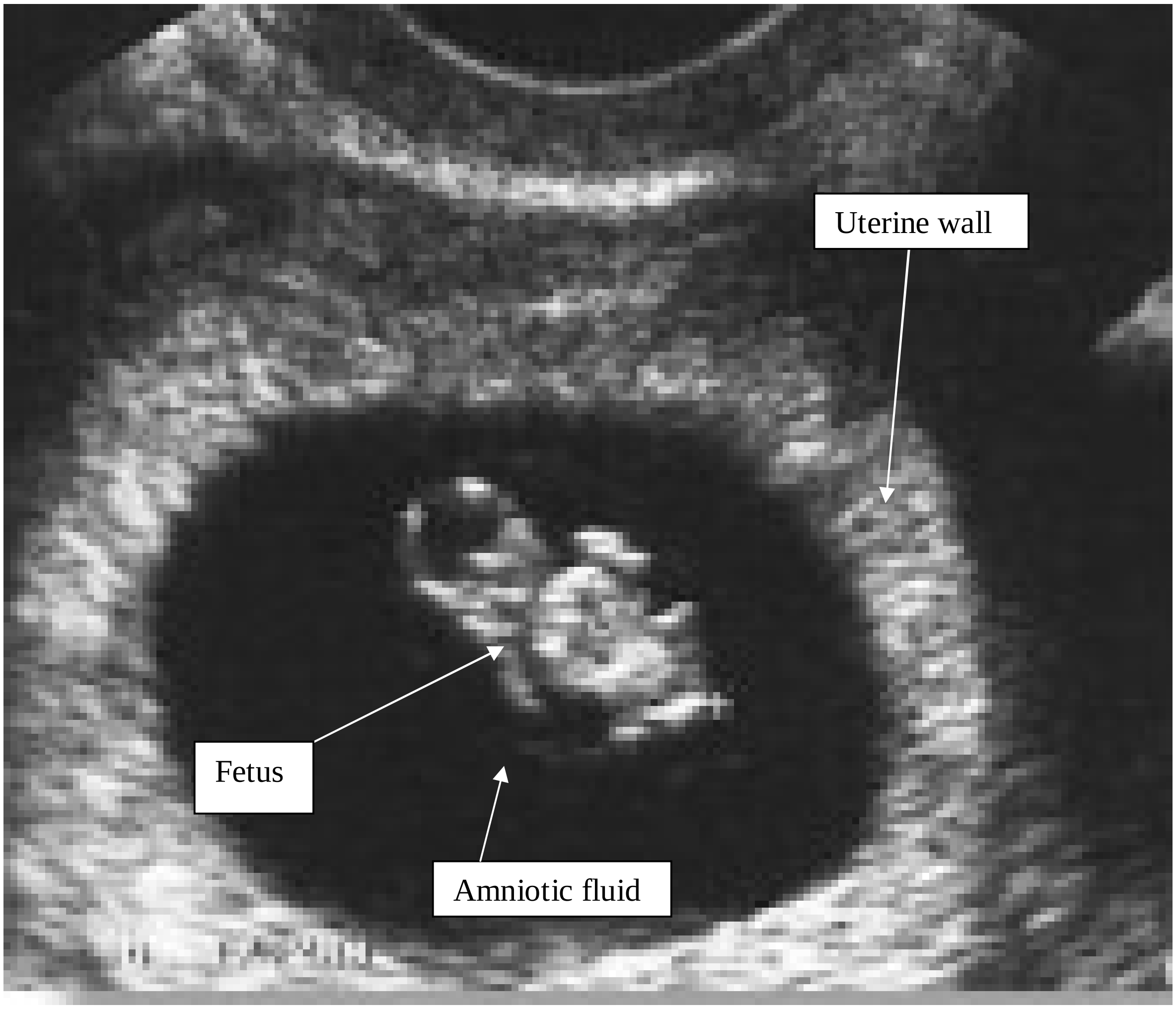

Plate 7. A picture of an ultrasound image of human fetus taken during an ultrasound examination session

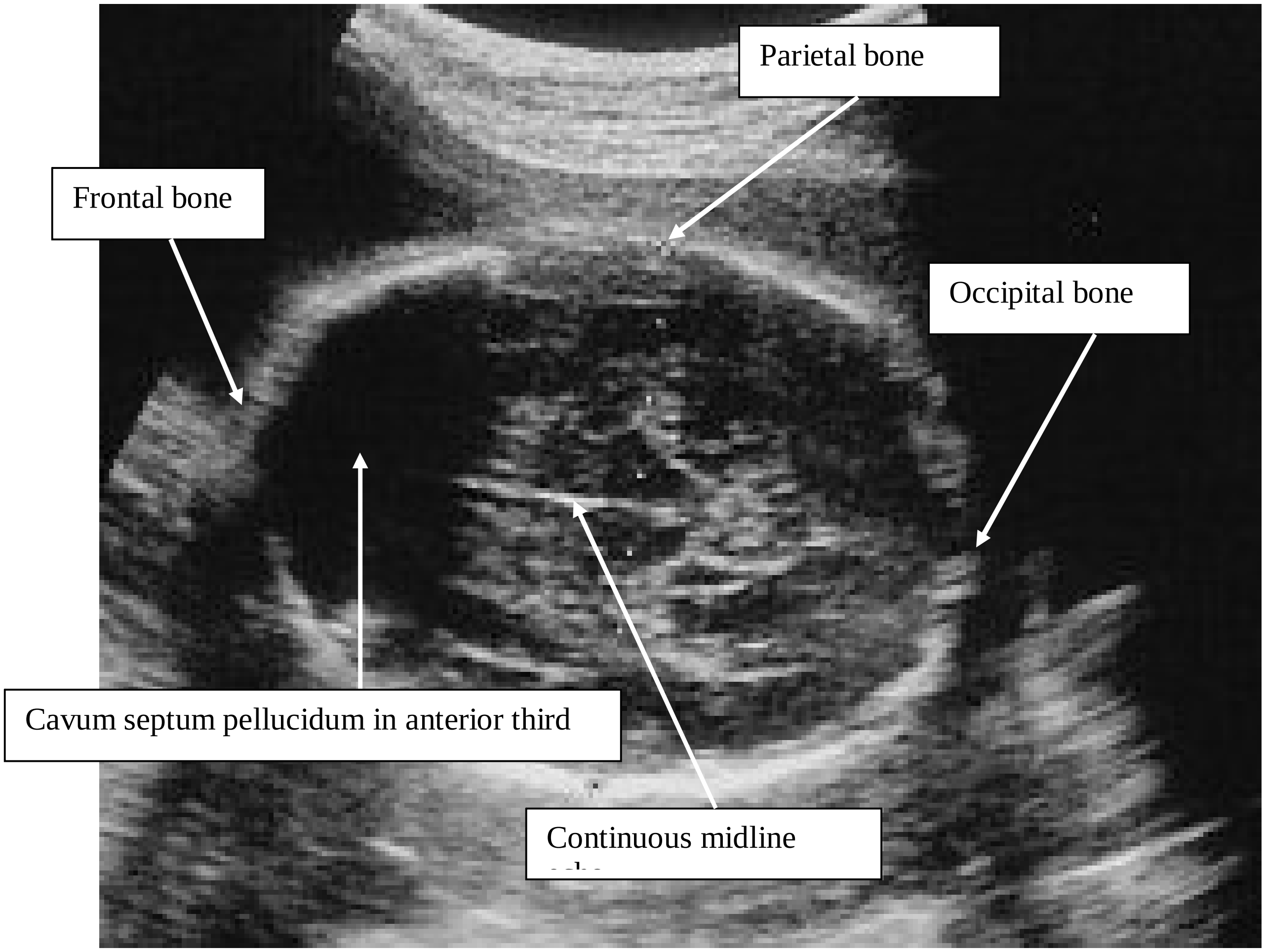

Plate 8. A picture of a transverse section through a fetal skull taken during one of the ultrasound examination sessions. Fetal head measurements were made in an axial plane at the level where the continuous midline echo is broken by the cavum septum pellucidum in the anterior third and that includes the thalamus

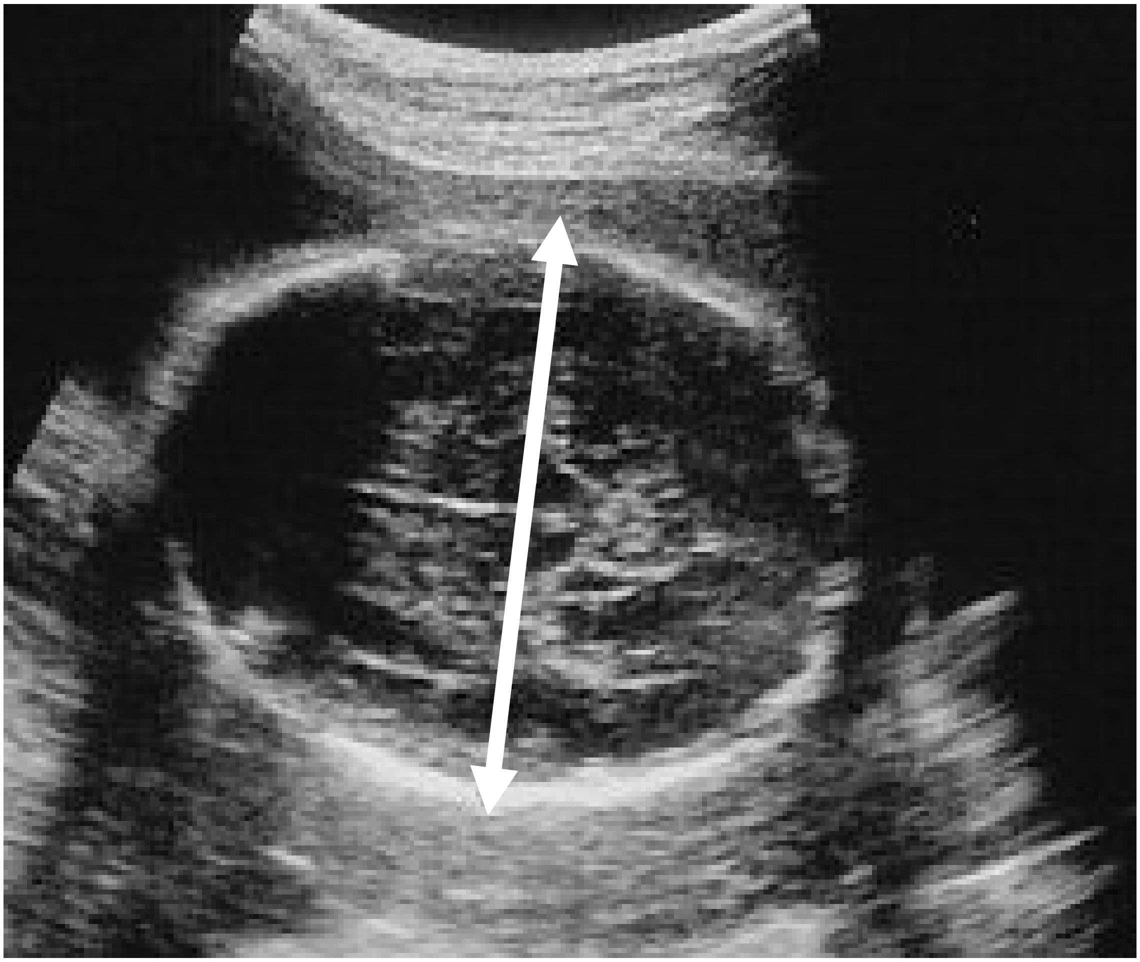

Plate 9. Picture showing biparietal diameter (BPD) Measurement. Measurement of BPD was from the outer edge of the closest temporomandibular bone to the outer edge of the opposite temporomandibular bone

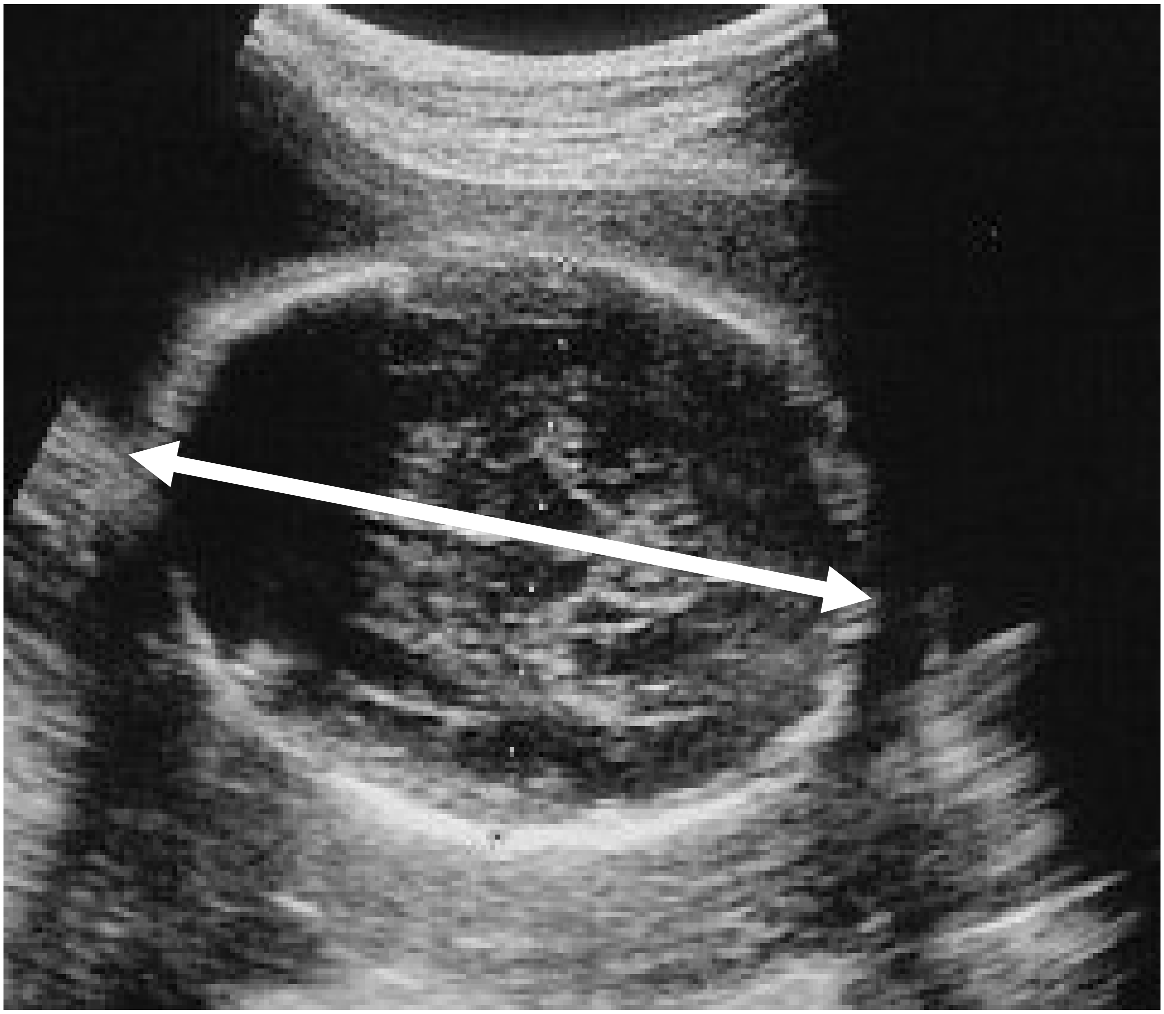

Plate 10. Picture showing occipitofrontal diameter (OFD) Measurement. Measurement of OFD was from the outer edge of the frontal bone to the outer edge of the occipital bone.

Plate 11. Picture showing head circumference (HC) Measurement. The HC was measured around the calvarium from the same axial image as for the BPD

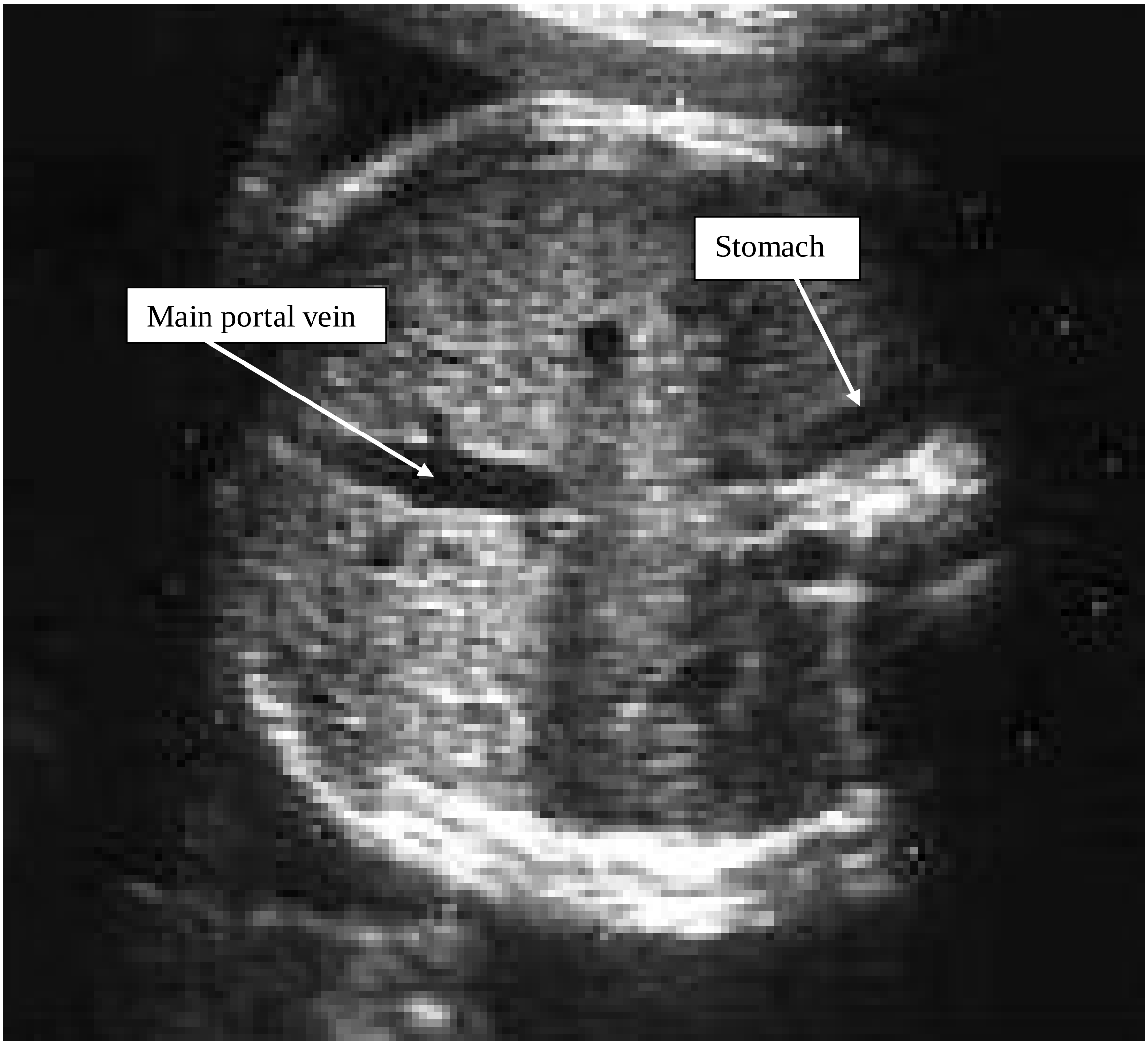

Plate 12. A picture of transverse section through fetal abdomen a the level of the stomach and bifurcation of the main portal vein into its right and left branches

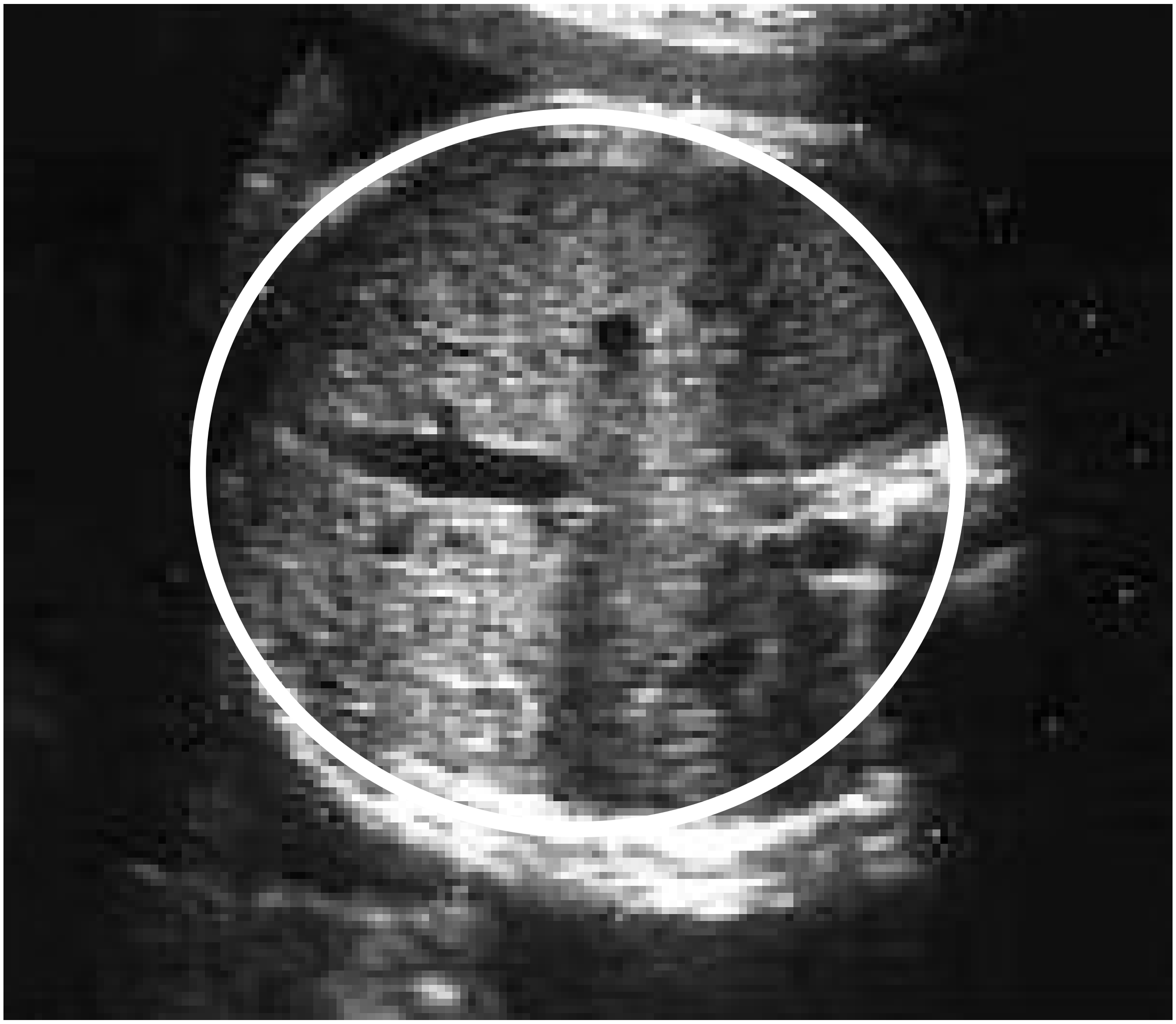

Plate 13. Picture of abdominal circumference (AC) measurement. Abdominal circumference was measured through the transverse section of the fetal abdomen at the level of the stomach and bifurcation of the main portal vein into its right and left branches.

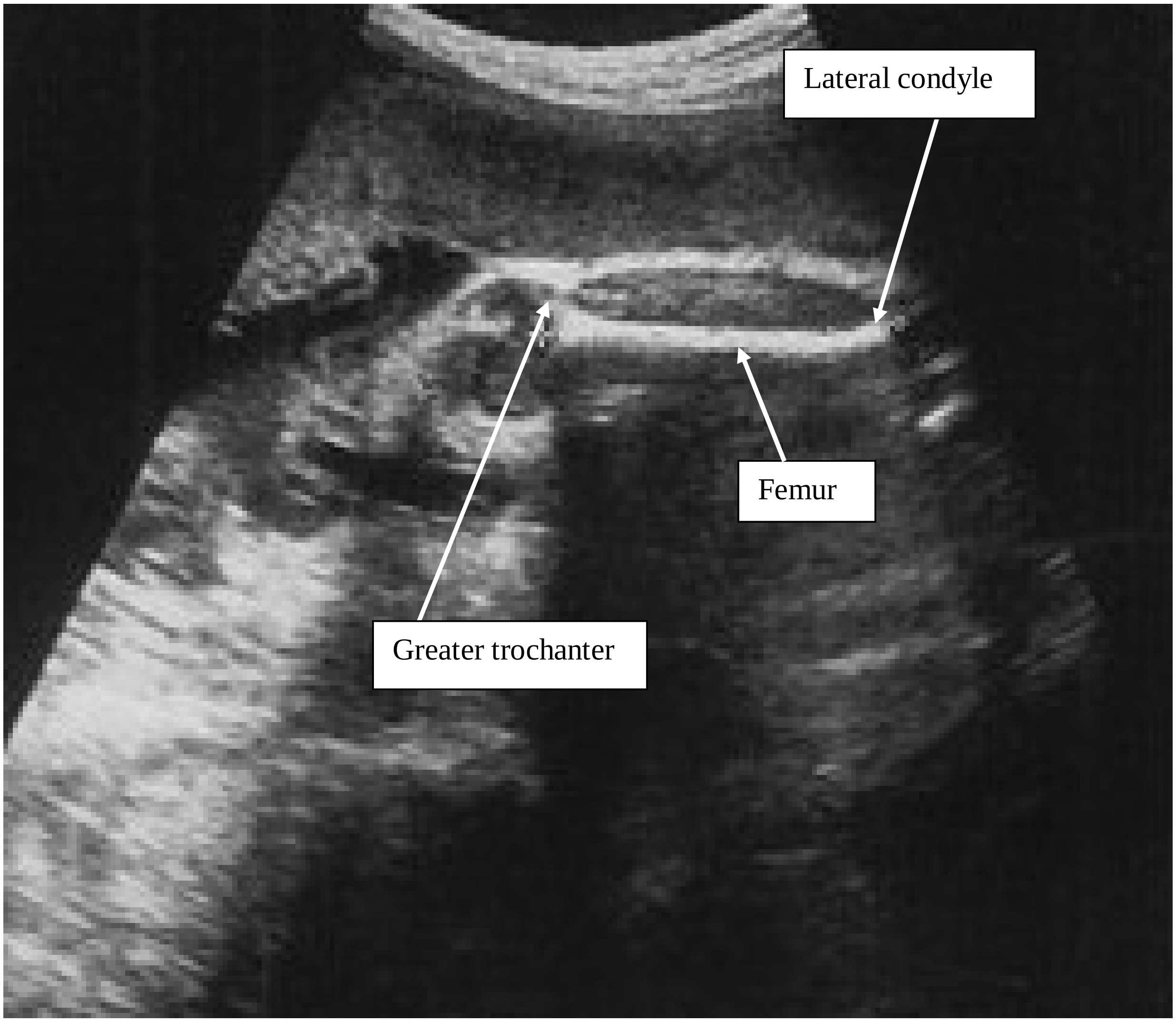

Plate 14. An ultrasound image of the thigh of the fetus showing the fetal femur

Plate 15. Picture showing femur length (FL) measurement. Femur length was measured from the greater trochanter to the lateral condyle, with both ends clearly visible and at a horizontal angle <45^0

3.6 STATISTICAL ANALYSIS

Statistical analyses were performed using Number cruncher statistical system (NCSS/PASS 2006 Dawson Edition, USA). The normality of measurements at each week of gestation was assessed using Shapiro-Wilk test, Anderson-Darling test, Martinex-Iglewicz test, Kolmogorov-Sminov test, D'Agostino Skewness test, D'Agostino Kurtosis test and D'Agostino Omnibus test. Given the large sample size, statistically significant nonnormality was accepted unless the normal plot showed clear deviation from a straight line (Altman and Chitty, 1994). For each measurement, a regression analysis was applied, examining linear, logarithmic, polynomial, power, exponential models for association with gestational age in weeks. The best model was selected based on visual inspection of the regression line that best fitted the data scattergram, F value for significance.

CHAPTER FOUR
RESULTS

The results of the study were reported in the following two topics

1. General characteristics of the sample
2. Analysis of biometric parameters

4.0 GENERAL CHARATERISTICS OF THE SAMPLE

The general characteristics of the mothers and fetuses were described as follows:

4.0.1 Age

The maternatal age was classified into eight groups as shown in Table 1. The mean age of the study sample was about 27 years. The maternal age group of 25 – 29 years was about 34.57 percent and was higher than the other groups. The lowest age was 14 years and the highest was 52 years.

Table 1. Percentage Distribution of Women Scanned by Age

Age	**Number**	**Percentage (%)**
<15	36	0.26
15 - 19years	915	6.66
20 - 24years	3,211	23.37
25 - 29years	4,750	34.57
30 - 34years	3,282	23.89
35 - 39years	1,298	9.45
40 - 44years	216	1.57
>45years	32	0.23
Total	**13,740**	**100%**

4.0.2 Parity

The number of deliveries in the pregnant women was classified from Para 0 to Para 13 with multiparae constituting 37.4 percent of the women that were scanned followed by those women who are pregnant but have never given birth before making 31.5 percent (figure 1). This figure revealed that Para 0 women were the highest in number in the study sample (32%). As the parity increases, the number of women that were scanned dropped. Again, it showed that there are women who delivered 13 times (Para 13) during their reproductive carrier.

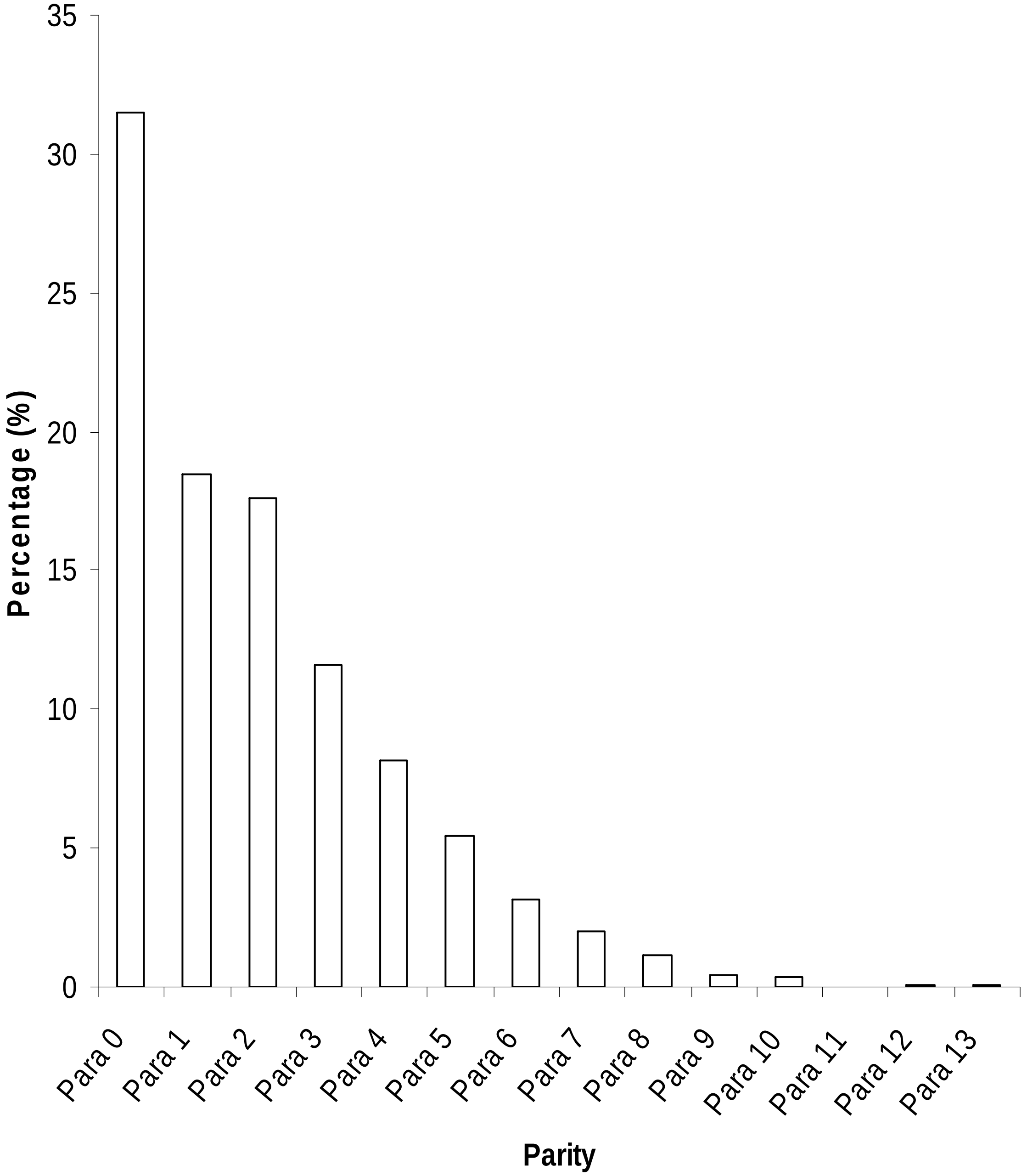

Figure 1. Bar Graph Showing Percentage Distribution of Women Scanned by Parity

4.0.3 Symphysio-fundal Height

The maternal symphysis-fundal height was measured from 14 weeks to 40 weeks. The highest mean value was 39.1 centimeters at 40 weeks gestation while the lowest mean value was at 14 weeks (Table 2). The variability of the symphysio-fundal height-fundal height values increases as gestational age increases with highest variability at term. With the exception of 40 weeks gestation, the standard error of mean was found to be less than one throughout the period of pregnancy. The 10th, 50th and 90th centiles are also as shown in this table. The 50th centile values are close to the mean values of symphysio-fundal height-fundal height. When symphysio-fundal height-fundal height mean values were plotted against gestational age in weeks, the line of best fit for the data points was represented by the regression equation $y = 0.9966x - 0.2373$ where y is the symphysio-fundal height in centimeters and x is the gestational age in weeks (figure 2). The correlation of determination (r^2) for this equation was 0.9959 ($p < 0.001$) which means that symphysio-fundal height-fundal height could predict the gestational age of fetuses by 99 percent ($r^2 = 0.9959$) in 405 women in this study.

Table 2. Mean, Standard deviation, standard error of mean and percentile for gestational age of Nigerian women symphysio-fundal height.

GA (wks)	Sample size (n)	Mean SFH (cm)	SD	std error	Percentile		
					10th	50th	90th
14	2	14.5	0.07	0.50	14.0	14.5	15.0
15	10	14.4	0.83	0.30	13.0	14.5	15.3
16	4	15.1	0.38	0.20	14.7	15.1	15.6
17	11	16.8	0.67	0.20	16.0	16.7	18.0
18	5	16.5	1.49	0.01	14.2	16.3	17.8
19	4	18.7	0.96	0.48	17.3	19.0	19.5
20	5	18.9	0.27	0.12	18.5	19.1	19.1
21	8	20.9	0.74	0.20	19.8	20.9	22.0
22	8	22.5	1.54	0.50	20.5	23.0	24.3
23	14	23.3	1.10	0.30	21.3	24.0	24.4
24	6	23.9	1.50	0.60	22.0	24.4	25.1
25	13	24.4	0.40	0.10	23.8	24.4	24.9
26	11	25.6	0.95	0.30	24.3	25.6	27.1
27	13	26.8	1.40	0.40	23.8	27.0	28.1
28	10	28.2	0.63	0.20	27.3	28.3	28.9
29	17	29.1	1.00	0.30	28.2	28.8	31.5
30	22	29.8	1.40	0.30	28.7	29.5	32.0
31	17	30.8	0.90	0.20	29.9	30.4	32.4
32	23	31.9	1.70	0.30	30.6	32.0	32.3
33	35	32.8	1.50	0.30	31.0	32.9	33.9
34	27	33.4	1.70	0.32	32.0	33.2	36.0
35	30	33.9	1.60	0.30	31.7	34.2	35.9
36	28	35.7	1.90	0.40	33.3	35.8	37.4
37	30	36.7	2.20	0.40	34.5	36.1	39.5
38	35	38.3	1.60	0.30	36.3	38.1	40.7
39	14	38.1	2.80	0.80	31.8	39.0	40.2
40	3	39.1	2.10	1.20	37.0	39.3	41.1
TOTAL	405						

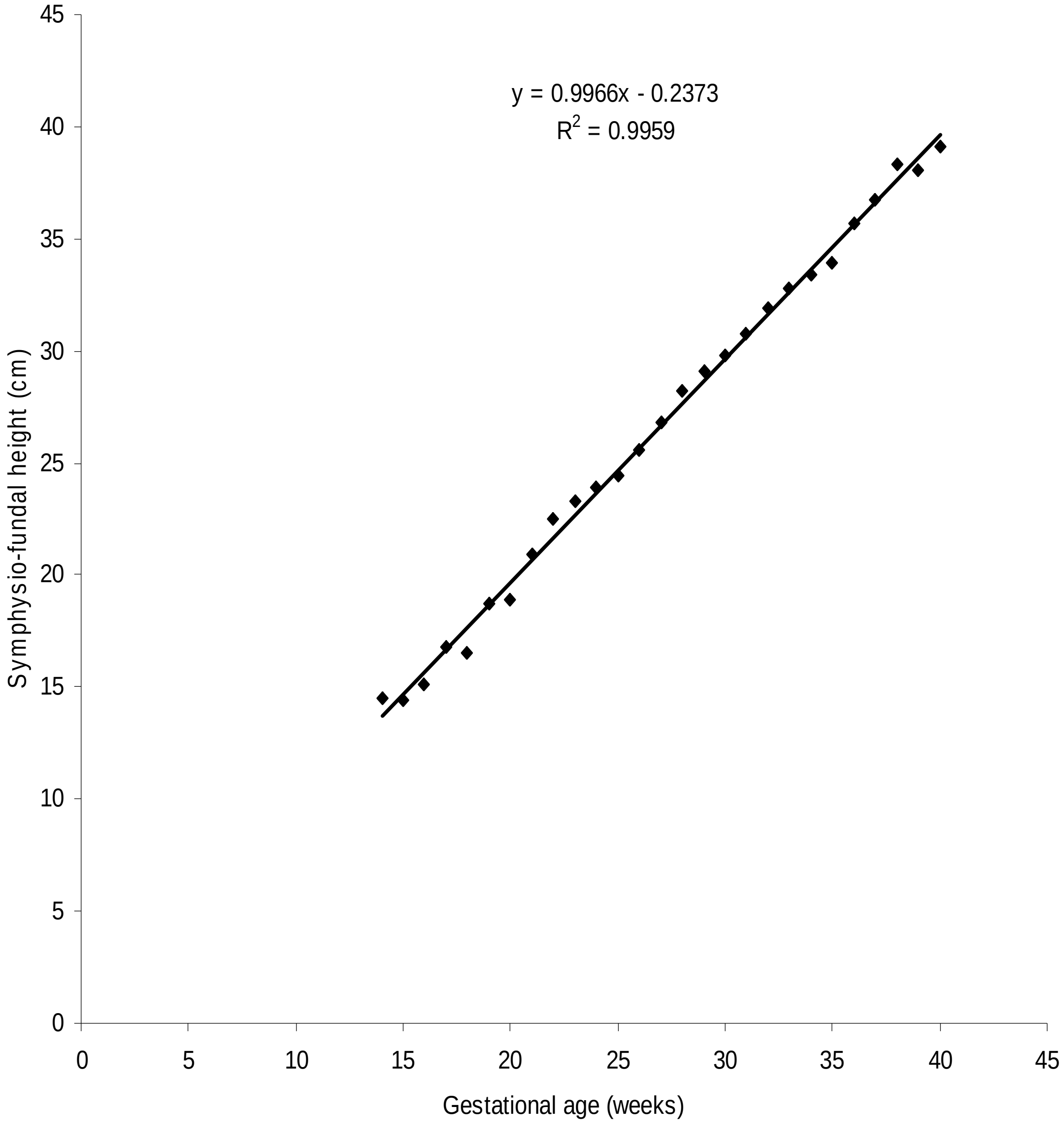

Figure 2. Correlation and regression equation of mean symphysio-fundal height plotted against gestational age in weeks

4.0.4 Gestational age of Pregnancy

The gestational age of pregnancy in this study was from 12 – 42 weeks. Figure 3 shows the percentage distribution of the fetuses scanned by age in months. From this graph, it can be seen that majority of fetuses in Jos were scanned at the 9th month of intrauterine life unlike at 4 months were only about 13 percent were scanned. In table 3, it can be seen that the 34 and 35 weeks of gestation were each 5.4 %. The 12 weeks of gestation were 0.4% as near as 0.5% of 41 weeks gestation. From this table, it can also be seen that 75% of the fetuses scanned were above 21 weeks of gestation. At each gestational week over 30 fetuses were examined, with the exception of week 42 where only 22 fetuses were examined.

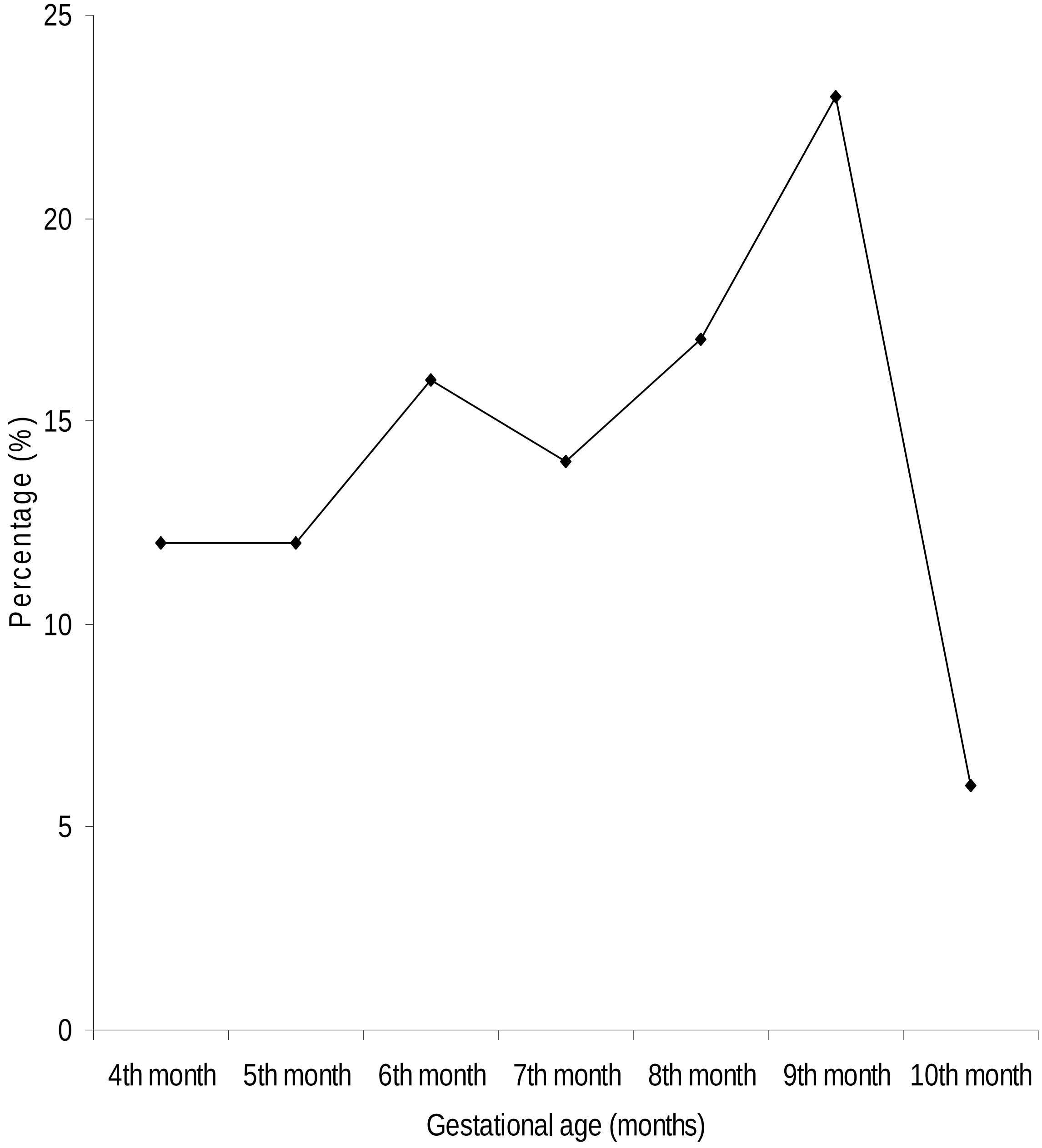

Figure 3: Graph Showing Percentage Distribution of Fetuses Scanned by Gestational Age in Months

Table 3: Frequency Distribution of Fetuses Scanned by Gestational Age

Gestational Age (wk, days)	Number of observation	Percentage (%)
12 to 12+6	49	0.4
13 to 13+6	384	2.8
14 to 14+6	371	2.7
15 to 15+6	351	2.6
16 to 16+6	505	3.7
17 to 17+6	427	3.1
18 to 18+6	446	3.2
19 to 19+6	282	2.1
20 to 20+6	553	4
21 to 21+6	400	2.9
22 to 22+6	398	2.9
23 to 23+6	478	3.5
24 to 24+6	520	3.8
25 to 25+6	388	2.8
26 to 26+6	511	3.7
27 to 27+6	432	3.1
28 to 28+6	548	4
29 to 29+6	484	3.5
30 to 30+6	625	4.5
31 to 31+6	523	3.8
32 to 32+6	583	4.2
33 to 33+6	516	3.8
34 to 34+6	744	5.4
35 to 35+6	739	5.4
36 to 36+6	599	4.4
37 to 37+6	532	3.9
38 to 38+6	481	3.5
39 to 39+6	525	3.8
40 to 40+6	252	1.8
41 to 41+6	72	0.5
42 to 42+6	22	0.2
Total	**13740**	**100**

4.1 ANALYSIS OF FETAL PARAMETERS

4.1.0 Normality Test

Shapiro-Wilk test, Anderson-Darling test, Martinex-Iglewicz test, Kolmogorov-Sminov test, D'Agostino Skewness test, D'Agostino Kurtosis test and D'Agostino Omnibus test's goodness of fit test carried out on measurements of fetal biparietal diameter (BPD), head circumference (HC), occipitofrontal diameter (OFD), abdominal circumference (AC), femur length (FL) and weight (Wt) from 12 – 42 weeks of gestation accepted normality of the data distribution. The visual test for normality of the data of fetal biparietal diameter, head circumference, occipitofrontal diameter, abdominal circumference, femur length and weight measured from 12 – 42 weeks of gestation is as shown in the histograms (Appendix I). These histograms gave a convincing visual impression of the normality of the distribution of fetal parameters measured from 12 – 42 weeks of gestation.

4.1.1Fetal Head Circumference

The fetal head circumference measurements were classified into thirty one groups (table 4). The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. Marked variability in the measurements was seen in groups 18 to 18+6, 29 to 29+6 and 40 to 42+6. In group 13 to 13+6, variation in the measurements was minimal. Standard error of mean of head circumference measurements from 12 – 42 weeks gestation was found to be less than 1 with the exception of groups 12, 18 and 29 where the standard error of mean is above 1.

The geometric mean values of head circumference measurements as seen in table 5 were found to be less than their arithmetic means but greater than their harmonic means indicating that all the fetal head circumference measurements were not identical. Table 6 shows the monthly fetal head circumference values from 4th month to the 10th month with their corresponding standard deviations and standard error of mean.

Table 4: Frequency distribution table of fetal head circumference measurements showing arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.

GA (week, days)	Number of fetuses (n)	Mean HC	SD	SEM
12 to 12+6	49	80.9	10.5	1.5
13 to 13+6	384	94.1	9.6	0.5
14 to 14+6	371	108.6	11.8	0.6
15 to 15+6	351	122.5	13.8	0.7
16 to 16+6	505	133.0	9.7	0.4
17 to 17+6	427	146.1	10.9	0.5
18 to 18+6	446	162.1	23.5	1.1
19 to 19+6	282	169.4	15.2	0.9
20 to 20+6	553	180.7	12.7	0.5
21 to 21+6	400	193.0	11.7	0.6
22 to 22+6	398	201.9	11.3	0.6
23 to 23+6	478	212.7	13.9	0.6
24 to 24+6	520	225.8	13.3	0.6
25 to 25+6	388	238.7	14.0	0.7
26 to 26+6	511	249.3	15.2	0.7
27 to 27+6	432	260.0	15.4	0.7
28 to 28+6	548	269.1	13.3	0.6
29 to 29+6	484	274.2	23.3	1.1
30 to 30+6	625	284.9	17.0	0.7
31 to 31+6	523	292.2	14.9	0.7
32 to 32+6	583	299.5	14.7	0.6
33 to 33+6	516	306.9	12.9	0.6
34 to 34+6	744	314.6	15.0	0.6
35 to 35+6	739	318.8	13.5	0.5
36 to 36+6	599	324.9	14.7	0.6
37 to 37+6	532	330.9	13.7	0.6
38 to 38+6	481	337.6	15.1	0.7
39 to 39+6	525	342.9	14.4	0.6
40 to 40+6	252	345.2	14.1	0.9
41 to 41+6	72	349.6	11.8	1.4
42 to 42+6	22	347.4	23.6	5.5
Total	**13740**			

Table 5: Frequency Distribution Table of Fetal Head Circumference Measurements Showing Arithmetic mean, Geometric mean and Harmonic mean from 12 – 42 weeks Gestation.

GA (week, days)	Number of fetuses (n)	Arithmetic mean	Geometric mean	Harmonic mean
12 to 12+6	49	80.87755	80.19505	79.49107
13 to 13+6	384	94.08594	93.57099	93.02122
14 to 14+6	371	108.6388	108.0839	107.5773
15 to 15+6	351	122.4758	121.847	121.3091
16 to 16+6	505	132.9644	132.612	132.2597
17 to 17+6	427	146.1148	145.7095	145.3004
18 to 18+6	446	162.1435	160.8212	159.7357
19 to 19+6	282	169.3652	168.754	168.1866
20 to 20+6	553	180.6998	180.2787	179.8754
21 to 21+6	400	192.9975	192.6456	192.2944
22 to 22+6	398	201.8869	201.58	201.2776
23 to 23+6	478	212.7113	212.2518	211.7762
24 to 24+6	520	225.8308	225.4465	225.0655
25 to 25+6	388	238.6649	238.2416	237.7988
26 to 26+6	511	249.2681	248.8127	248.3601
27 to 27+6	432	260.0023	259.5373	259.0611
28 to 28+6	548	269.135	268.7951	268.4434
29 to 29+6	484	274.2252	272.6465	269.6992
30 to 30+6	625	284.8512	284.3175	283.7497
31 to 31+6	523	292.1931	291.7838	291.3389
32 to 32+6	583	299.5266	299.1455	298.7357
33 to 33+6	516	306.8663	306.5755	306.2606
34 to 34+6	744	314.5565	314.1824	313.7874
35 to 35+6	739	318.7767	318.4873	318.1912
36 to 36+6	599	324.9232	324.5829	324.2289
37 to 37+6	532	330.8741	330.5896	330.302
38 to 38+6	481	337.6008	337.2799	336.973
39 to 39+6	525	342.8629	342.5604	342.2585
40 to 40+6	252	345.2064	344.9261	344.6524
41 to 41+6	72	349.5555	349.3567	349.1544
42 to 42+6	22	347.3636	346.5916	345.81
Total	**13740**			

Table 6: Monthly mean fetal head circumference values (in mm) of Nigerian fetuses in Jos

GA (months)	Fetuses (n)	Mean (mm)	SD	SEM
4	1660	114.5	16.9	8.4
5	1708	164.6	14.5	7.2
6	2184	214.4	18.3	8.1
7	1975	263.2	10.9	5.5
8	2247	295.9	9.5	4.7
9	3095	325.4	9.2	4.1
10	871	346.3	2.9	1.4
Total	13,740			

The 9th month has more number of observations than the other months. The fetal head circumference values during second and third trimesters are shown in table 7 with third trimester having almost three-quarters of the number of fetuses scanned. The centile values of fetal head circumference measurements from 12 – 42 weeks gestation are as shown in table 8. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal head circumference measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 10th percentile of head circumference at 18 to 18 + 6 weeks gestation is 146 millimeters. This means that 10% of the fetuses in Jos at 18 to 18 + 6 had a mean head circumference less than 146 millimeters, while 90% had a mean head circumference greater than 146 millimeters. Similarly, the 97th percentile of head circumference at 39 to 39 + 6 is 378 millimeters. Hence 97% of fetuses at 39 to 39 + 6 had a mean head circumference less than 378 millimeters while 3% had a mean head circumference greater than 378 millimeters.

The standard score or z-score of head circumference measurements in 13,740 fetuses in Jos ranging from 12 – 42 weeks of gestation is as shown in table 9. The z-score enables one to look at head measurements at each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, head circumference measurements at 12 weeks are – 0.002 standard deviations from the mean while measurements at 14 weeks are 0.003 standard deviations from the mean. Again, from the above z-score table, it can be seen that the head circumference measurements at 20 and 38 weeks are 0.000 deviations from the mean. When comparing the z-score at 12, 14, 20 and 38 weeks of gestation, it can be seen that z-score at 14 weeks gestation is higher followed by 20 weeks while at 12 weeks it is much lower because it is negative (-0.002).

Table 7: Trimester mean fetal head circumference values

Trimester	Fetuses (n)	Mean	SD	SEM	Minimum	Maximum	Range
2nd	5552	162.1	49.7	13.3	80.9	238.7	157.8
3rd	8188	308.7	32.6	7.9	249.3	349.6	100.3
Total	13,740						

Table 8. Centiles of fetal head circumference measurements

	Head circumference centiles (mm)						
Gestational age	3rd	5th	10th	50th	90th	95th	97th
12 to 12+6	56.0	61.5	69.0	79.0	96.0	98.5	101.0
13 to 13+6	75.0	78.0	82.0	94.0	106.0	108.0	109.0
14 to 14+6	92.2	94.0	96.0	108.0	118.8	122.0	126.0
15 to 15+6	104.6	110.0	111.0	120.0	134.0	141.0	155.4
16 to 16+6	116.0	119.0	121.0	133.0	145.0	149.0	151.0
17 to 17+6	122.7	130.0	135.0	146.0	159.0	163.0	170.0
18 to 18+6	131.0	134.0	146.0	159.0	172.2	196.2	203.0
19 to 19+6	140.0	150.0	156.3	168.0	183.0	191.9	200.5
20 to 20+6	160.0	164.0	169.0	180.0	195.0	201.0	210.0
21 to 21+6	171.0	175.0	181.0	193.0	206.9	214.0	222.0
22 to 22+6	181.0	186.0	190.0	201.0	215.0	220.1	223.0
23 to 23+6	183.0	191.0	199.0	212.0	227.0	233.0	239.6
24 to 24+6	200.0	205.0	214.0	225.0	239.9	247.0	250.0
25 to 25+6	206.4	216.5	225.9	238.0	253.0	261.7	265.0
26 to 26+6	220.0	226.0	232.2	249.0	265.0	272.0	279.0
27 to 27+6	230.0	232.7	240.3	260.0	278.0	287.0	292.0
28 to 28+6	243.0	247.0	255.0	270.0	284.0	289.0	292.0
29 to 29+6	229.2	246.3	260.0	277.0	290.0	294.0	302.0
30 to 30+6	250.0	262.3	269.0	286.0	300.0	309.0	315.4
31 to 31+6	253.0	267.0	276.0	293.0	309.0	311.0	314.3
32 to 32+6	274.1	279.2	284.4	300.0	316.0	320.0	322.0
33 to 33+6	280.0	286.0	293.0	308.0	321.0	324.0	328.0
34 to 34+6	286.0	290.5	300.0	315.0	330.5	335.0	340.0
35 to 35+6	291.2	297.0	301.0	320.0	333.0	338.0	340.8
36 to 36+6	301.0	303.0	306.0	326.0	339.0	346.0	351.0
37 to 37+6	300.0	302.7	312.3	333.0	344.7	351.0	358.0
38 to 38+6	310.9	315.0	320.0	337.0	352.0	359.0	364.0
39 to 39+6	318.0	320.3	326.2	342.0	359.0	372.0	378.0
40 to 40+6	323.0	324.3	330.0	344.0	360.0	373.5	382.5
41 to 41+6	316.0	329.0	335.0	348.5	366.0	366.0	367.6
42 to 42+6	306.0	306.0	306.0	353.0	387.0	387.0	387.0

Table 9: Standard score (z-score) of head circumference measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation.

Gestational age	Fetuses (n)	Mean z-score
12 to 12+6	49	-2.14E-03
13 to 13+6	384	-1.46E-03
14 to 14+6	371	3.29E-03
15 to 15+6	351	-1.75E-03
16 to 16+6	505	-3.67E-03
17 to 17+6	427	1.35E-03
18 to 18+6	446	1.85E-03
19 to 19+6	282	-2.29E-03
20 to 20+6	553	-1.42E-05
21 to 21+6	400	-2.14E-04
22 to 22+6	398	-1.16E-03
23 to 23+6	478	8.13E-04
24 to 24+6	520	2.31E-03
25 to 25+6	388	-2.50E-03
26 to 26+6	511	-3.48E-03
27 to 27+6	432	1.50E-04
28 to 28+6	548	2.63E-03
29 to 29+6	484	1.08E-03
30 to 30+6	625	-2.87E-03
31 to 31+6	523	-4.62E-04
32 to 32+6	583	1.81E-03
33 to 33+6	516	-2.61E-03
34 to 34+6	744	-2.90E-03
35 to 35+6	739	-1.72E-03
36 to 36+6	599	1.58E-03
37 to 37+6	532	-1.89E-03
38 to 38+6	481	5.51E-05
39 to 39+6	525	-2.58E-03
40 to 40+6	252	4.50E-04
41 to 41+6	72	-3.77E-03
42 to 42+6	22	-1.56E-03
Total	**13740**	

When head circumference data of 13,740 Nigerian fetuses in Jos was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (figure 4), it was found that the distribution of head circumference measurements has a longer “tail” to the right of the central maximum than to the left or is skewed to the right from 13 – 24 weeks. From 25 – 37weeks, the distribution has a longer “tail” to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the head circumference data was subjected to kurtosis analysis (figure 5), the analysis was found to be leptokurtic at 14, 15, 18, 19, 29. 33 and 38 weeks of gestation while at 12, 13, 16,17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 20, 31, 32,34, 35, 36, 39, 40, 41 and 42 weeks of gestation, the kurtosis was mesokurtic. The coefficient of dispersion of head circumference data of 13,740 fetuses in Jos at different gestational age shows a decrease in value as gestational age advances except at 18, 23, 25, 26, 29, 30 and 42 weeks where it peaks (figure 6).

The head circumference scattergram in figure 7 shows that there are very few bad data points or outliers in the head circumference measurements of 13,740 fetuses in Jos. The outliers are more from 26 – 42 weeks of gestation. This shows the pattern of growth recognized for neural tissue which suggests growth of brain.

In figure 8, mean head circumference is plotted against gestational age with error bars showing standard deviation.

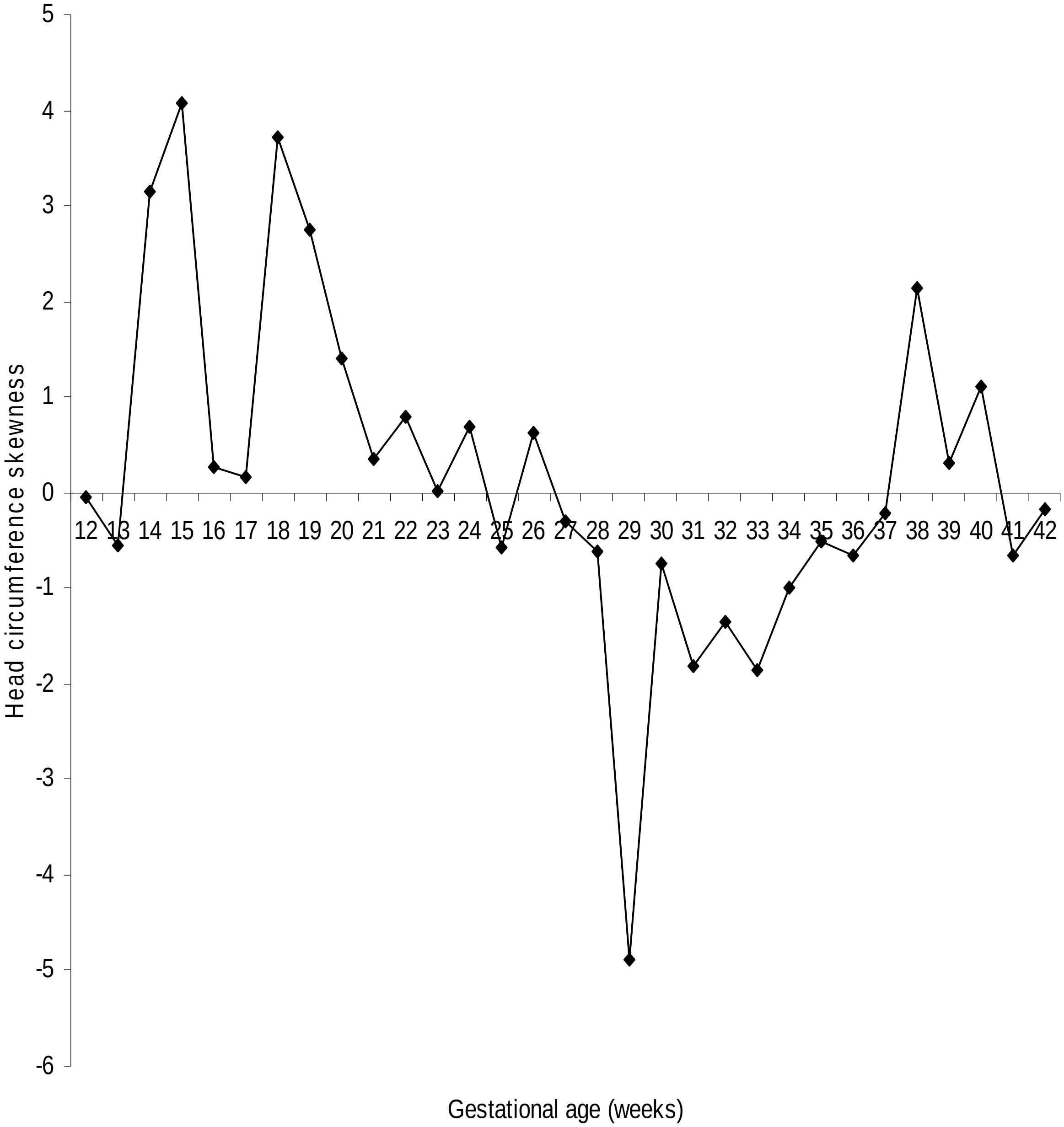

Figure 4: Head Circumference data of 13,740 Fetuses Subjected to Skewness Analysis at Different Gestational Age Ranging from 12 – 42 weeks.

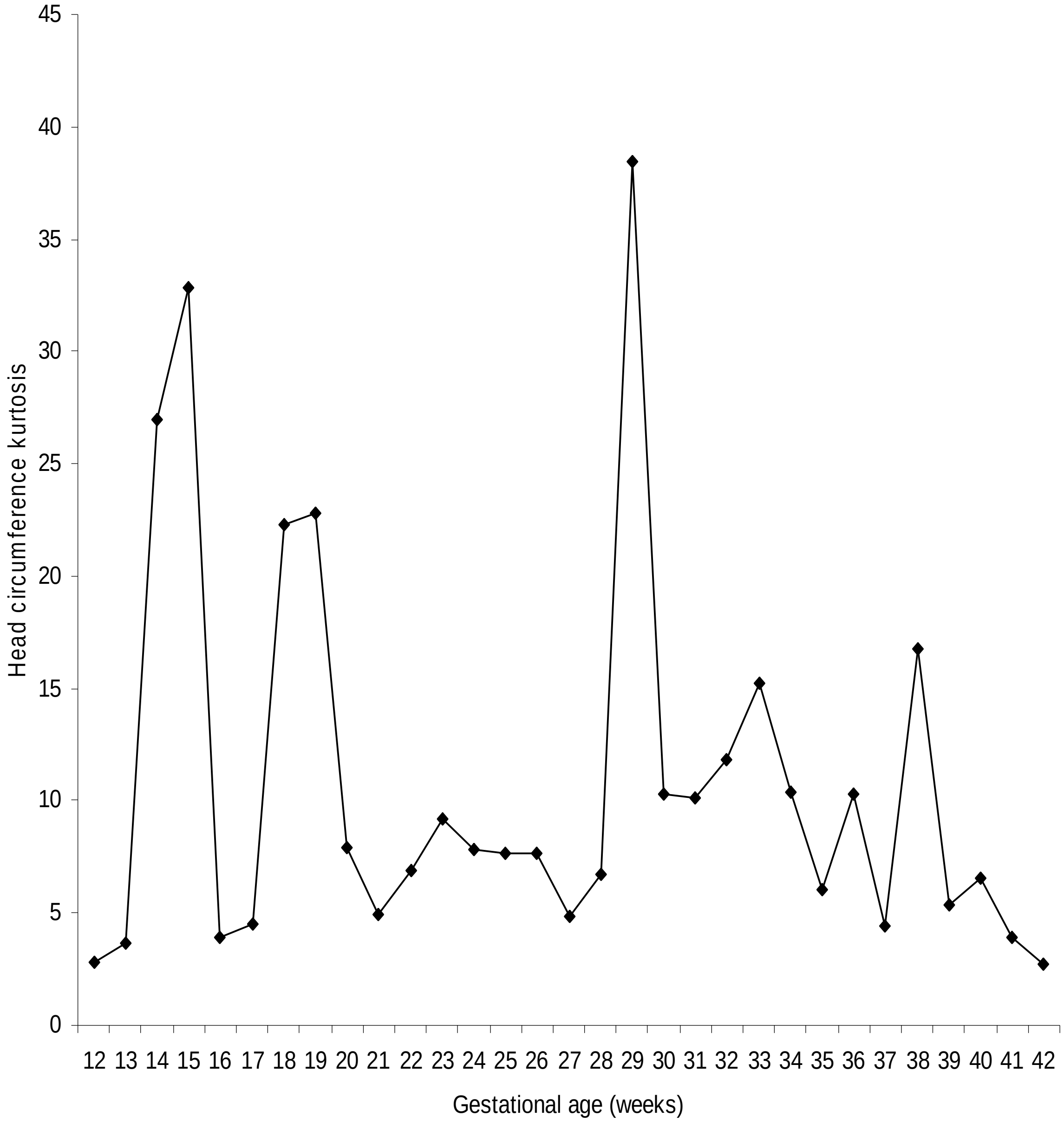

Figure 5: Head circumference data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.

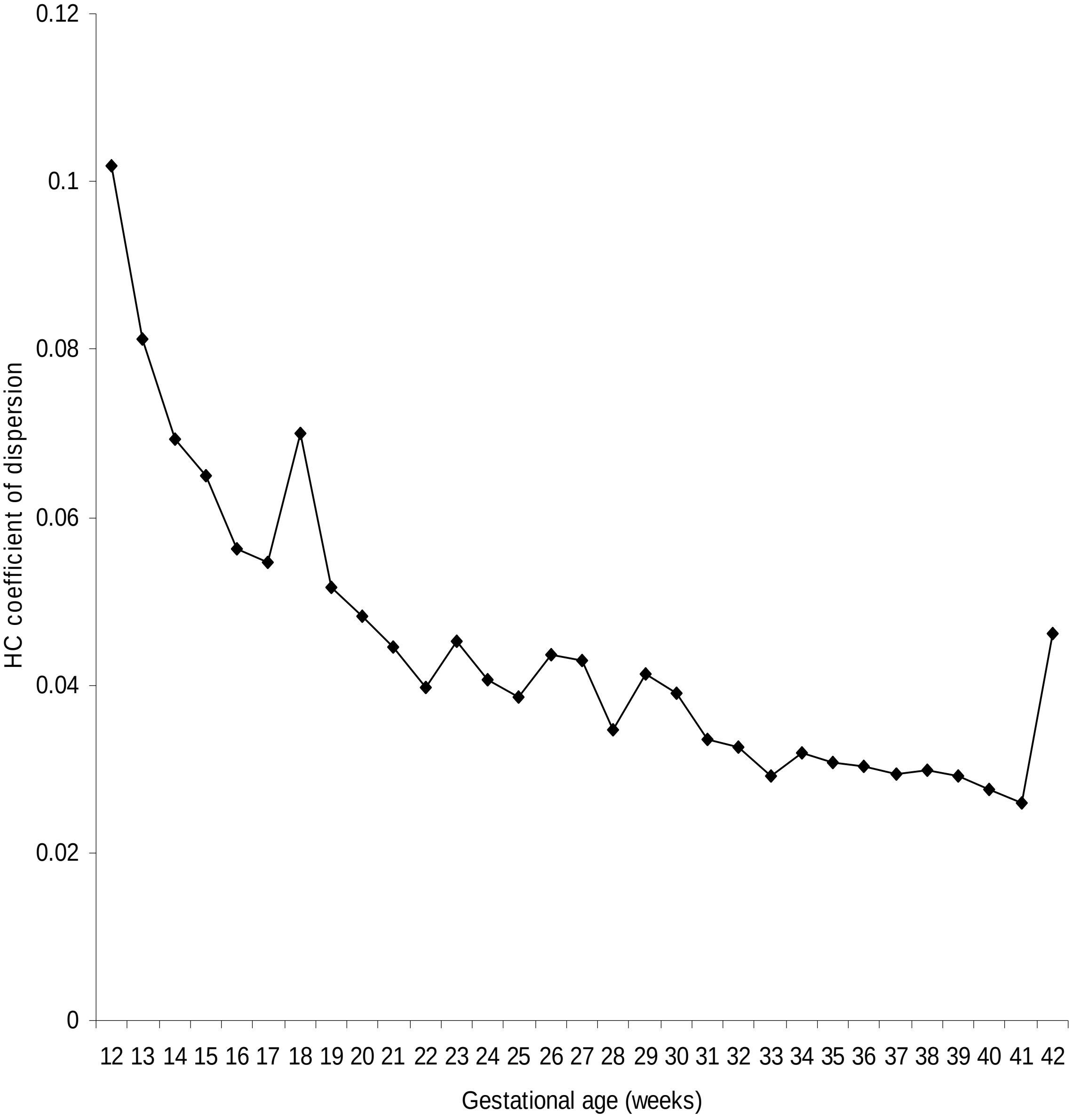

Figure 6: Head circumference coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.

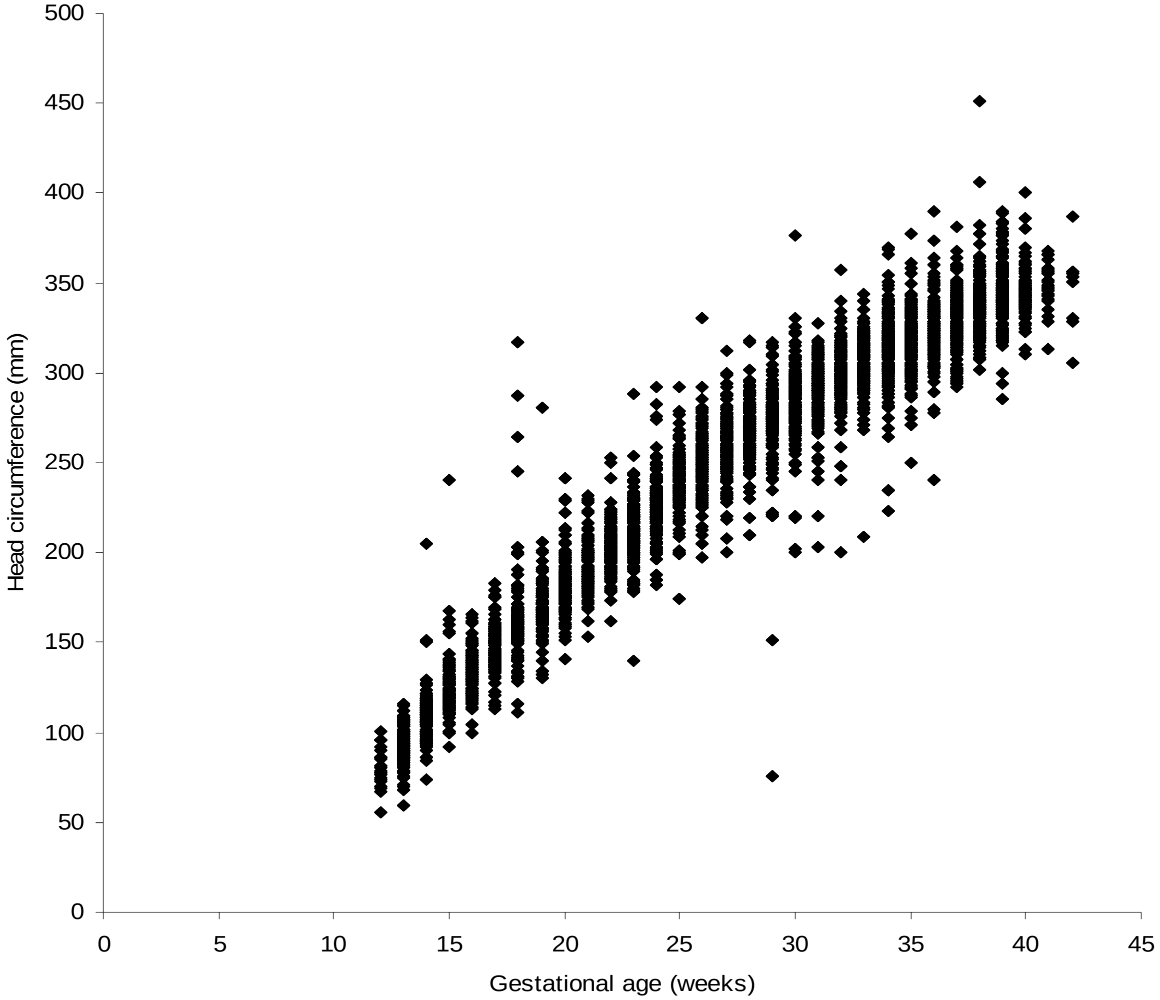

Figure 7: Scattergram of 13,740 fetal head circumference measurements from 12 – 42 weeks gestation.

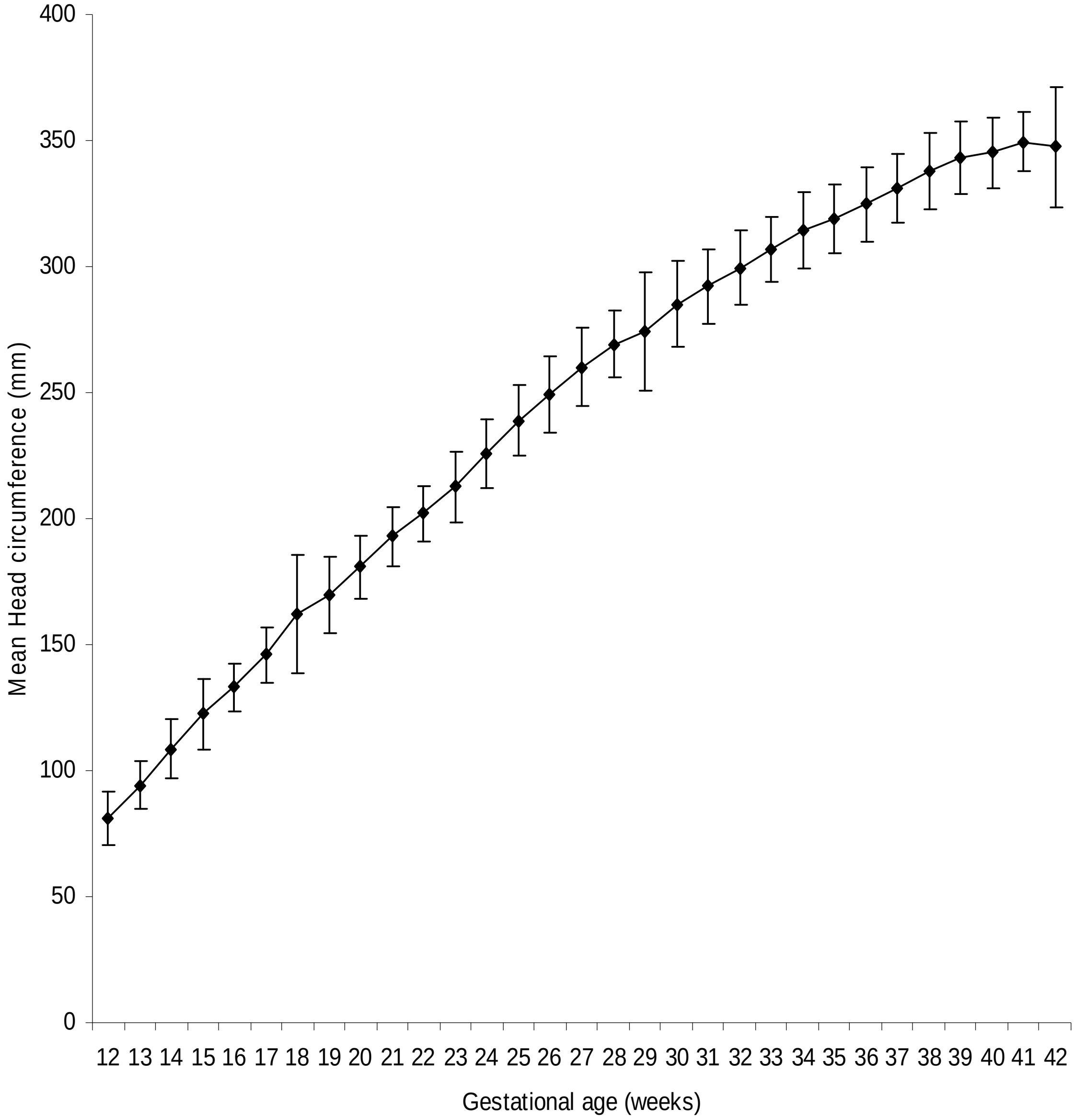

Figure 8: Mean fetal head circumference values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.

Mathematical modeling of head circumference data plotted against gestational age demonstrated that the best-fitted regression model (figure 9) to describe the relationship between head circumference and gestational age was the third order polynomial regression equation $y = -0.0029x^3 + 0.0518x^2 + 13.136x - 78.198$ with a correlation of determination of $R^2 = 0.9996$ ($P < 0.0001$) where y is the head circumference in millimeters and x is the gestational age in weeks. This means that head circumference could predict the gestational age of fetuses in Jos by 99.96 percent ($R^2 = 0.9996$) in 13,740 fetuses in this study. When monthly mean values of head circumference are plotted against gestational age in months, a positive polynomial correlation between gestational age and head circumference with a correlation of determination of $R^2 = 0.9991$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 10). The relationship is best described by the second order polynomial regression equation $y = -3.3238x^2 + 85.755x - 177.78$ where y is the head circumference in millimeters and x is the gestational age in months. Figure 11 shows histogram of monthly mean of head circumference whose values are also shown. Figure 12 shows histogram with means for 2nd and 3rd trimesters. When other fetal anthropometric parameters like biparietal diameter, occipitofrontal diameter, abdominal circumference, femur length and weight are plotted against head circumference certain hidden relationships can be forced out. For example, figure 13 shows the relationship of head circumference with biparietal diameter. From the graph, it can be seen that there is a positive linear correlation between biparietal diameter and head circumference with a correlation of determination of $R^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 0.2792x - 0.8656$ where y is the biparietal diameter in millimeters and x is the head circumference in millimeters. Figure 14 shows relationship of head circumference with occipitofrontal diameter (OFD) which has regression equation of $y = 0.347 + 0.0528$; $R^2 = 1$; $P<0.0001$.

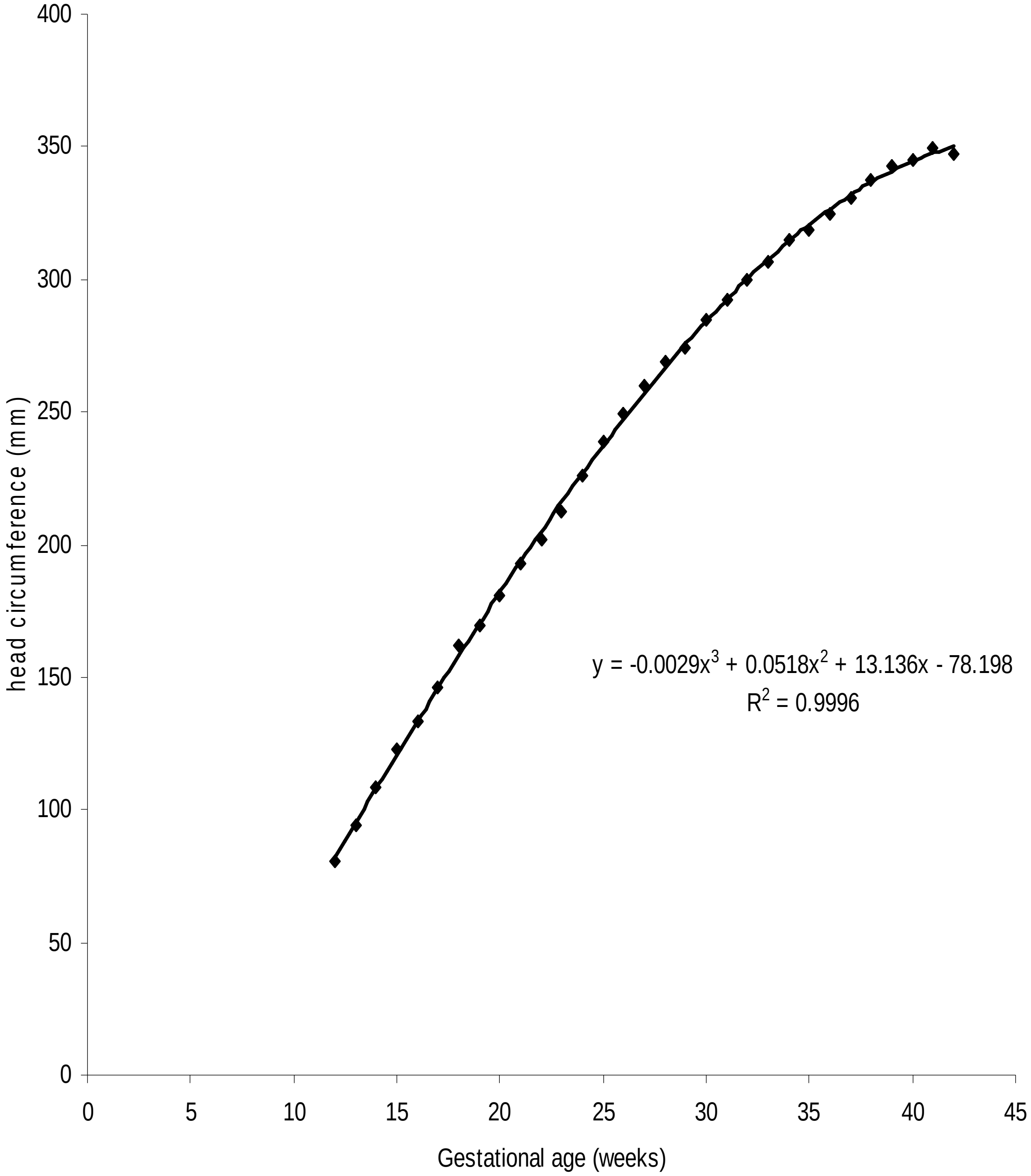

Figure 9: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks

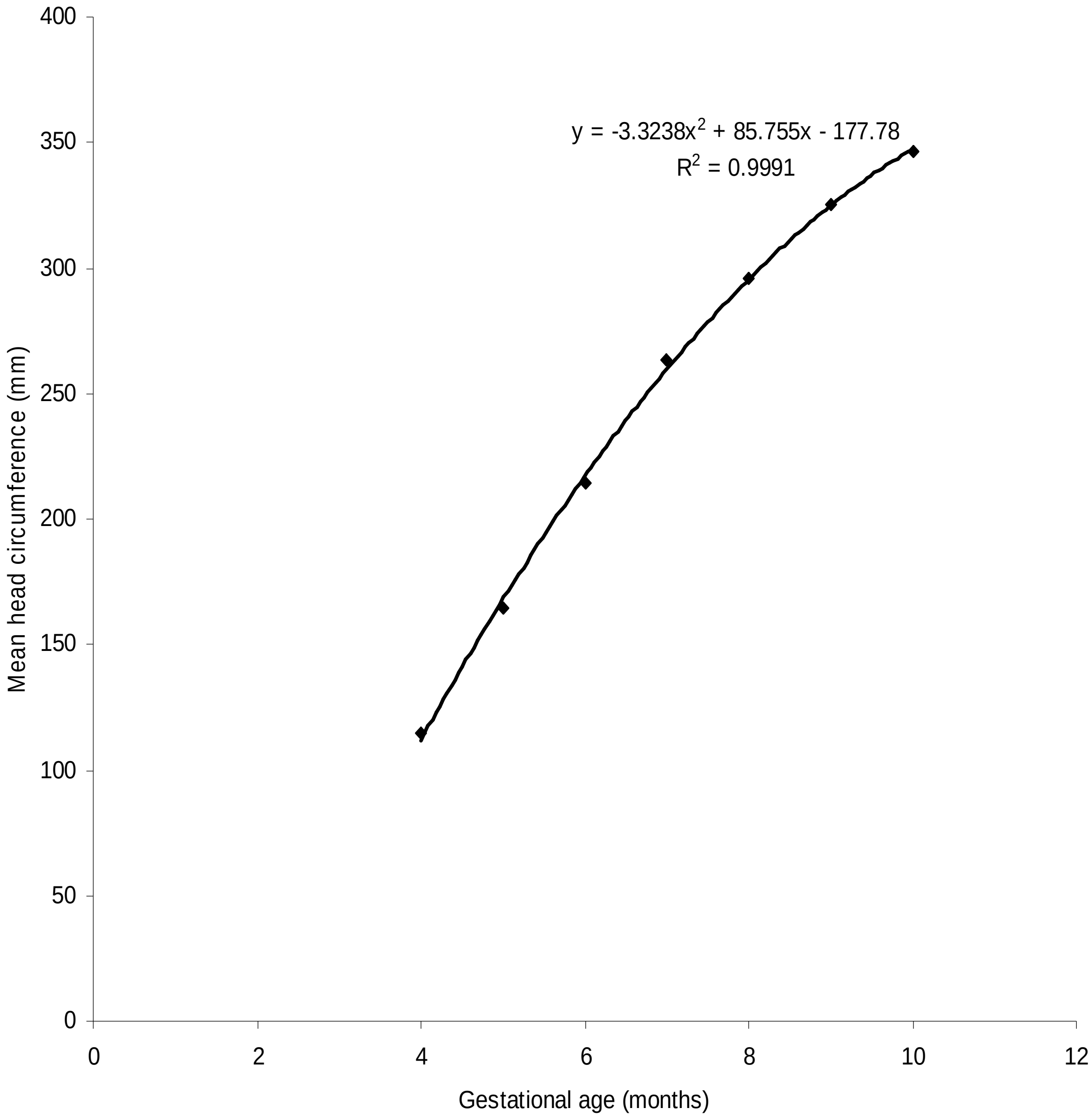

Figure 10: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months

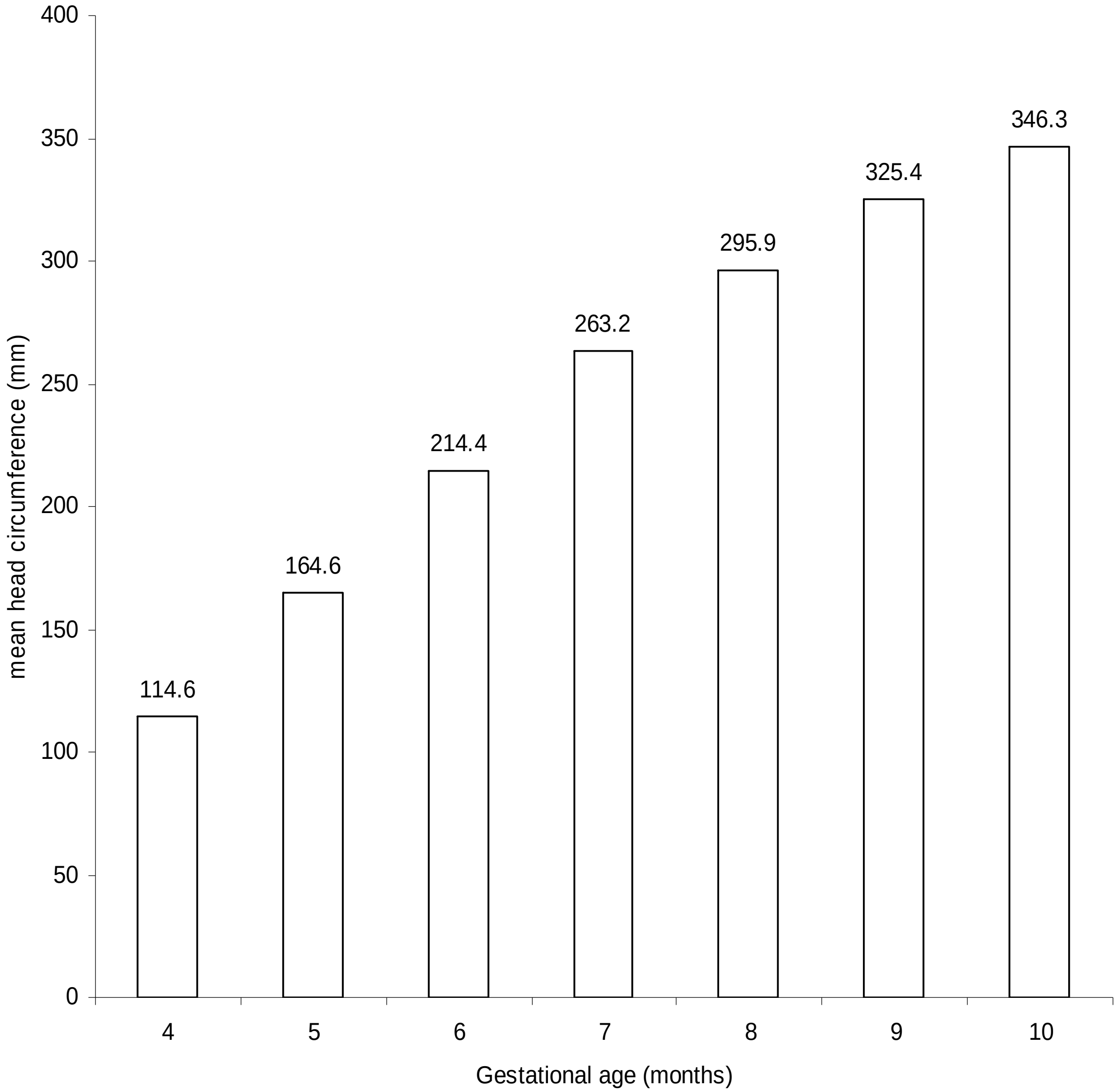

Figure 11: Histogram showing mean head circumference values in 13,740 head circumference data of fetuses in women of gestational ages from 4 to 10 months

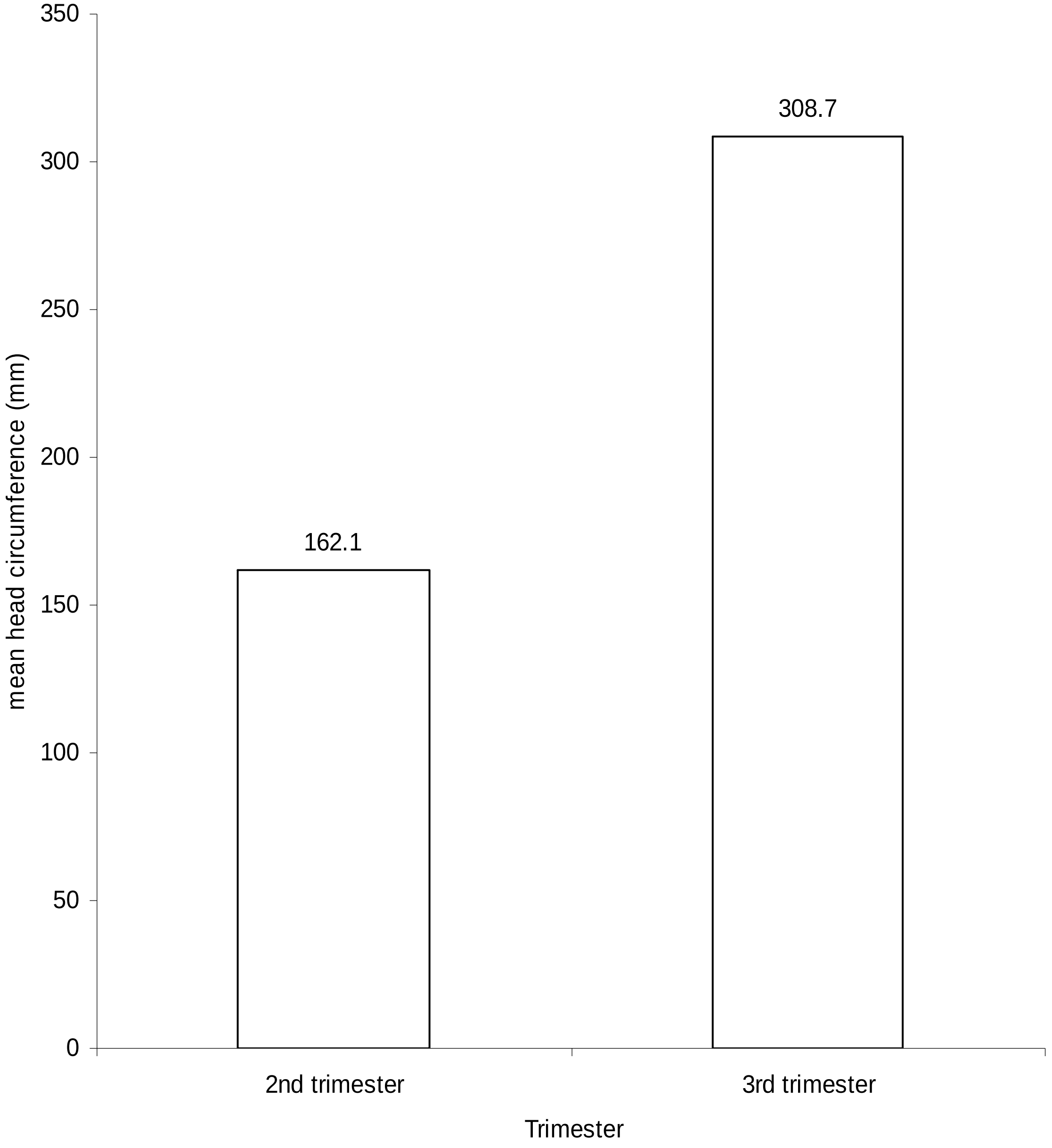

Figure 12: Histogram showing mean head circumference values in 13,740 head circumference data of fetuses in women of gestational ages from 4 to 10 months divided into two trimesters

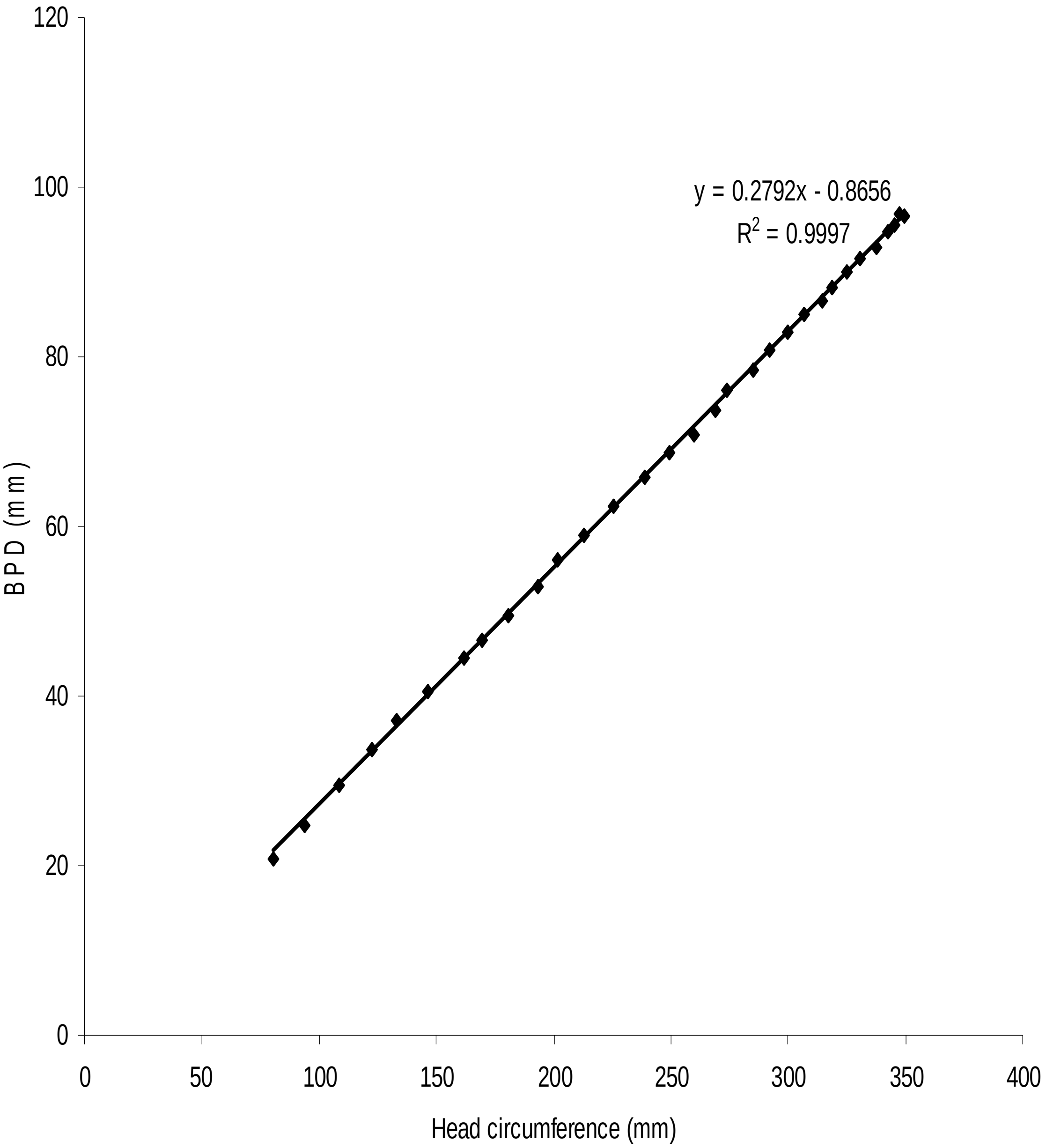

Figure 13: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter

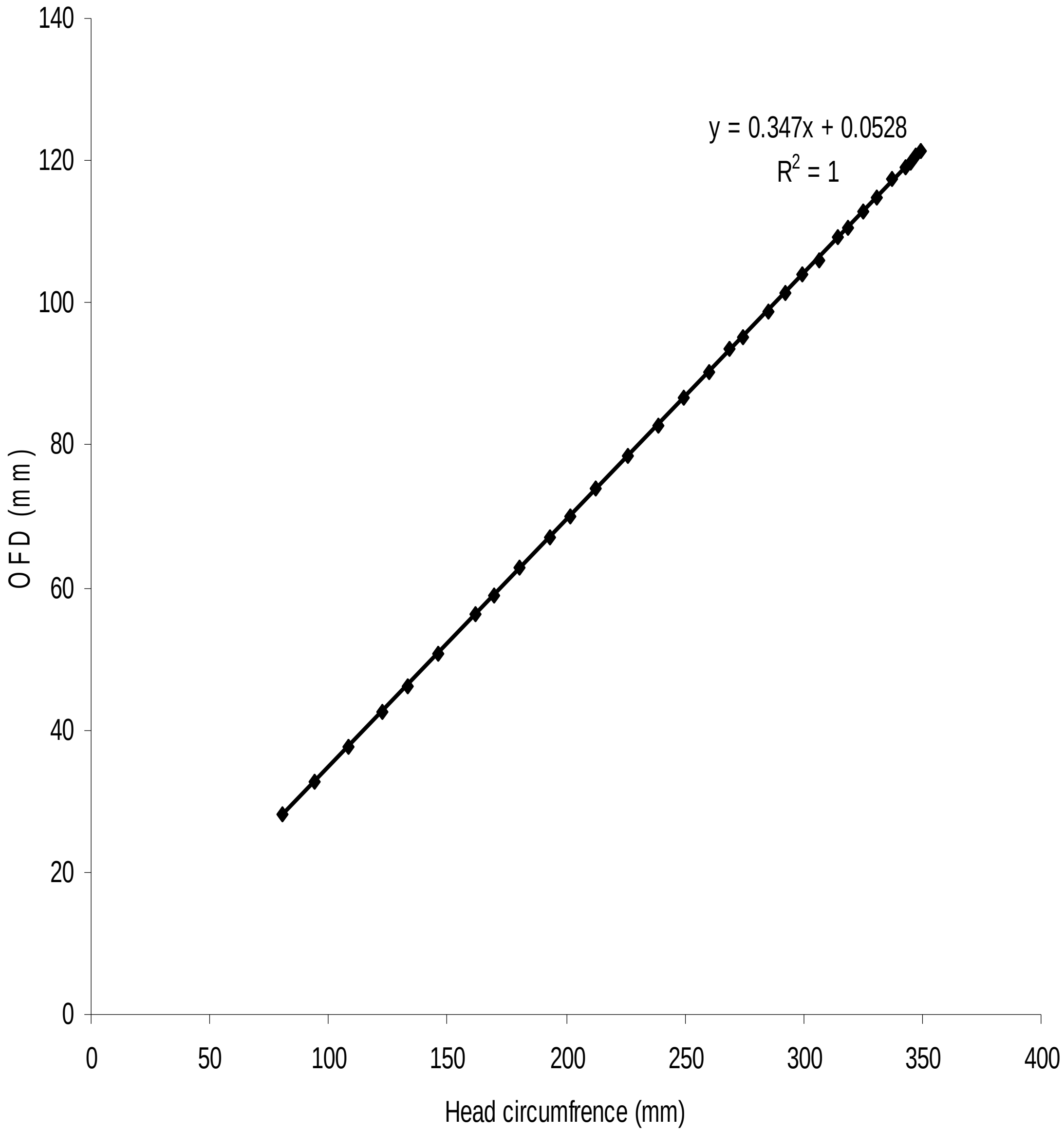

Figure 14: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter

Figure 15 shows the relationship between cephalic index and head circumference. The relationship is best described by the fourth order polynomial regression equation $y = 1E\text{-}08x^4 + 1E\text{-}05x^3 - 0.0036x^2 + 0.5497x + 49.656$ where y is the cephalic index and x is the head circumference in millimeters; $R^2 = 0.7451$; $P<0.0001$).

Other relationships can be calculated outside the skull. Figure 16 shows relationship of head circumference with abdominal circumference. From the graph, it can be seen that there is a positive linear correlation between abdominal circumference and head circumference with a correlation of determination of $R^2 = 0.994$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 1.0644x - 29.032$ where y is the abdominal circumference in millimeters and x is the head circumference in millimeters.

Figure 17 shows relationship between femur length and head circumference. There is a positive power correlation between femur length and head circumference with a correlation of determination of $R^2 = 0.9962$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.046x^{1.2897}$ where y is the femur length in millimeters and x is the head circumference in millimeters. Figure 18 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and head circumference. The relationship is best described by the exponential regression equation $y = 57.144e^{0.012x}$ where y is the fetal weight in grams and x is the head circumference in millimeters.

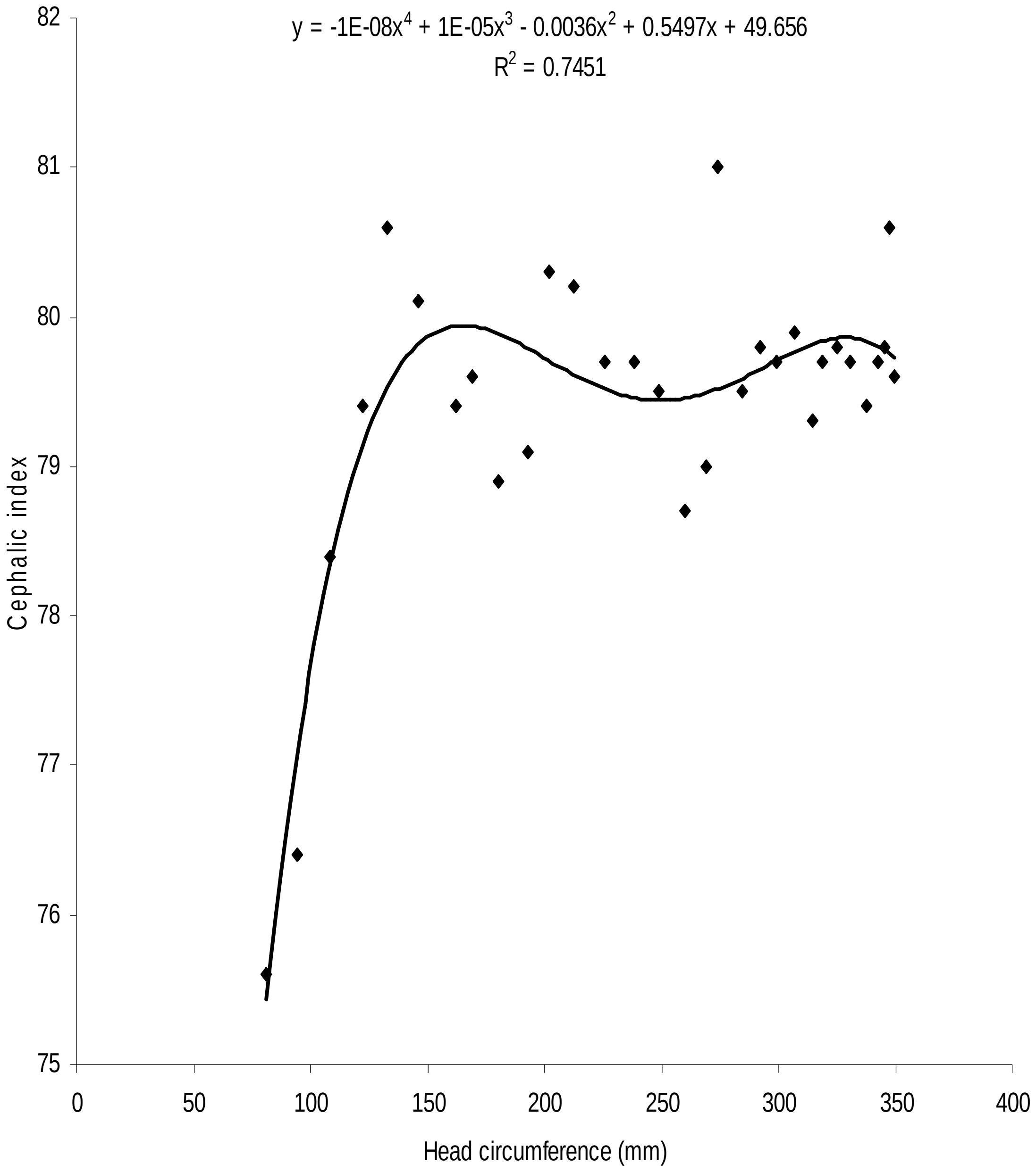

Figure 15: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against cephalic index.

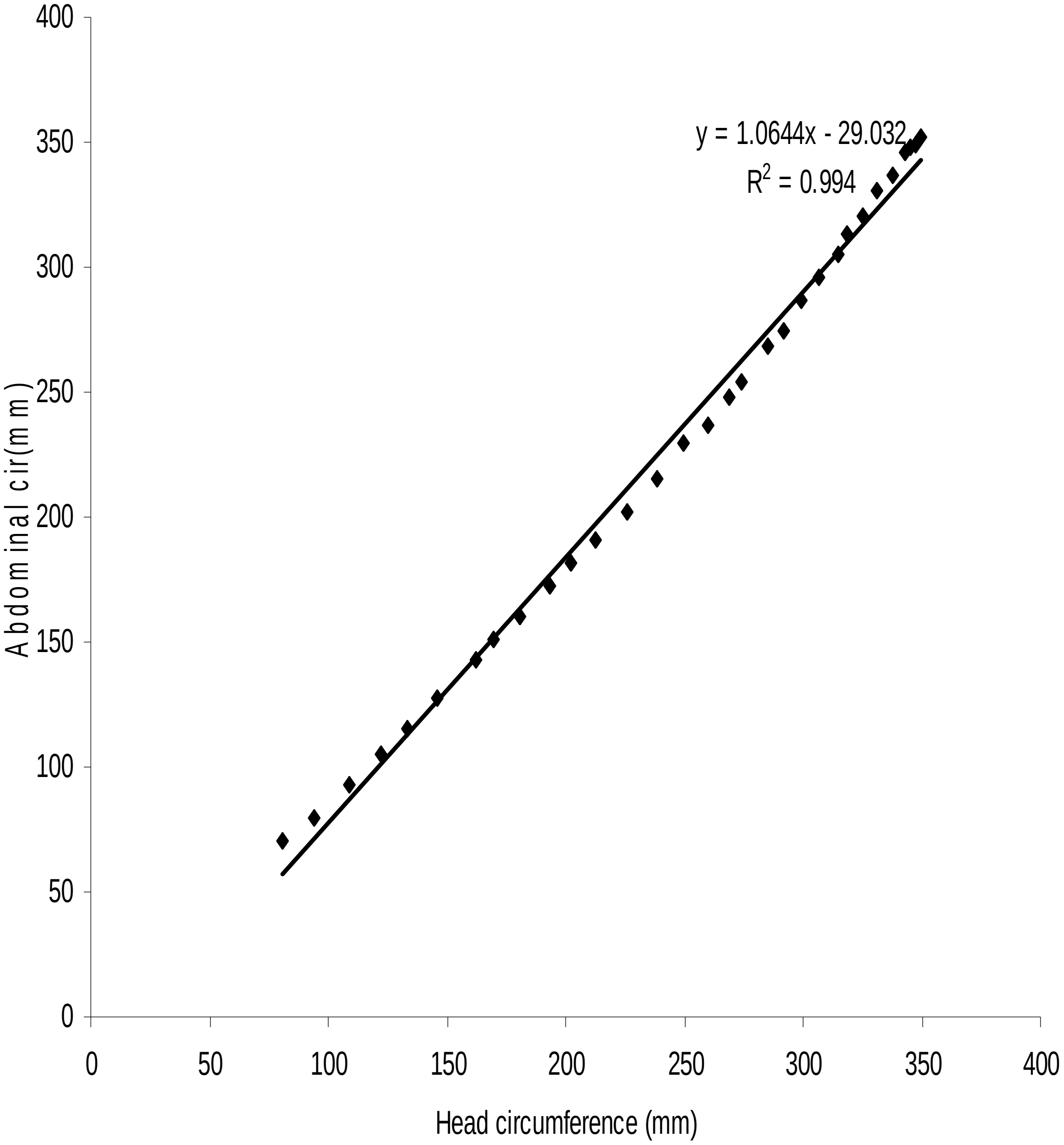

Figure 16: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference

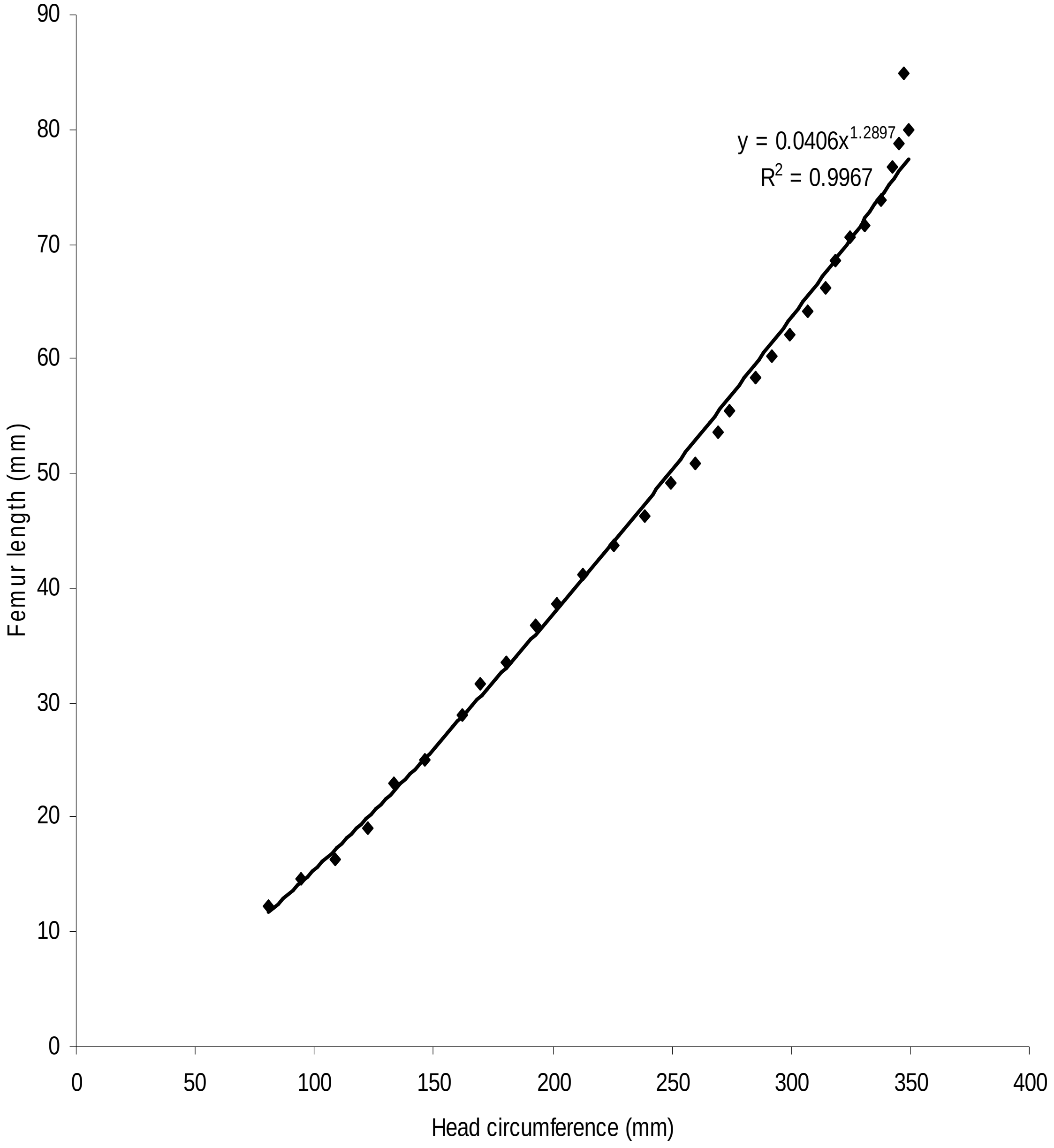

Figure 17: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against femur length.

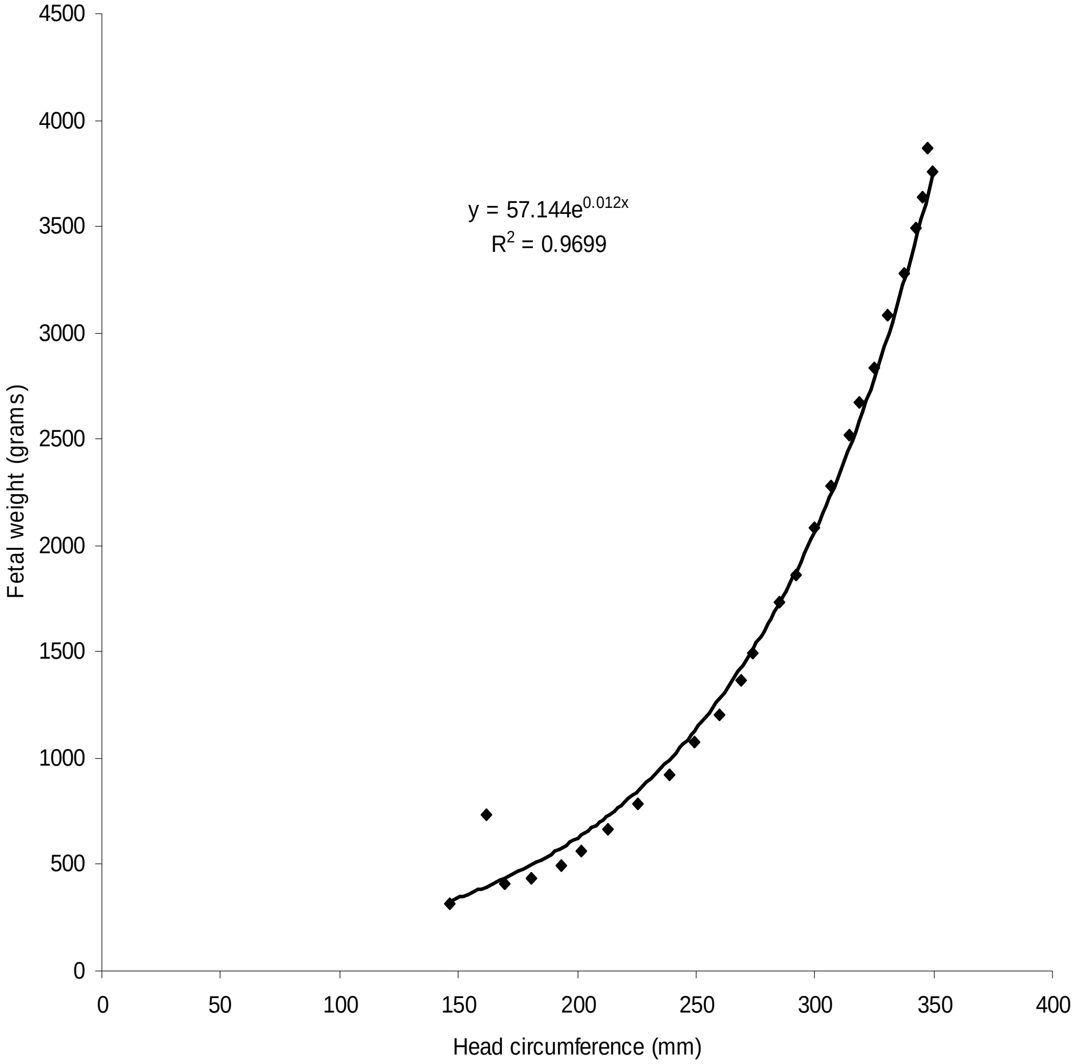

Figure 18: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.

When the relationship between head circumference and symphysio-fundal height was determined, it was found that there is a positive polynomial correlation between symphysio-fundal height and head circumference with a correlation of determination of $R^2 = 0.9954$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the sixth order polynomial regression equation $y = -2E\text{-}05x^6 + 0.0037x^5 - 0.2533x^4 + 9.0473x^3 - 177.54x^2 + 1823.4x - 7544.3$ where y is the head circumference in millimeters and x is the symphysio-fundal height in centimeters (figure 19).

Centile values for 5th, 50th and 95th are plotted as shown in figure 20. In figure 21, the 5th, 50th and 95th centile values of head circumference measurement are smoothened into a growth chart which can be utilized to determine growth and of course brain size development, strongly related to intelligence and wellness, using head circumference. Figure 22 is a graphical display showing the growth rate of the measured fetal head circumference with a quadratic polynomial mathematical model predictive formula $y = 0.0008x^2 - 0.0095x + 2.1811$ ($R^2 = 0.721$; $p<0.0001$); where y is the fetal head circumference growth rate in millimeters and x is the gestational age in weeks. It is clear from this graph that growth rate is much higher in the early stages of development than the late ones which precede term.

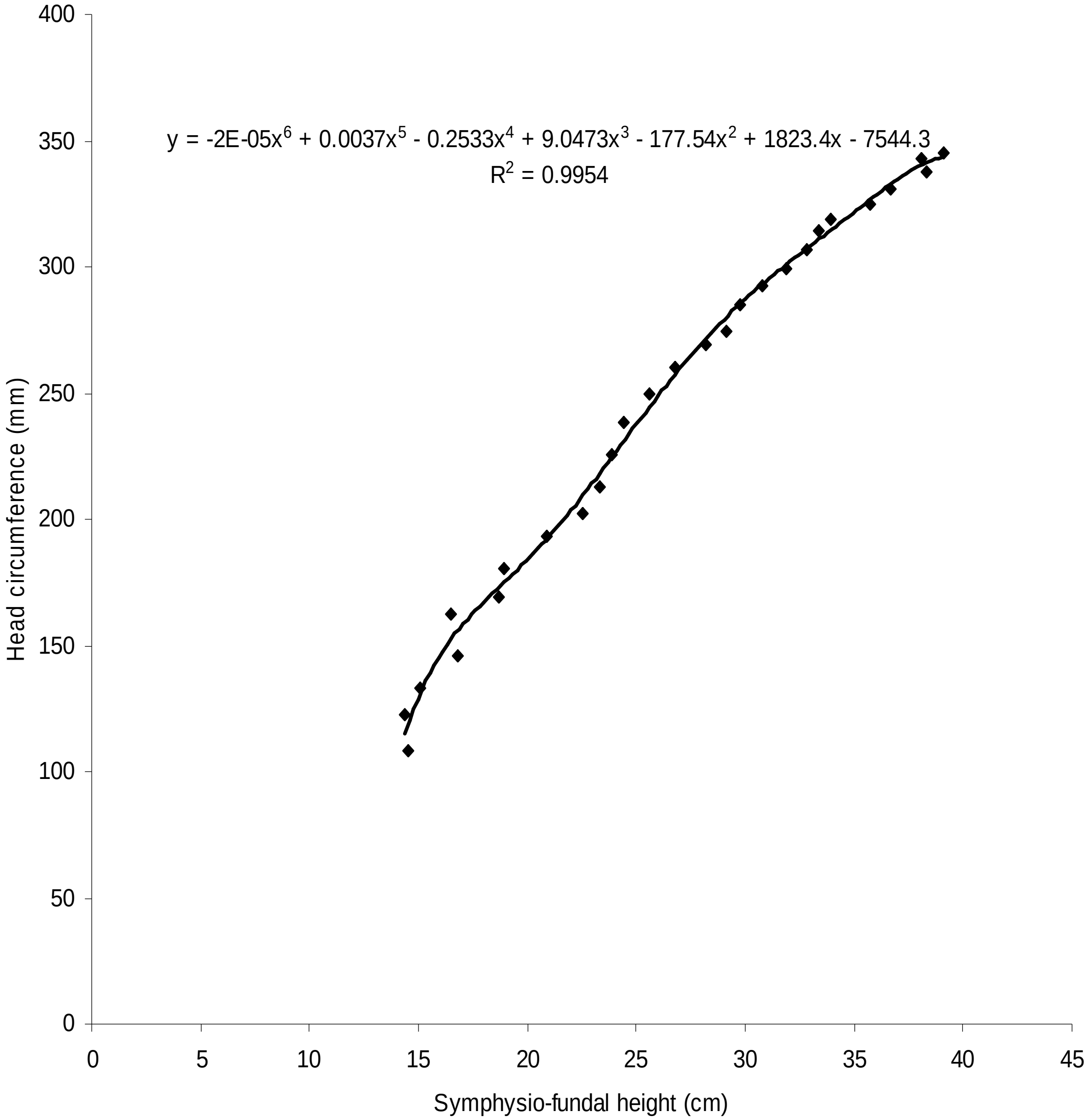

Figure 19: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against symphysio-fundal height.

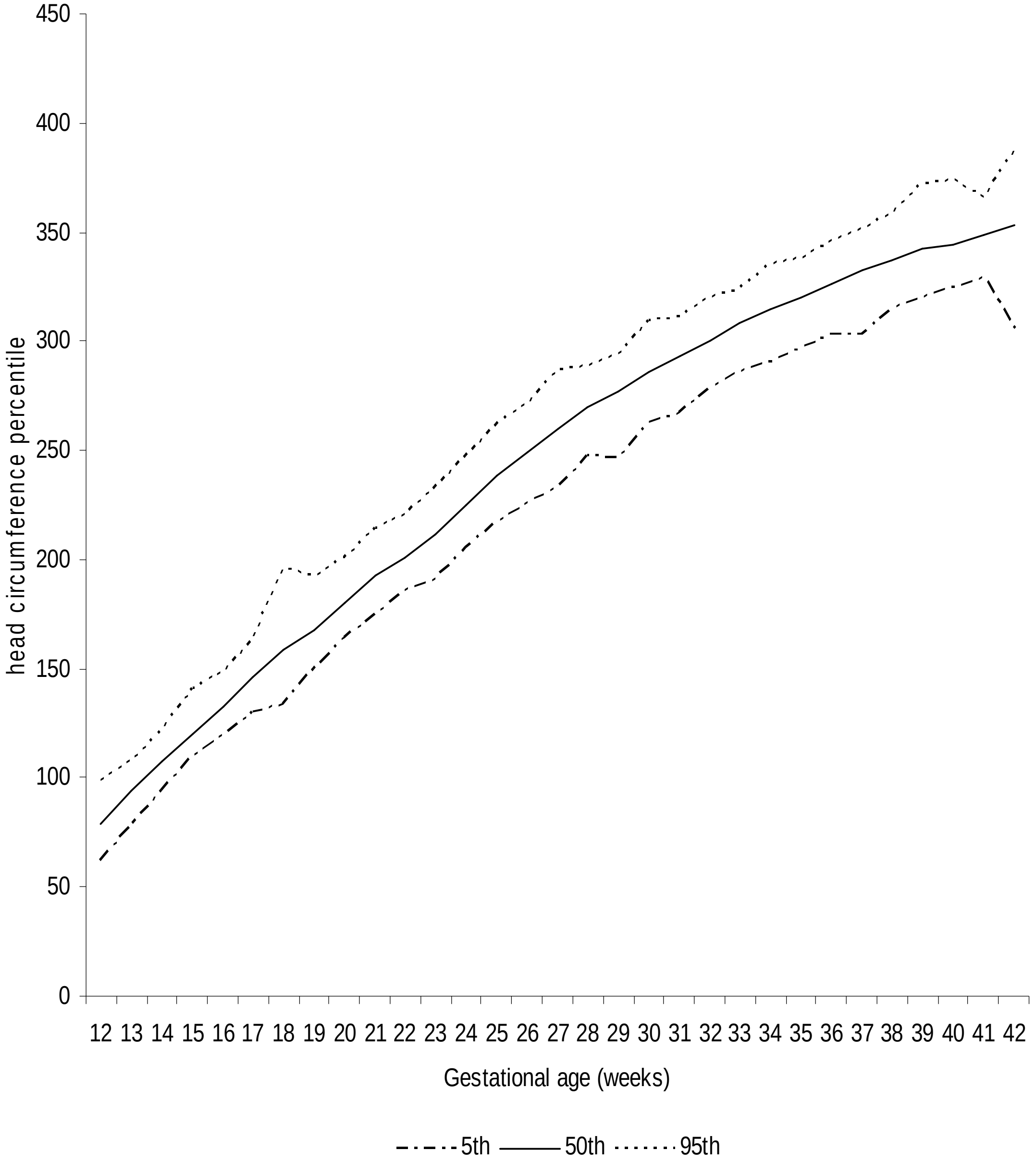

Figure 20: Fifth, 50th and 97th centiles for head circumference in 13,740 fetuses at different gestational ages from 12 to 42 weeks.

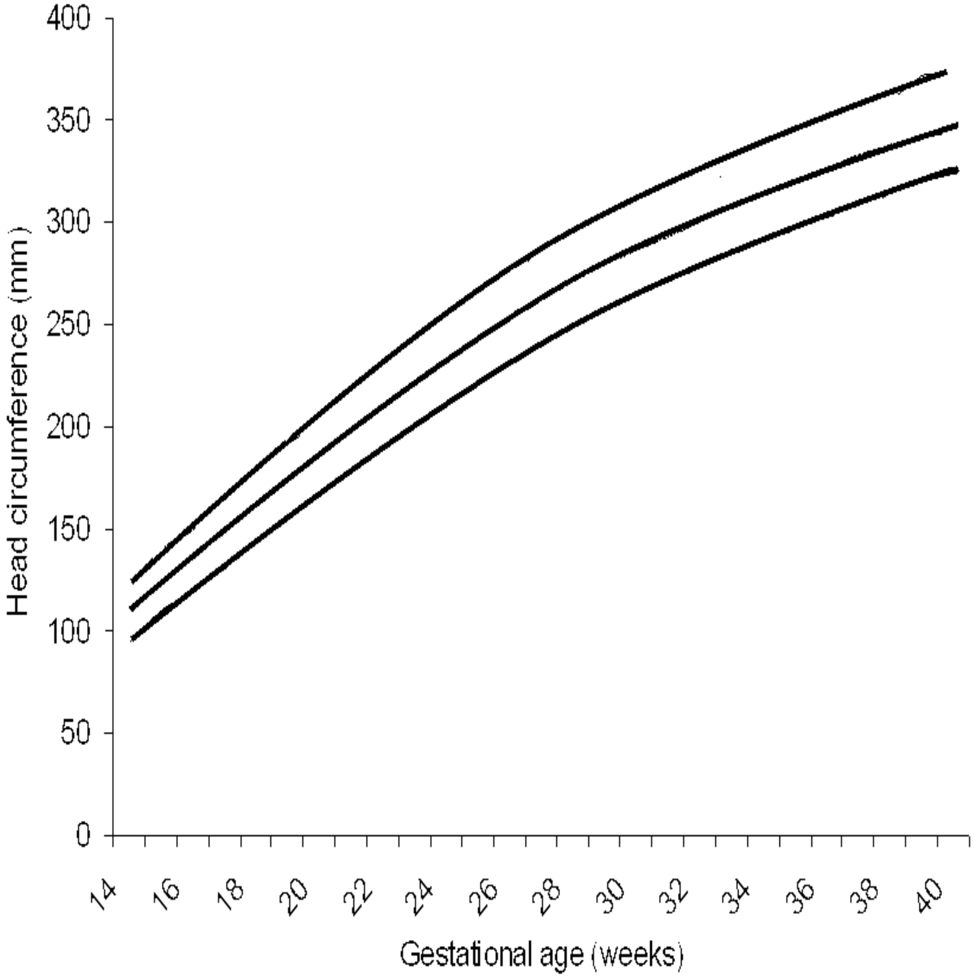

Figure 21: Curves created from 3rd, 50th and 97th fetal head circumference centiles.

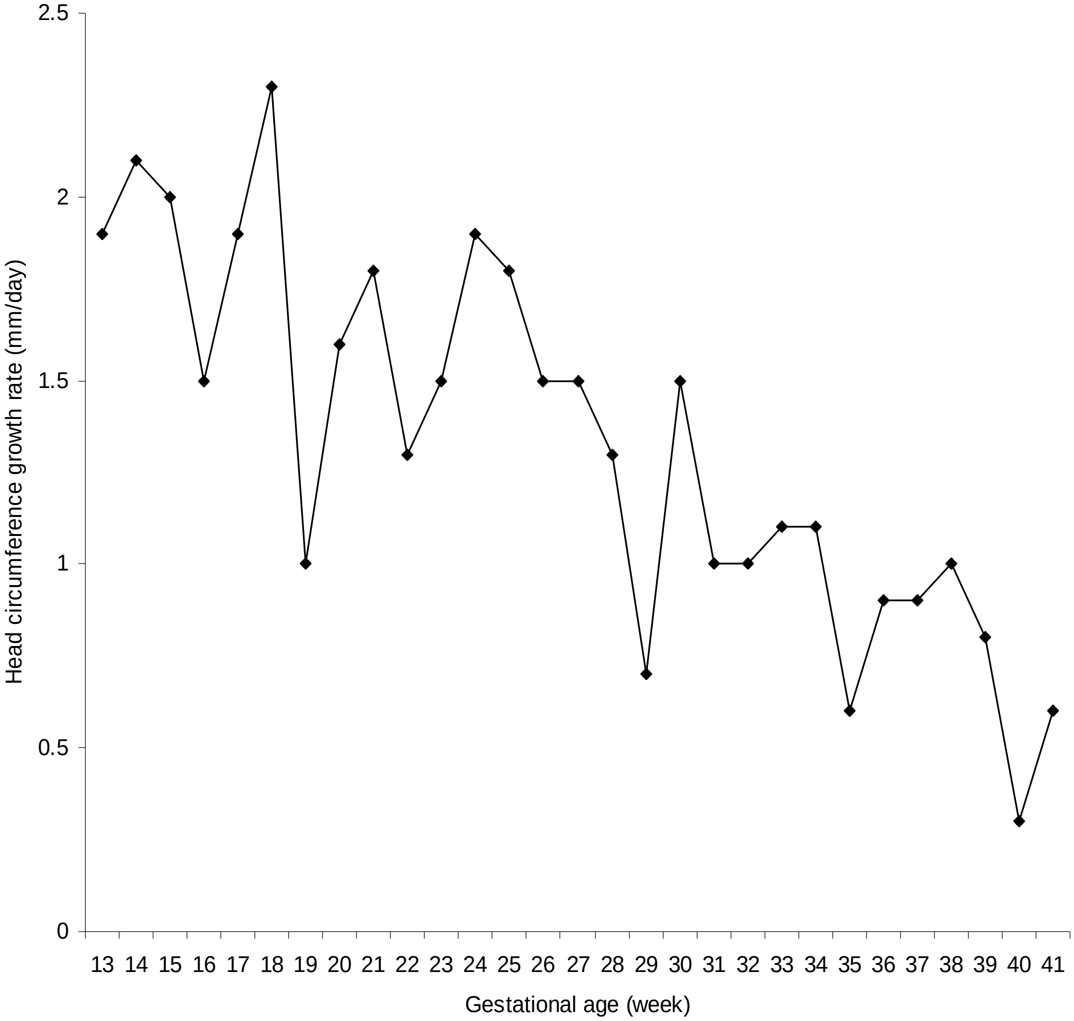

Figure 22: Growth velocity pattern of head circumference in 13,740 Nigerian fetuses in Jos

4.1.2 Fetal Biparietal Diameter

The fetal biparietal diameter measurements were classified into thirty one groups (table 10). The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. The measurements varied more at 18 to 18+6 group. The standard error of mean of BPD measurements is relatively small suggesting that the sample mean is very close to the population mean. For example, at 13 weeks gestation, the mean fetal biparietal diameter was 94.1mm while the standard error of mean was 0.5. This means that the difference between the mean biparietal diameter of the sample of fetuses at 13 weeks is just 0.5mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (table 11) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal biparietal diameter measurements were not identical. Table 12 shows the monthly fetal biparietal diameter values from 4th month to the 10th month with their corresponding standard deviations and standard error of mean. The fetal biparietal diameter values during second and third trimesters are shown in table 13 while table 14 gives the centile values of fetal biparietal diameter measurements. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal biparietal diameter measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 10th percentile of biparietal diameter at 20 to 20 + 6 weeks gestation is 48 millimeters. This means that 10% of the fetuses at 20 to 20 + 6 had a mean biparietal diameter less than 48 millimeters, while 90% had a mean biparietal diameter greater than 48 millimeters. Similarly, the 97th percentile of biparietal diameter at 36 to 36 + 6 is 94 millimeters. Hence 97% of fetuses at 36 to 36 + 6 had a mean biparietal diameter less than 94 millimeters while 3% had a mean biparietal diameter greater than 94 millimeters.

Table 10: Frequency Distribution Table of Fetal Biparietal Diameter Measurements Showing the Arithmetic mean, Standard Deviation and Standard Error of Mean from 12 – 42 weeks gestation.

GA (wks, days)	Fetuses (n)	BPD(mm)	SD	SEM
12 to 12+6	49	20.9	2.0	0.2
13 to 13+6	384	24.8	2.1	0.1
14 to 14+6	371	29.4	2.0	0.1
15 to 15+6	351	33.6	3.0	0.2
16 to 16+6	505	37.1	1.7	0.0
17 to 17+6	427	40.5	2.0	0.0
18 to 18+6	446	44.4	5.1	0.2
19 to 19+6	282	46.6	2.8	0.2
20 to 20+6	553	49.4	2.2	0.0
21 to 21+6	400	52.9	1.7	0.0
22 to 22+6	398	56.1	2.7	0.1
23 to 23+6	478	59.0	1.8	0.0
24 to 24+6	520	62.3	2.3	0.1
25 to 25+6	388	65.8	2.2	0.1
26 to 26+6	511	68.6	2.3	0.1
27 to 27+6	432	70.8	2.2	0.1
28 to 28+6	548	73.6	3.6	0.2
29 to 29+6	484	76.0	3.3	0.2
30 to 30+6	625	78.4	3.5	0.1
31 to 31+6	523	80.7	2.5	0.1
32 to 32+6	583	82.8	2.7	0.1
33 to 33+6	516	85.0	2.0	0.0
34 to 34+6	744	86.6	3.4	0.1
35 to 35+6	739	88.2	2.7	0.0
36 to 36+6	599	90.0	2.8	0.1
37 to 37+6	532	91.5	2.2	0.0
38 to 38+6	481	93.0	2.5	0.1
39 to 39+6	525	94.7	2.6	0.1
40 to 40+6	252	95.6	2.3	0.2
41 to 41+6	72	96.5	2.3	0.3
42 to 42+6	22	96.9	2.7	0.6
Total	**13,740**			

Table 11: Frequency distribution table of fetal head circumference measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.

GA (week, days)	Number of fetuses (n)	Arithmetic mean	Geometric mean	Harmonic mean
12 to 12+6	49	20.89796	20.8133	20.73384
13 to 13+6	384	24.79427	24.6967	24.58586
14 to 14+6	371	29.3504	29.27582	29.19156
15 to 15+6	351	33.60399	33.50901	33.43465
16 to 16+6	505	37.05941	37.01759	36.9743
17 to 17+6	427	40.52693	40.47596	40.42076
18 to 18+6	446	44.40359	44.19772	44.04385
19 to 19+6	282	46.61702	46.55173	46.4993
20 to 20+6	553	49.37613	49.33103	49.28833
21 to 21+6	400	52.9325	52.90432	52.87666
22 to 22+6	398	56.11055	56.05551	56.00847
23 to 23+6	478	59.03138	59.00269	58.97365
24 to 24+6	520	62.31538	62.27158	62.22575
25 to 25+6	388	65.84021	65.80398	65.76709
26 to 26+6	511	68.61644	68.57739	68.53812
27 to 27+6	432	70.84259	70.80765	70.77187
28 to 28+6	548	73.64051	73.49528	73.23101
29 to 29+6	484	75.98967	75.89696	75.77091
30 to 30+6	625	78.4288	78.34548	78.25781
31 to 31+6	523	80.73422	80.69387	80.65249
32 to 32+6	583	82.78902	82.73907	82.68323
33 to 33+6	516	84.98062	84.9576	84.93434
34 to 34+6	744	86.55645	86.48273	86.39934
35 to 35+6	739	88.15833	88.11768	88.07617
36 to 36+6	599	90.00835	89.96366	89.91594
37 to 37+6	532	91.49436	91.46841	91.44218
38 to 38+6	481	92.98753	92.95243	92.91693
39 to 39+6	525	94.74857	94.71294	94.67731
40 to 40+6	252	95.56349	95.53491	95.5063
41 to 41+6	72	96.45834	96.43224	96.40612
42 to 42+6	22	96.90909	96.87257	96.83514
Total	**13740**			

Table 12: Monthly mean fetal biparietal diameter values (in mm) in a Nigerian population

GA (months)	Fetuses (n)	Mean (mm)	SD	SEM
4	1660	29.2	6.52	2.92
5	1708	45.2	3.76	1.88
6	2184	59.2	5.06	2.26
7	1975	72.3	3.23	1.62
8	2247	81.7	2.83	1.41
9	3095	89.9	2.55	1.14
10	871	95.9	0.98	0.49
Total	13,740			

Table 13: Trimester mean fetal biparietal diameter values

Trimester	Fetuses (n)	Mean	SD	SEM	Minimum	Maximum	Range
2nd	5552	44.5	14.08	3.76	20.9	65.8	44.9
3rd	8188	85.2	9.26	2.24	68.6	96.9	28.3
Total	13,740						

Table 14: Fetal biparietal diameter centiles from 12 – 42 weeks

	Biparietal diameter (mm)						
GA (wks, days)	3rd	5th	10th	50th	90th	95th	97th
12 to 12+6	19.0	19.0	19.0	20.0	24.0	25.5	26.0
13 to 13+6	20.0	22.0	22.5	25.0	27.0	27.0	27.0
14 to 14+6	26.2	27.0	28.0	29.0	31.0	31.0	32.0
15 to 15+6	31.0	31.0	32.0	34.0	35.0	35.0	35.4
16 to 16+6	33.0	34.0	35.0	37.0	39.0	39.0	39.0
17 to 17+6	37.0	38.0	38.8	41.0	42.0	42.0	43.2
18 to 18+6	41.0	41.0	42.0	44.0	45.0	46.0	47.0
19 to 19+6	44.0	44.2	45.0	46.0	47.0	49.0	50.0
20 to 20+6	46.0	47.0	48.0	49.0	51.0	52.0	53.4
21 to 21+6	49.0	50.0	51.0	53.0	54.0	55.0	56.0
22 to 22+6	53.0	53.0	54.0	56.0	57.0	59.0	60.0
23 to 23+6	55.0	56.0	57.0	59.0	61.0	61.0	62.0
24 to 24+6	56.6	58.0	60.0	63.0	64.0	65.0	67.0
25 to 25+6	62.0	63.0	64.0	66.0	68.0	69.0	70.0
26 to 26+6	63.0	64.0	66.0	69.0	70.0	72.0	74.0
27 to 27+6	64.0	66.0	68.0	71.0	72.7	74.0	75.0
28 to 28+6	69.0	71.0	72.0	74.0	75.1	77.0	78.0
29 to 29+6	70.7	73.0	74.0	76.0	78.0	78.8	79.0
30 to 30+6	71.0	72.0	74.0	79.0	81.0	84.0	85.0
31 to 31+6	74.7	76.0	78.0	81.0	83.0	84.0	84.3
32 to 32+6	77.0	78.0	80.0	83.0	85.0	87.0	87.0
33 to 33+6	80.0	82.0	82.0	85.0	87.0	88.0	88.0
34 to 34+6	80.4	82.0	83.5	87.0	89.0	91.0	92.0
35 to 35+6	82.0	83.0	85.0	89.0	91.0	92.0	93.0
36 to 36+6	84.0	85.0	87.0	90.0	92.0	93.0	94.0
37 to 37+6	87.0	87.0	89.0	92.0	94.0	94.0	95.0
38 to 38+6	88.0	89.0	90.0	93.0	96.0	97.0	98.0
39 to 39+6	90.0	91.0	92.0	94.0	98.0	99.0	99.0
40 to 40+6	91.0	91.0	93.0	95.0	98.7	100.0	100.0
41 to 41+6	91.2	92.0	93.0	96.0	100.0	101.0	101.0
42 to 42+6	91.0	91.0	91.0	98.0	99.0	99.0	99.0

The standard score or z-score of biparietal diameter measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in table 15. The z-score enables us to look at biparietal diameter measurements in each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, biparietal diameter measurements at 15 weeks are 0.00133 standard deviations from the mean while measurements at 30 weeks are – 0.0407 standard deviations from the mean. Again, from the above z-score table, it can be seen that the biparietal diameter measurements at 38 weeks gestation are – 0.00499 standard deviations from the mean. When biparietal diameter data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (figure 23), it can be seen that the distribution of biparietal diameter measurements has a longer “tail” to the left of the central maximum than to the right or is skewed to the left throughout pregnancy except at 14, 15, 18, 19, 20, 21 and 39 weeks where the distribution has a longer “tail” to the right of the central maximum than to the left or is skewed to the right.

When the biparietal diameter data was subjected to kurtosis analysis (figure 24), the analysis was found to be leptokurtic at 15, 18, 19, 22 and 29 weeks of gestation while at 12, 13, 16,17, 20, 21, 23, 24, 25, 26, 27, 28, 20, 31, 32,34, 35, 36, 39, 40, 41 and 42 weeks of gestation, the kurtosis was mesokurtic. The coefficient of dispersion of biparietal diameter data of 13,740 fetuses at different gestational age shows a decrease in value as gestational age advances except at 18, 20, 30 and 42 weeks where it peaks. At 25 weeks, it falls to zero before rising again (figure 25). The biparietal diameter scattergram in figure 26 shows that there are very few bad data points or outliers in the biparietal diameter measurements of 13,740 fetuses. The outliers are more from 26 – 42 weeks of gestation. This shows the pattern of growth recognized for neural tissue which suggests growth of brain.

Table 15: Standard score (z-score) of biparietal diameter measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation

Gestational age	Fetuses (n)	Mean z-score
12 to 12+6	49	-2.71565
13 to 13+6	384	-2.73E-03
14 to 14+6	371	-2.48E-02
15 to 15+6	351	1.33E-03
16 to 16+6	505	-2.39E-02
17 to 17+6	427	3.47E-03
18 to 18+6	446	7.03E-04
19 to 19+6	282	6.08E-03
20 to 20+6	553	-1.08E-02
21 to 21+6	400	1.91E-02
22 to 22+6	398	3.91E-03
23 to 23+6	478	1.74E-02
24 to 24+6	520	6.69E-03
25 to 25+6	388	1.83E-02
26 to 26+6	511	7.15E-03
27 to 27+6	432	1.94E-02
28 to 28+6	548	1.13E-02
29 to 29+6	484	-3.13E-03
30 to 30+6	625	-4.89E-02
31 to 31+6	523	1.52E-03
32 to 32+6	583	-4.07E-03
33 to 33+6	516	-9.69E-03
34 to 34+6	744	-1.41E-02
35 to 35+6	739	-1.54E-02
36 to 36+6	599	2.98E-03
37 to 37+6	532	-2.56E-03
38 to 38+6	481	-4.99E-03
39 to 39+6	525	1.87E-02
40 to 40+6	252	-1.59E-02
41 to 41+6	72	-1.81E-02
42 to 42+6	22	3.37E-03
Total	**13740**	

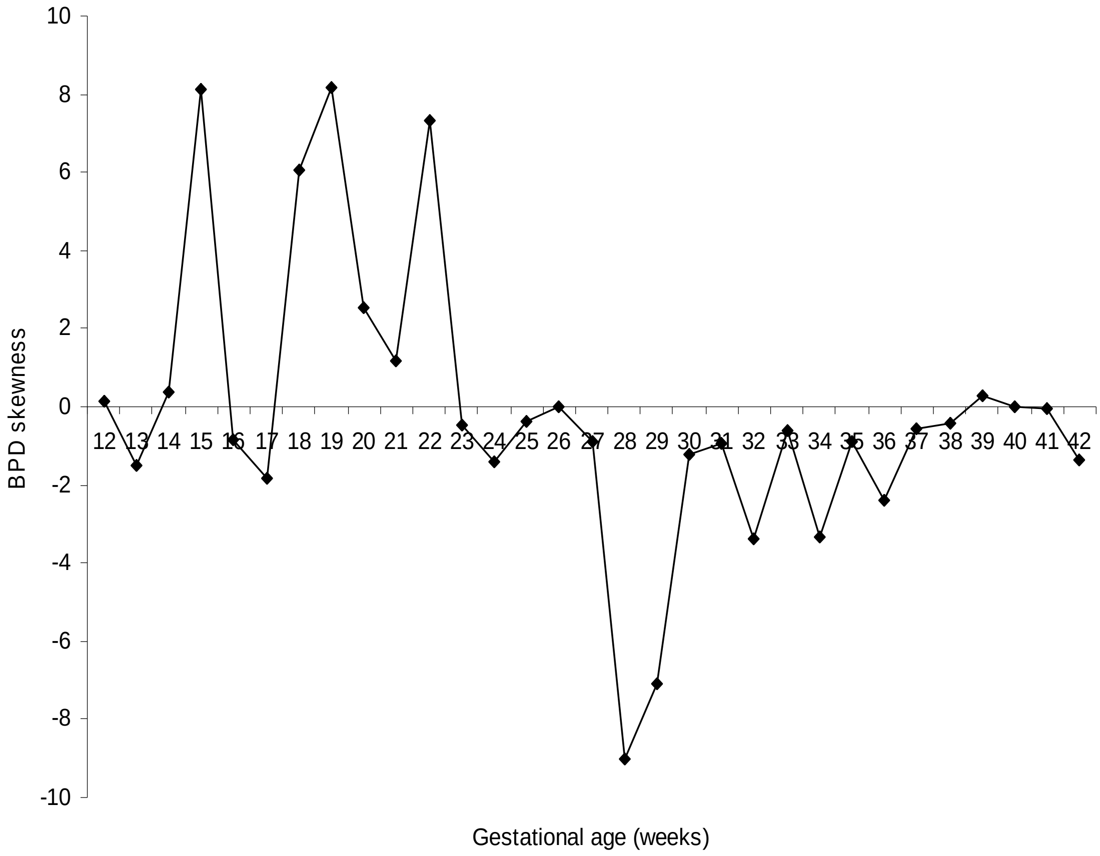

Figure 23: Biparietal diameter data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.

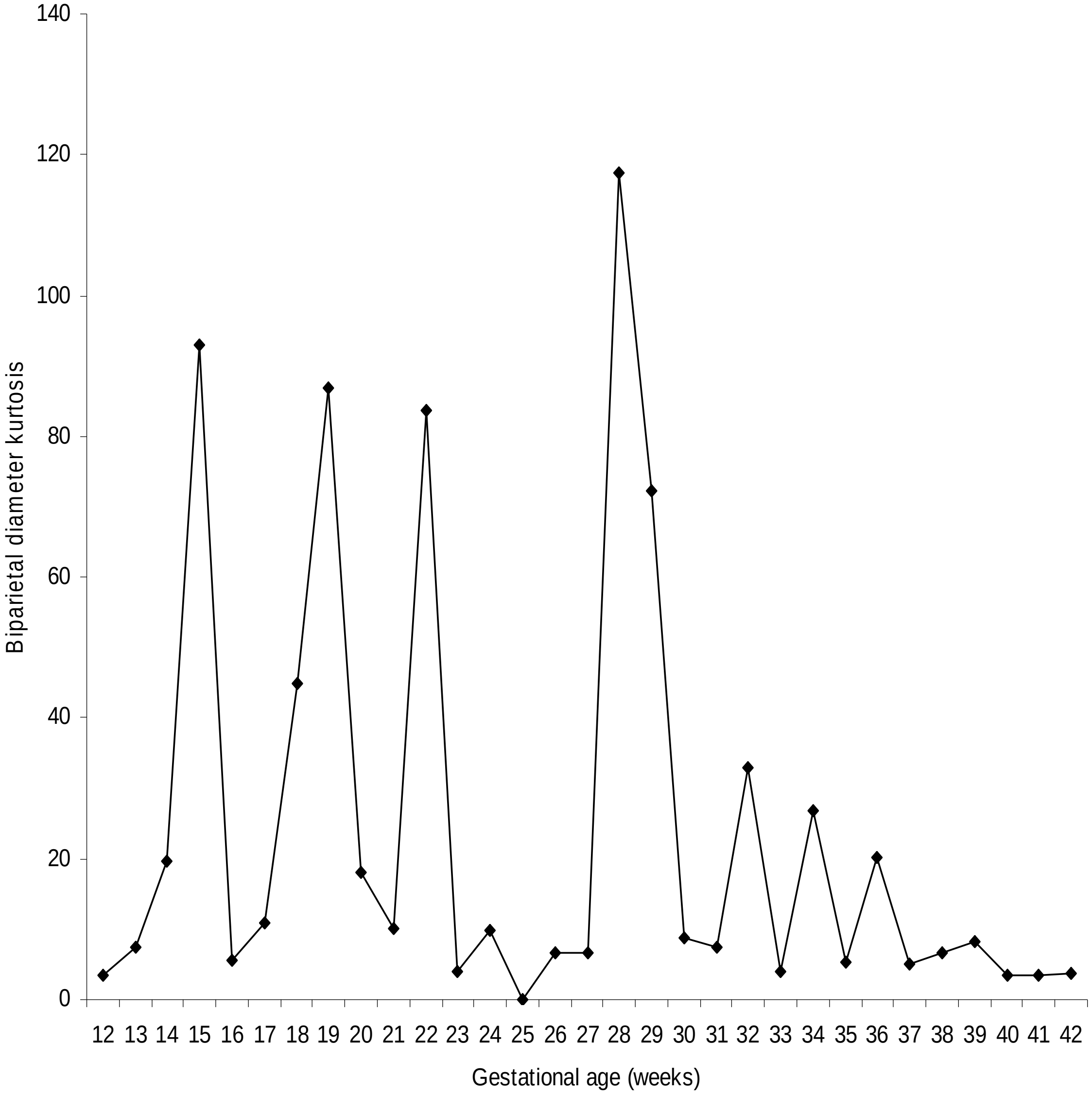

Figure 24: Biparietal diameter data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.

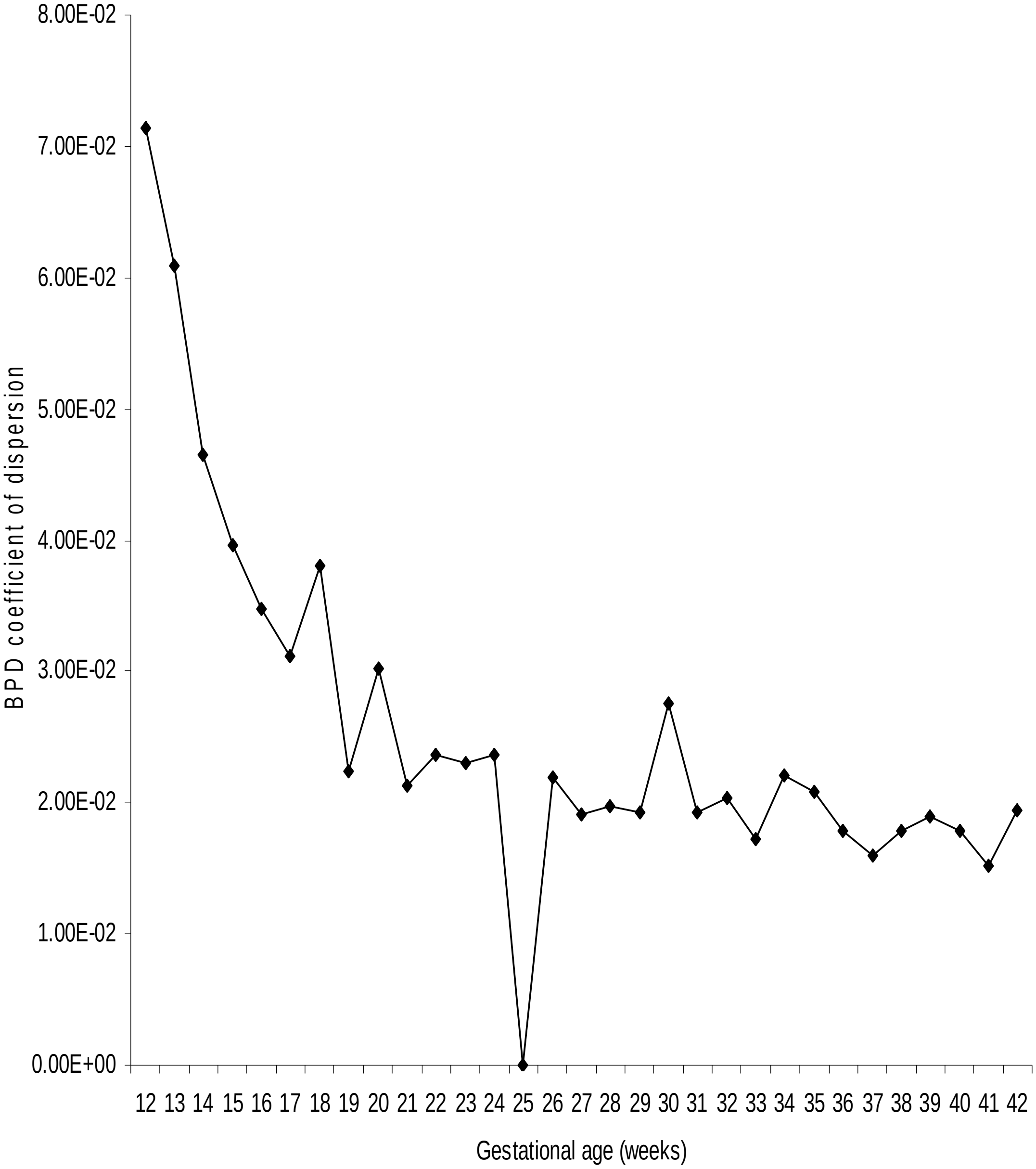

Figure 25: Biparietal diameter coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.

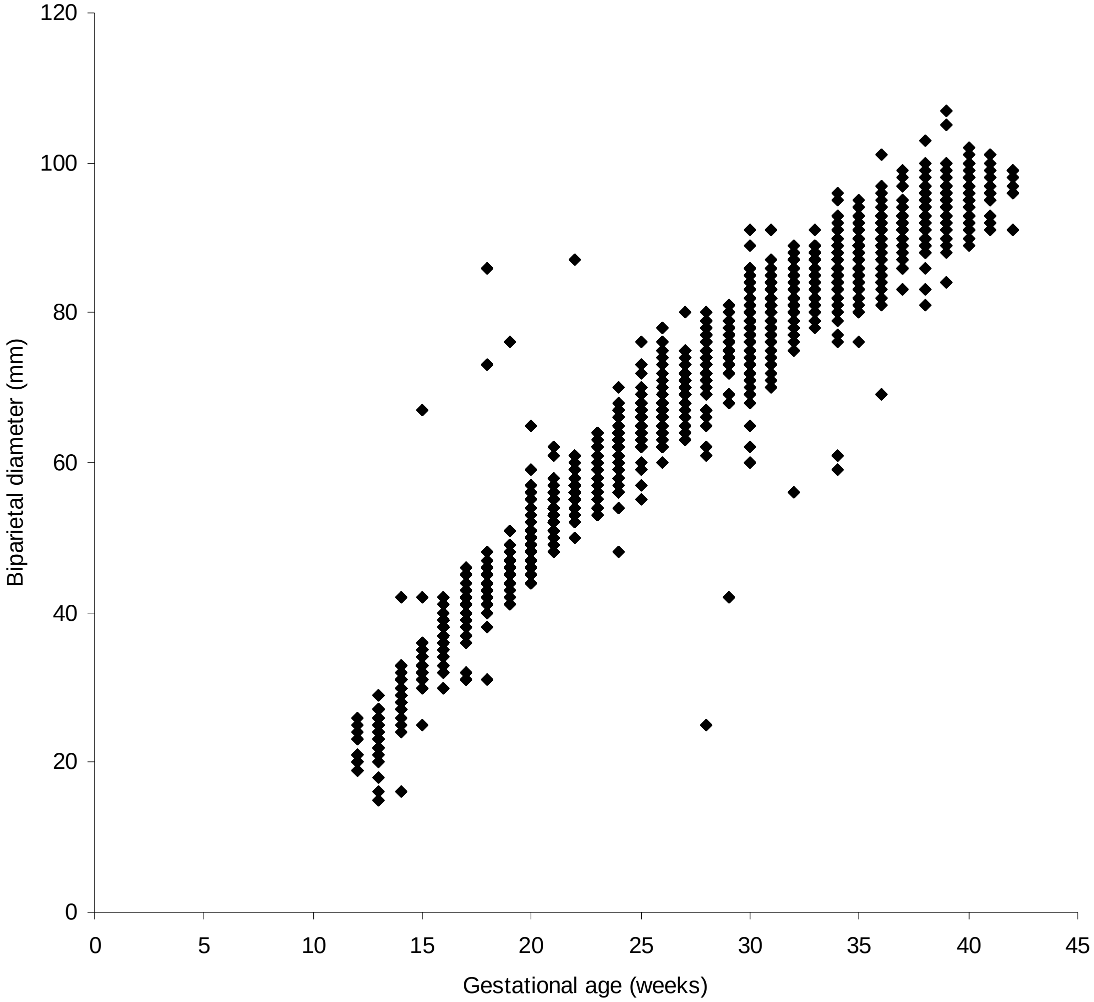

Figure 26: Scattergram of 13,740 fetal biparietal diameter measurements from 12 – 42 weeks gestation.

In figure 27, mean biparietal diameter is plotted against gestational age with error bars showing standard deviation. Arithmetic mean and standard deviation go together like star and satellite. With the mean, we have some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean ± 1 standard deviation will include about 2 out of 3 numbers in the group while the mean ± 2 standard deviations will include about 95 out of 100 numbers in the group and the mean ± 3 standard deviations will include 997 numbers out of 1,000. Mathematical modeling of fetal biparietal diameter data demonstrated that the best-fitted regression model to describe the relationship between biparietal diameter and gestational age is as shown in figure 28. There is a positive polynomial correlation between gestational age and biparietal diameter with a correlation of determination of $R^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the second order polynomial regression equation $y = -0.0511x^2 + 5.3221x - 35.511$where y is the biparietal diameter in millimeters and x is the gestational age in weeks. . This means that biparietal diameter could predict the gestational age of fetuses by 99.99 percent ($R^2 = 0.9999$) in 13,740 fetuses in this study. When monthly mean values of biparietal diameter in are plotted against gestational age in months, a positive polynomial correlation between gestational age and biparietal diameter with a correlation of determination of $R^2 = 0.9999$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 29). The relationship is best described by the second order polynomial regression equation $y = -1.0286x^2 + 25.543x - 56.657$ where y is the biparietal diameter in millimeters and x is the gestational age in months. Figure 30 shows histogram of monthly mean biparietal diameter whose values are also shown. Figure 31 shows histogram with mean for 2nd and 3rd trimesters.

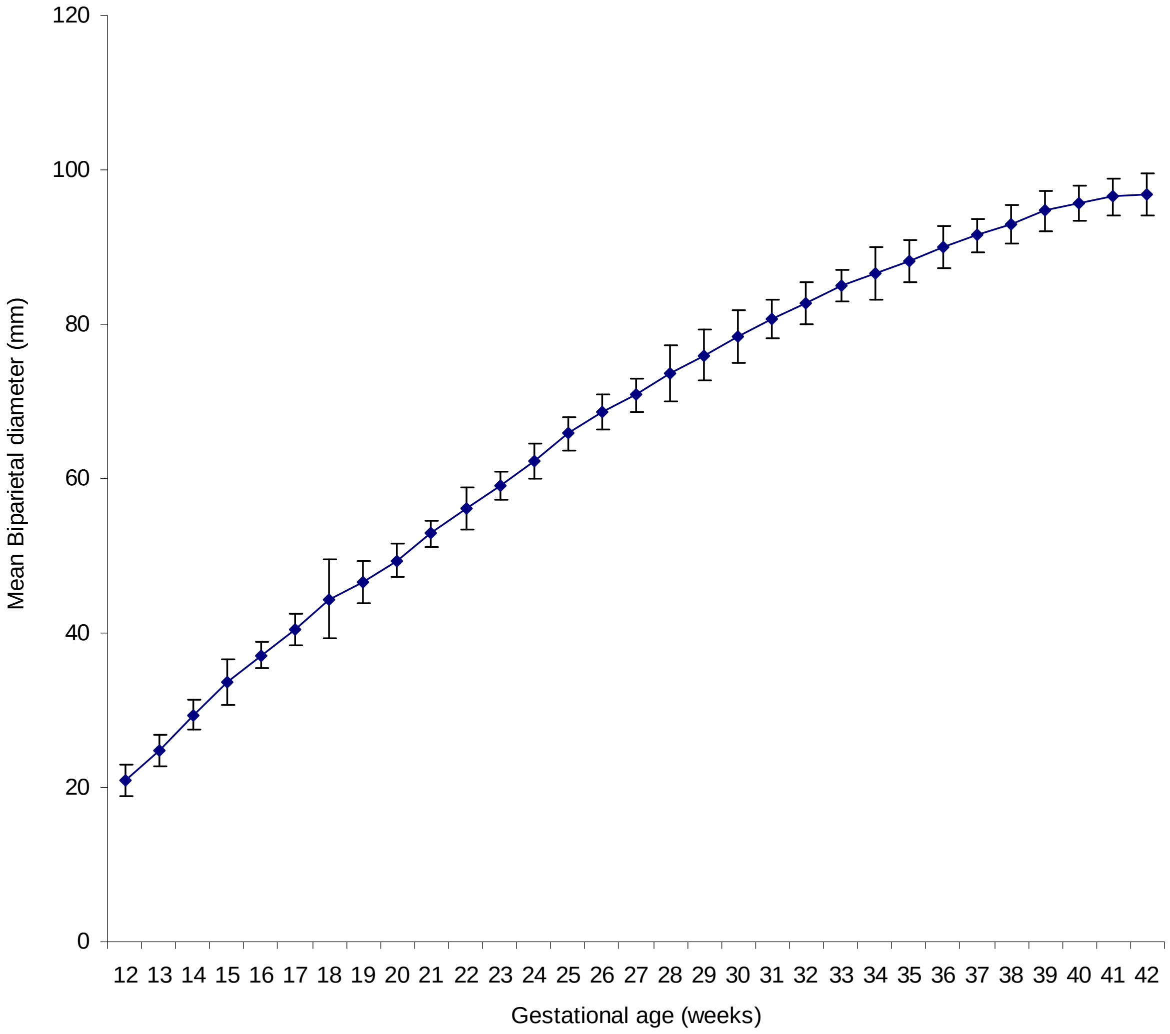

Figure 27: Mean fetal biparietal diameter values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.

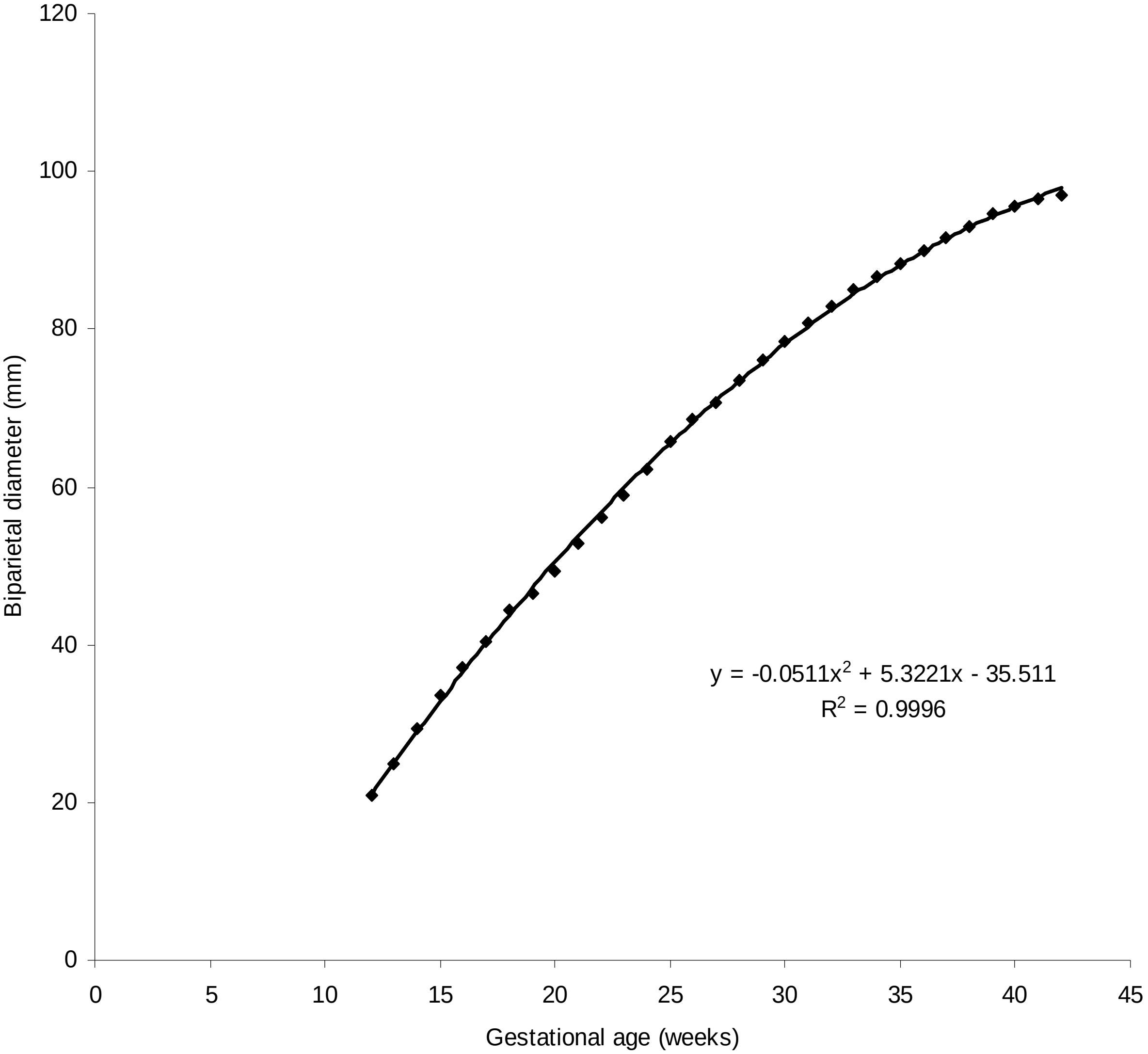

Figure 28: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks

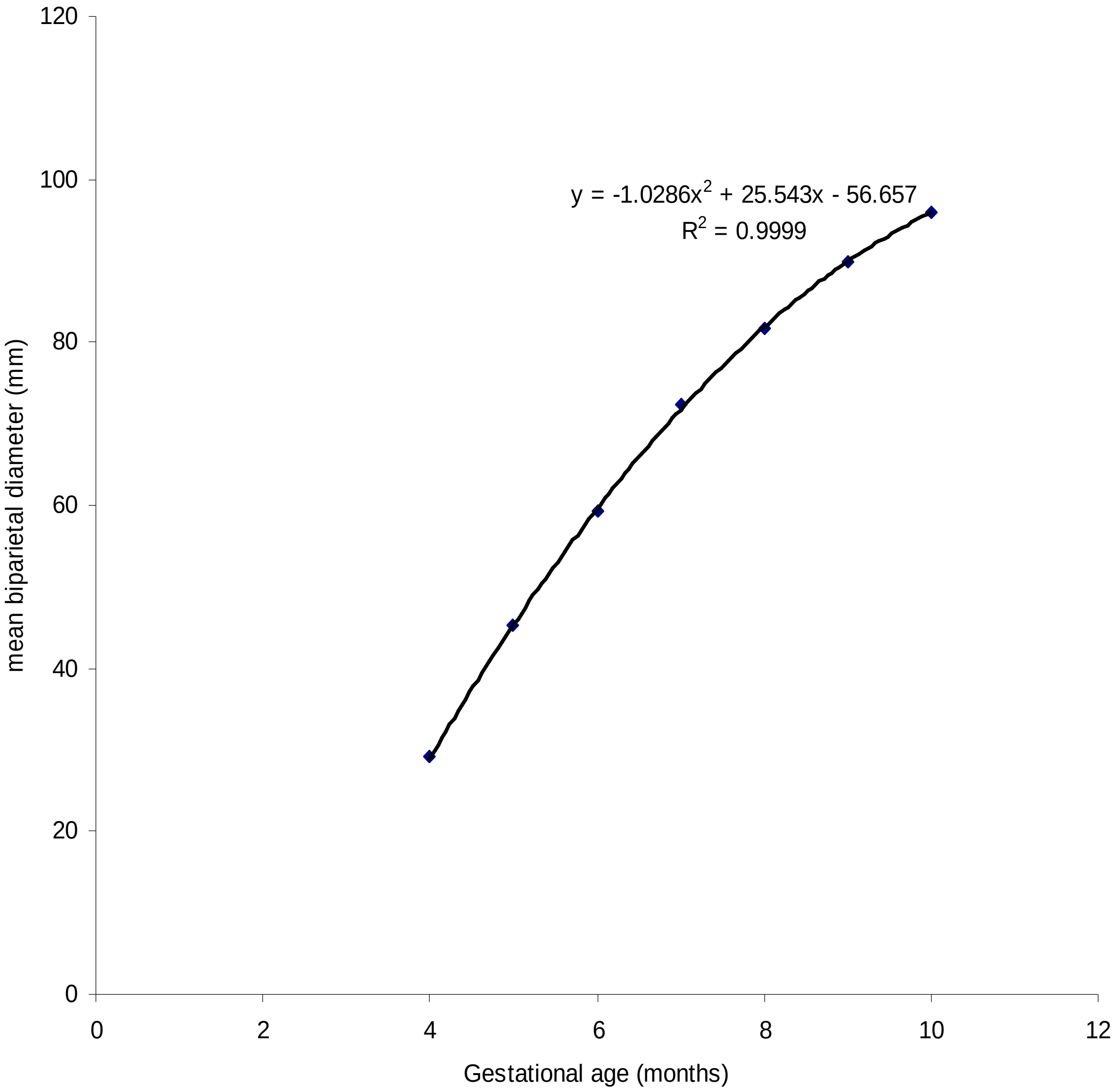

Figure 29: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months.

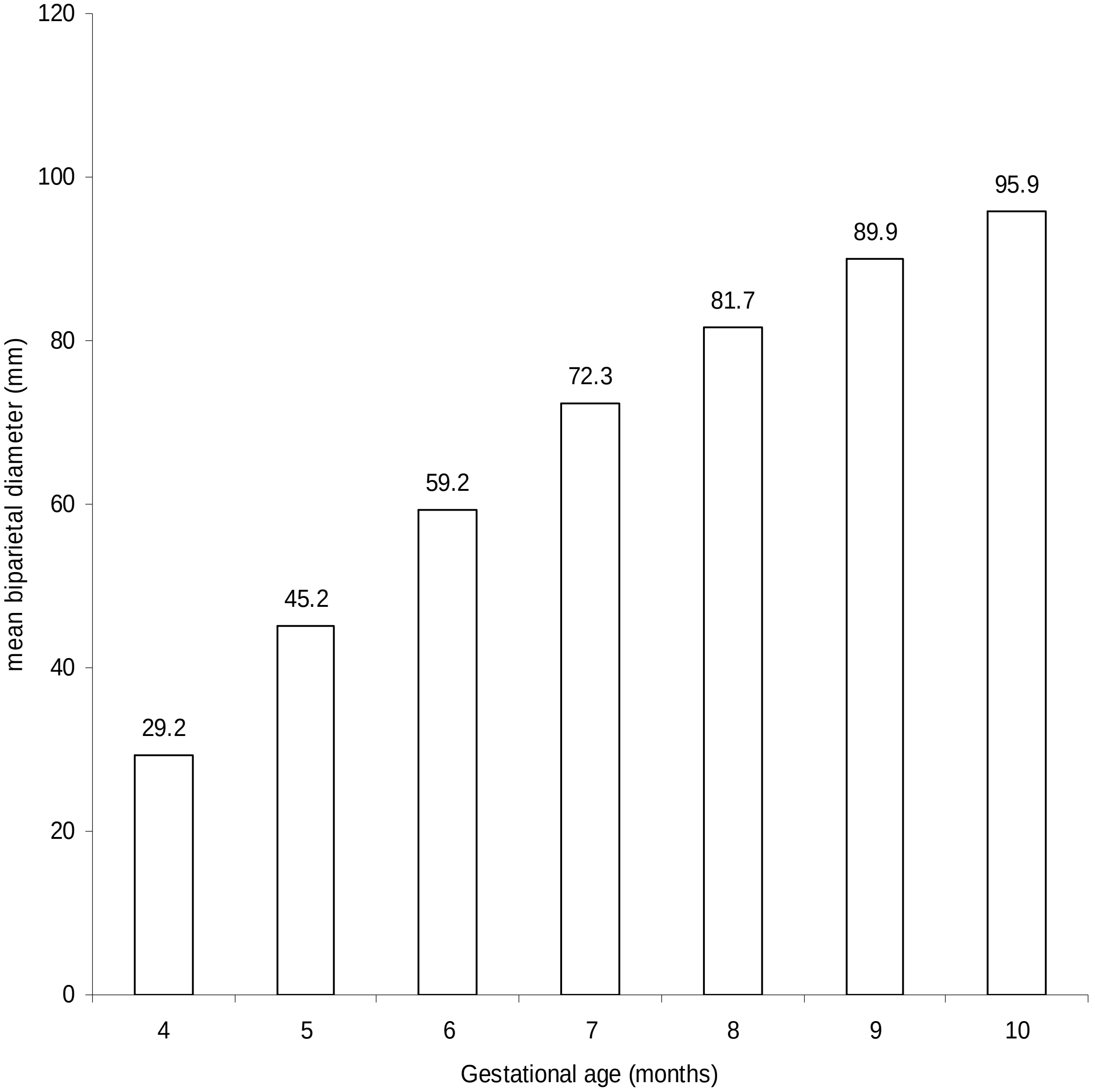

Figure 30: Histogram showing mean biparietal diameter values in 13,740 fetuses from 4 to 10 months

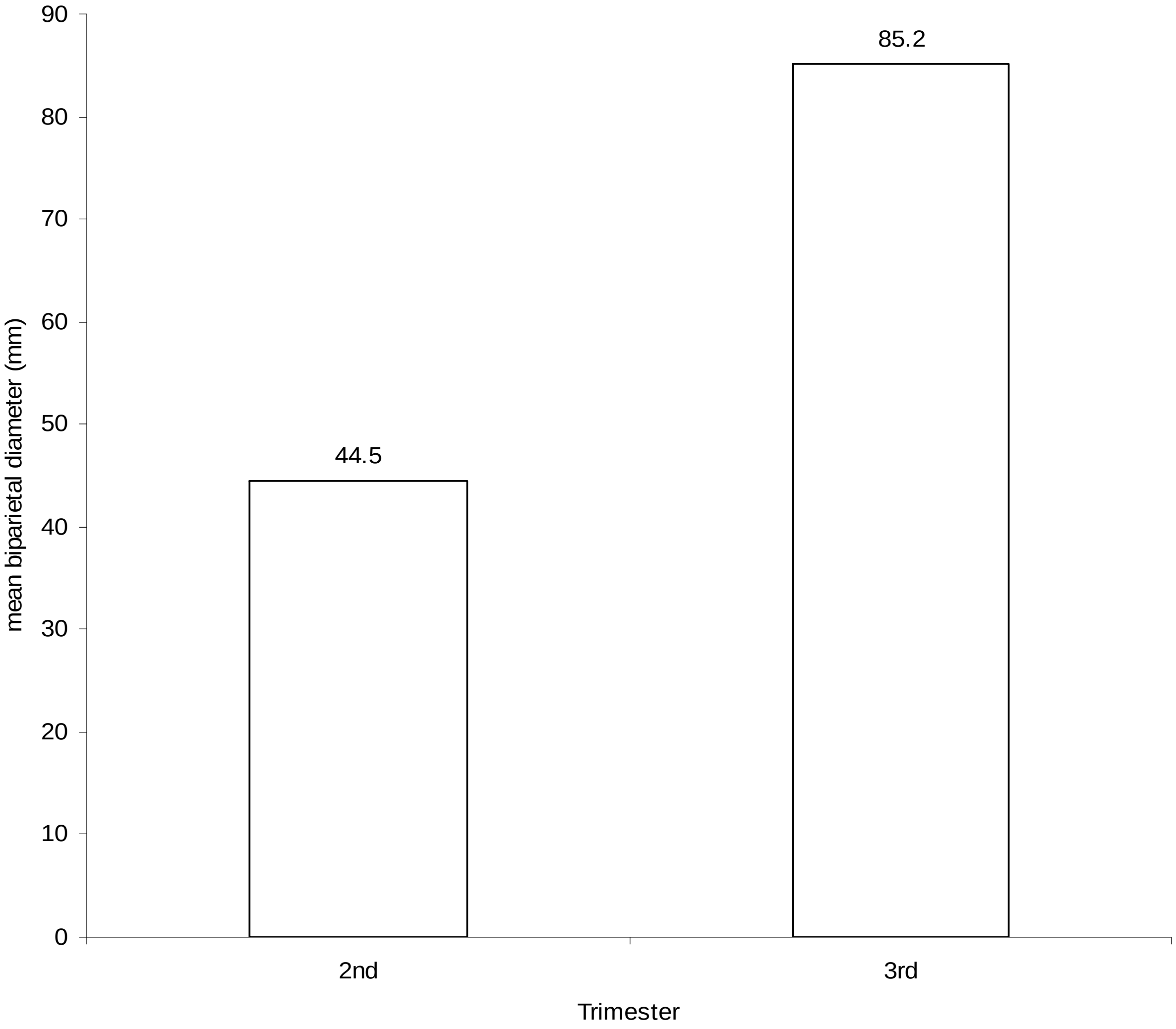

Figure 31: Histogram showing mean biparietal diameter values in 13,740 fetuses during second and third trimesters

When other fetal anthropometric parameters like head circumference, occipitofrontal diameter, abdominal circumference, femur length and weight are plotted against biparietal diameter certain hidden relationships can be forced out. For example, figure 32 shows the relationship between biparietal diameter and head circumference. From the graph, it can be seen that there is a positive linear correlation between biparietal diameter and head circumference with a correlation of determination of $R^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 3.5811x + 3.1775$ where x is the biparietal diameter in millimeters and y is the head circumference in millimeters. Figure 33 shows the relationship of biparietal diameter with occipitofrontal diameter. From the graph, it can be seen that there is a positive linear correlation between occipitofrontal diameter and biparietal diameter with a correlation of determination of $R^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 1.2425x + 1.1552$ where y is the occipitofrontal diameter in millimeters and x is biparietal diameter in millimeters. Figure 34 shows the relationship between cephalic index and biparietal diameter. There is a positive polynomial correlation between cephalic index and biparietal diameter with a correlation of determination of $R^2 = 0.8068$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = 1E\text{-}06x^4 + 0.0004x^3 - 0.0385x^2 + 1.65x + 54.486$ where y is the cephalic index and x is the biparietal diameter in millimeters.

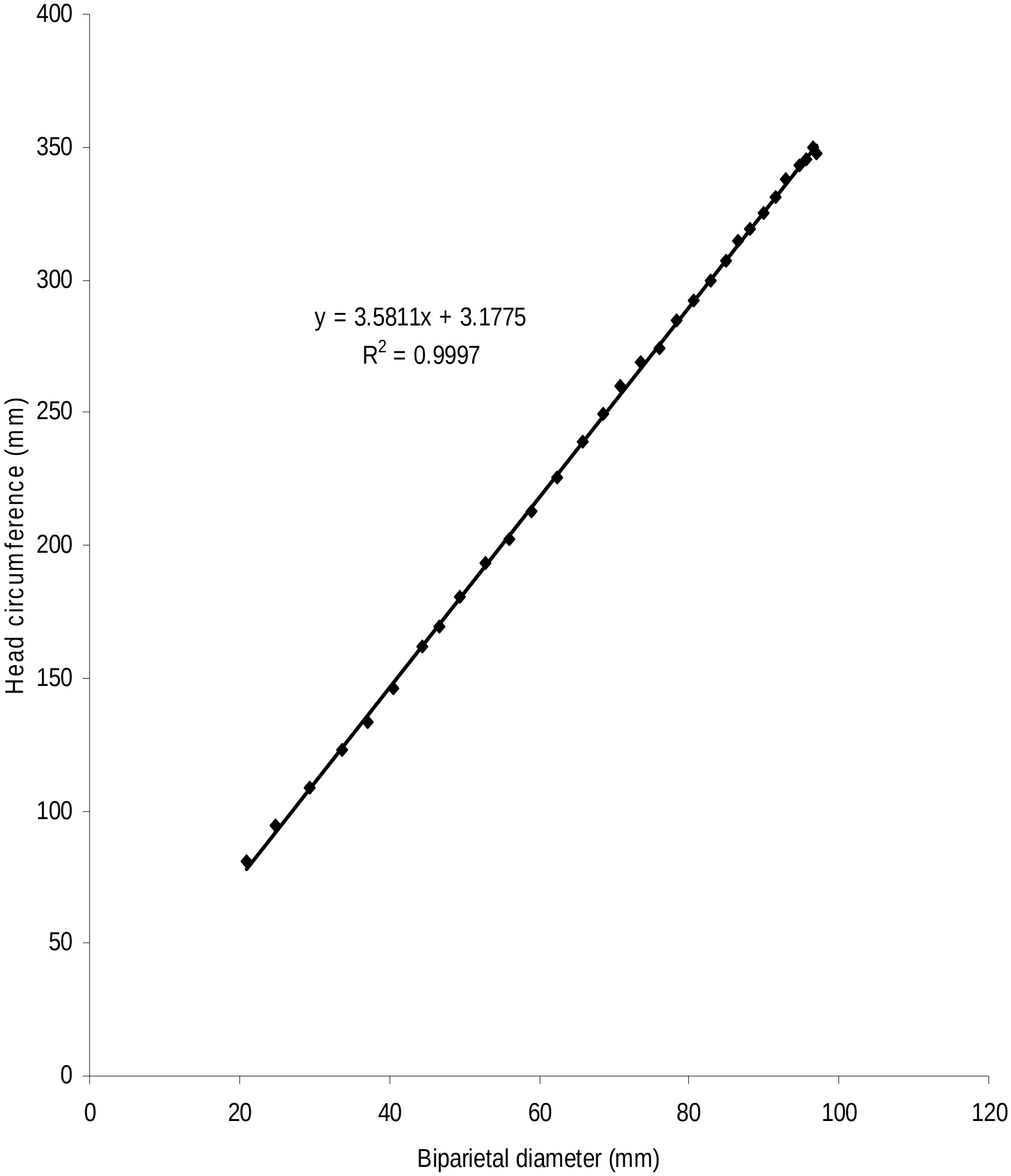

Figure 32: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter

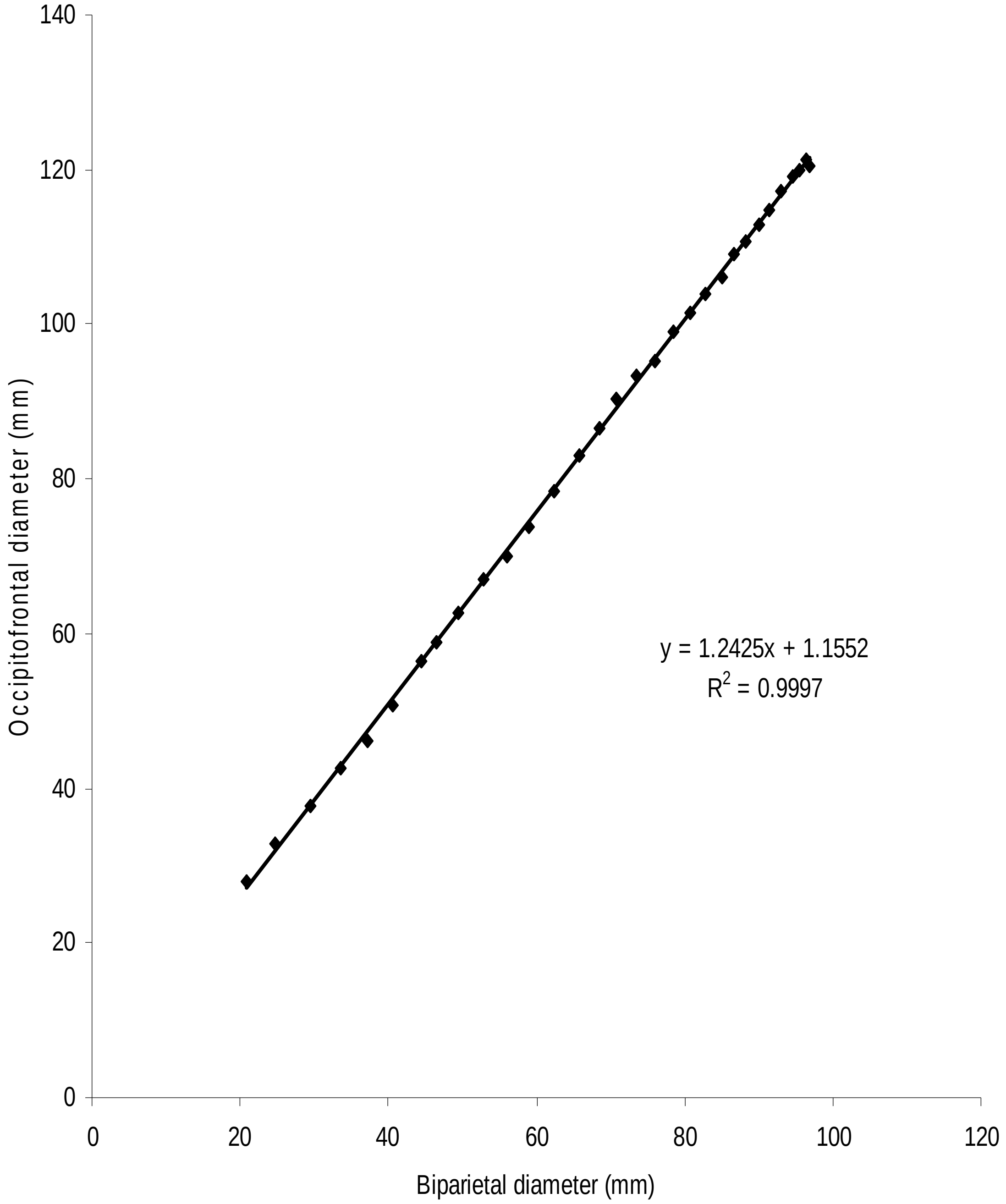

Figure 33: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter

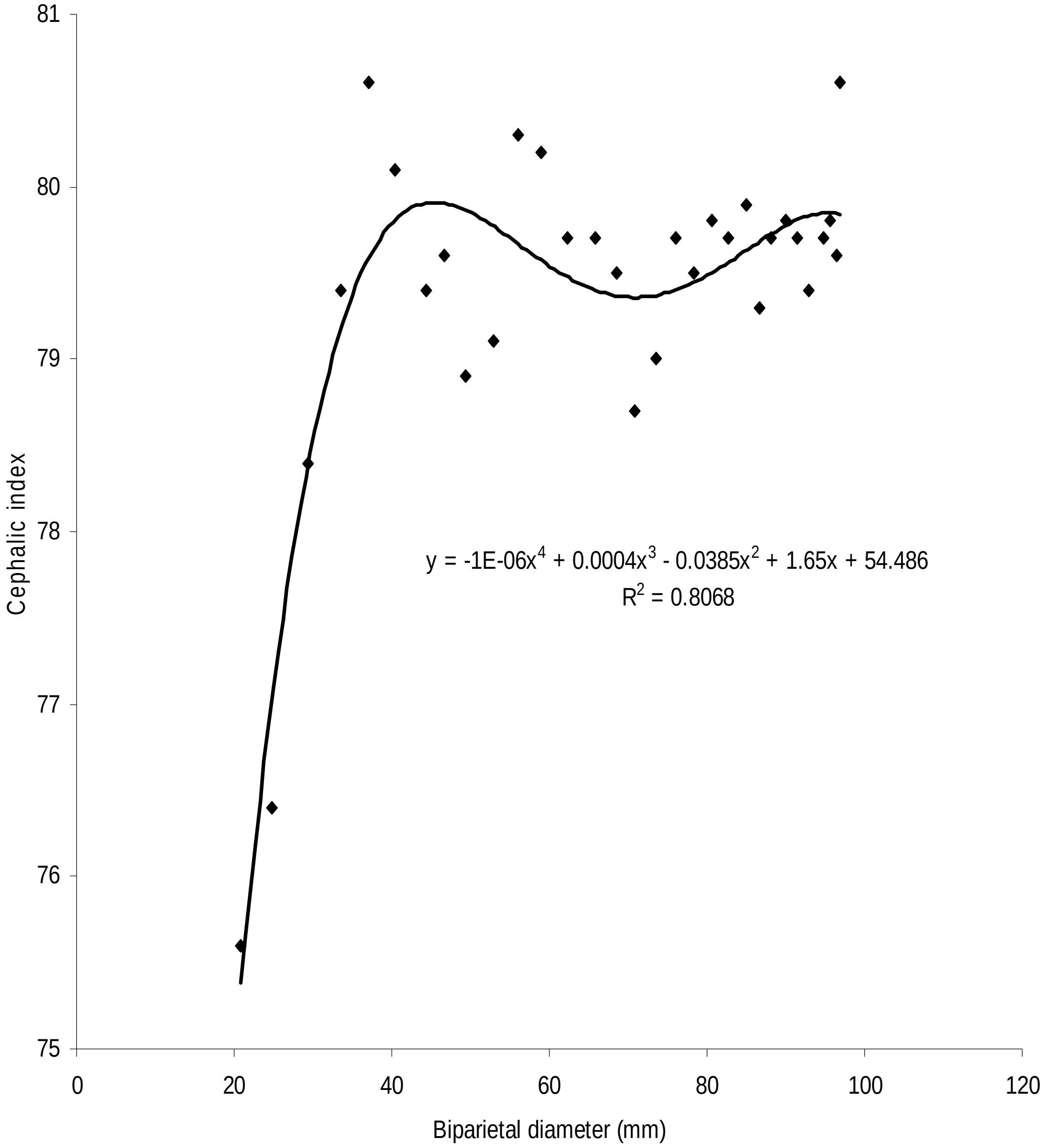

Figure 34: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against cephalic index.

Figure 35 shows the relationship of biparietal diameter with abdominal circumference. From the graph, it can be seen that there is a positive linear correlation between abdominal circumference and biparietal diameter with a correlation of determination of $R^2 = 0.9994$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by second order polynomial regression equation

$y = 0.0144x^2 + 2.0241x + 21.816$ where y is the abdominal circumference in millimeters and x is the biparietal diameter in millimeters.

Figure 36 shows relationship between femur length and biparietal diameter. There is a positive power correlation between femur length and biparietal diameter with a correlation of determination of $r^2 = 0.9986$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = 5E\text{-}06x^4 – 0.0011x^3 + 0.0855x^2 – 2.0951x + 27.664$ where y is the femur length in millimeters and x is the biparietal diameter in millimeters. Figure 37 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and biparietal diameter. There is a positive exponential correlation between fetal weight and biparietal diameter with a correlation of determination of $r^2 = 0.9988$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the exponential regression equation $y = 45.141e^{0.0461x}$ where y is the fetal weight in grams and x is the biparietal diameter in millimeters.

When the relationship between biparietal diameter and symphysio-fundal height was determined, it was found that there is a positive polynomial correlation between symphysio-fundal height and biparietal diameter with a correlation of determination of $r^2 = 0.9958$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the sixth order polynomial regression equation $y = – 5E\text{-}06x^6 + 0.0009x^5 – 0.0628x^4 + 2.2514x^3 – 44.398x^2 + 458.64x – 1907.6$ where y is the biparietal diameter in millimeters and x is the symphysio-fundal height in centimeters (figure 38).

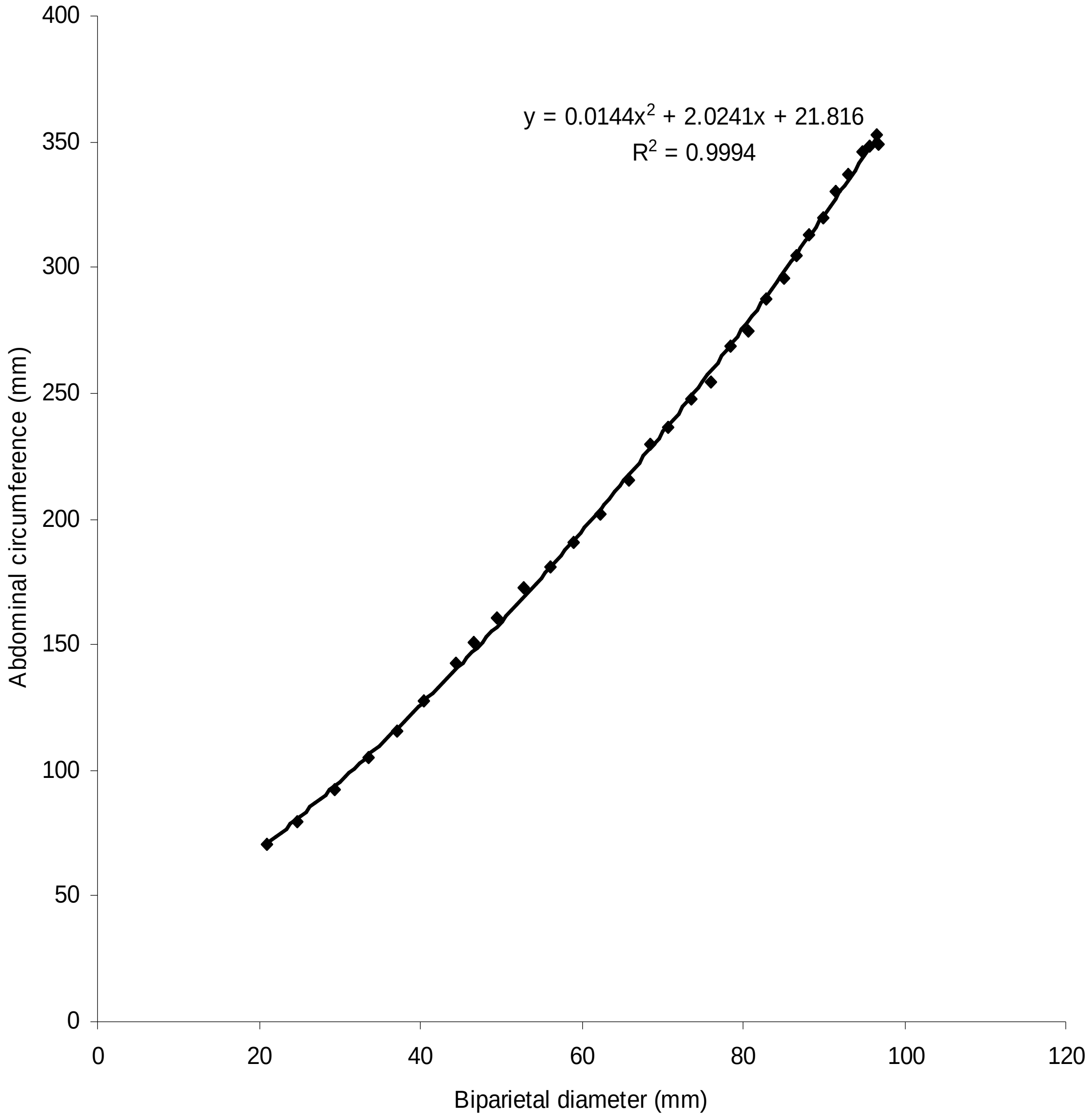

Figure 35: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference.

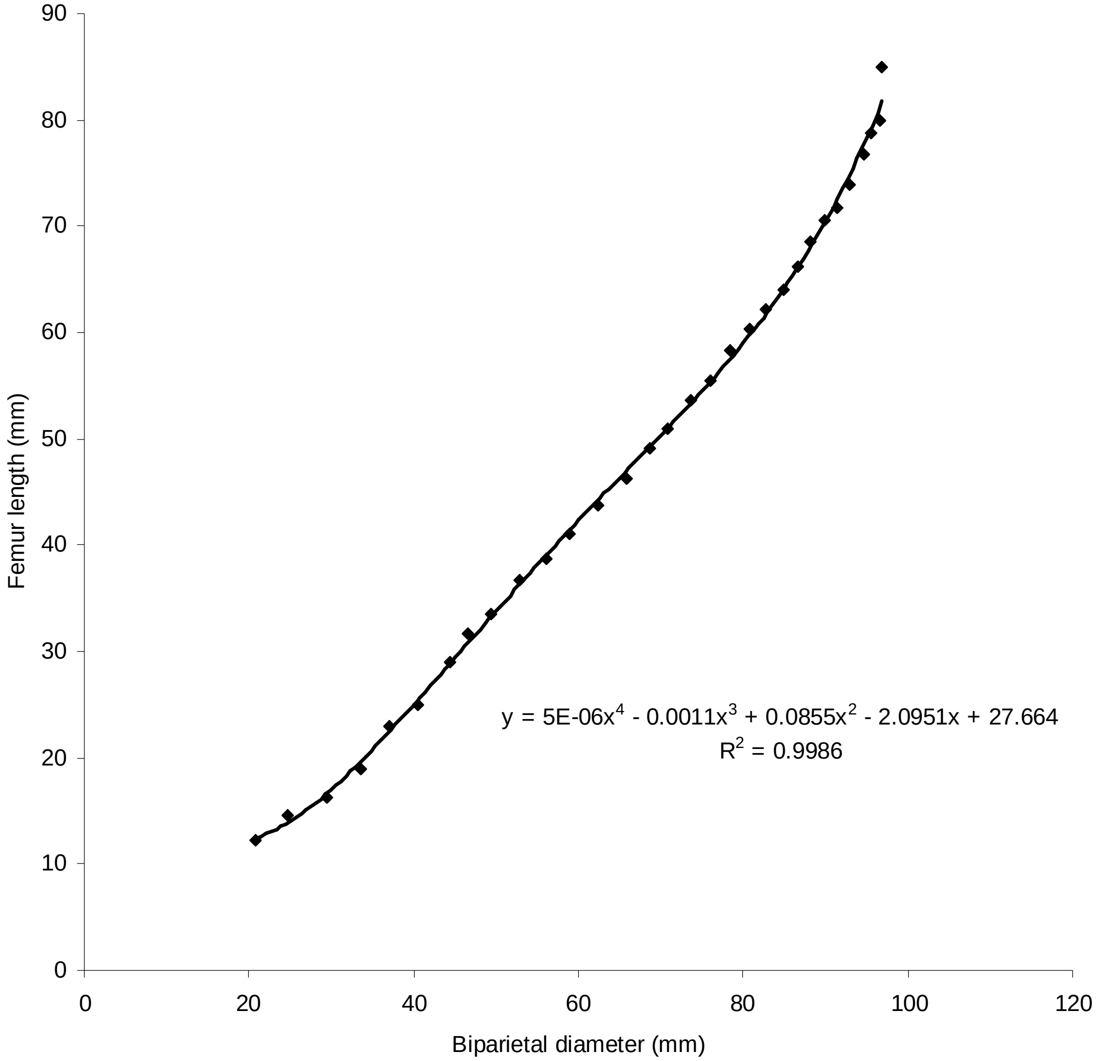

Figure 36: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against femur length.

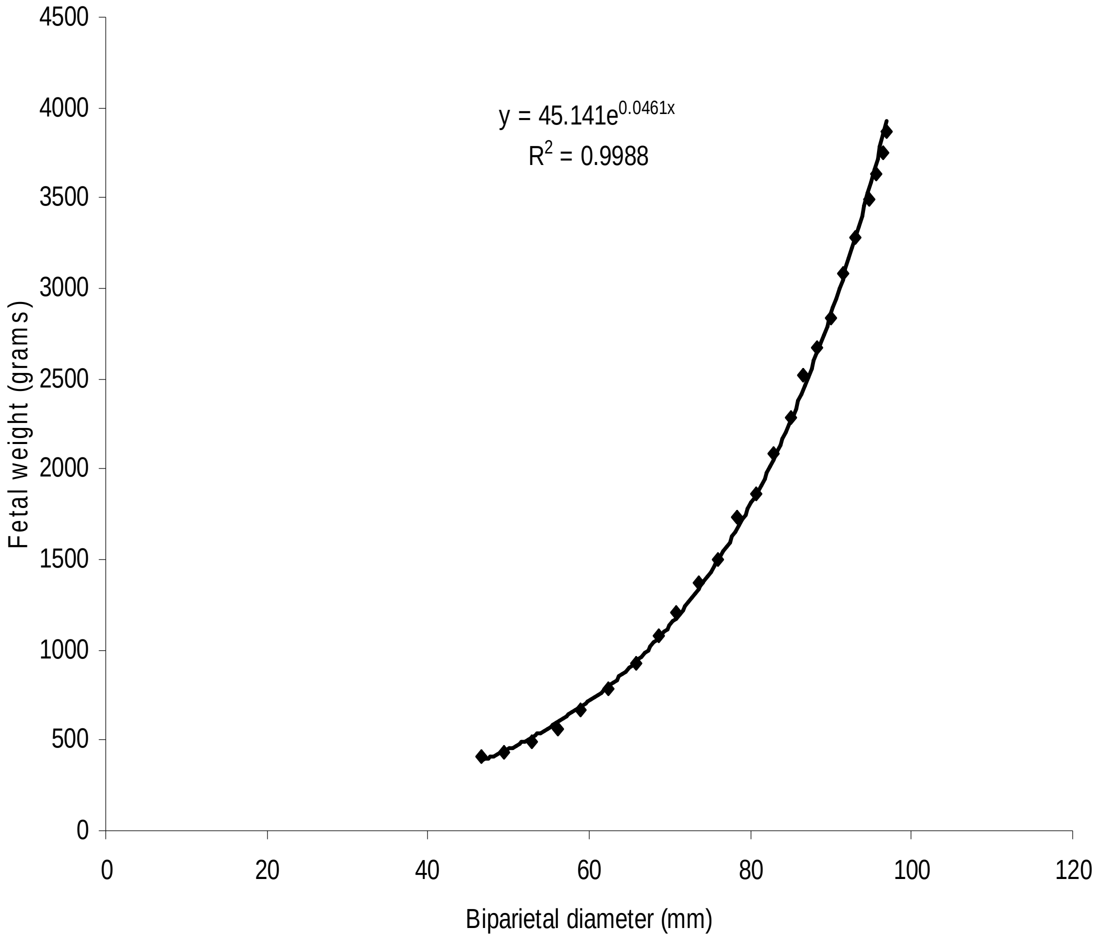

Figure 37: Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.

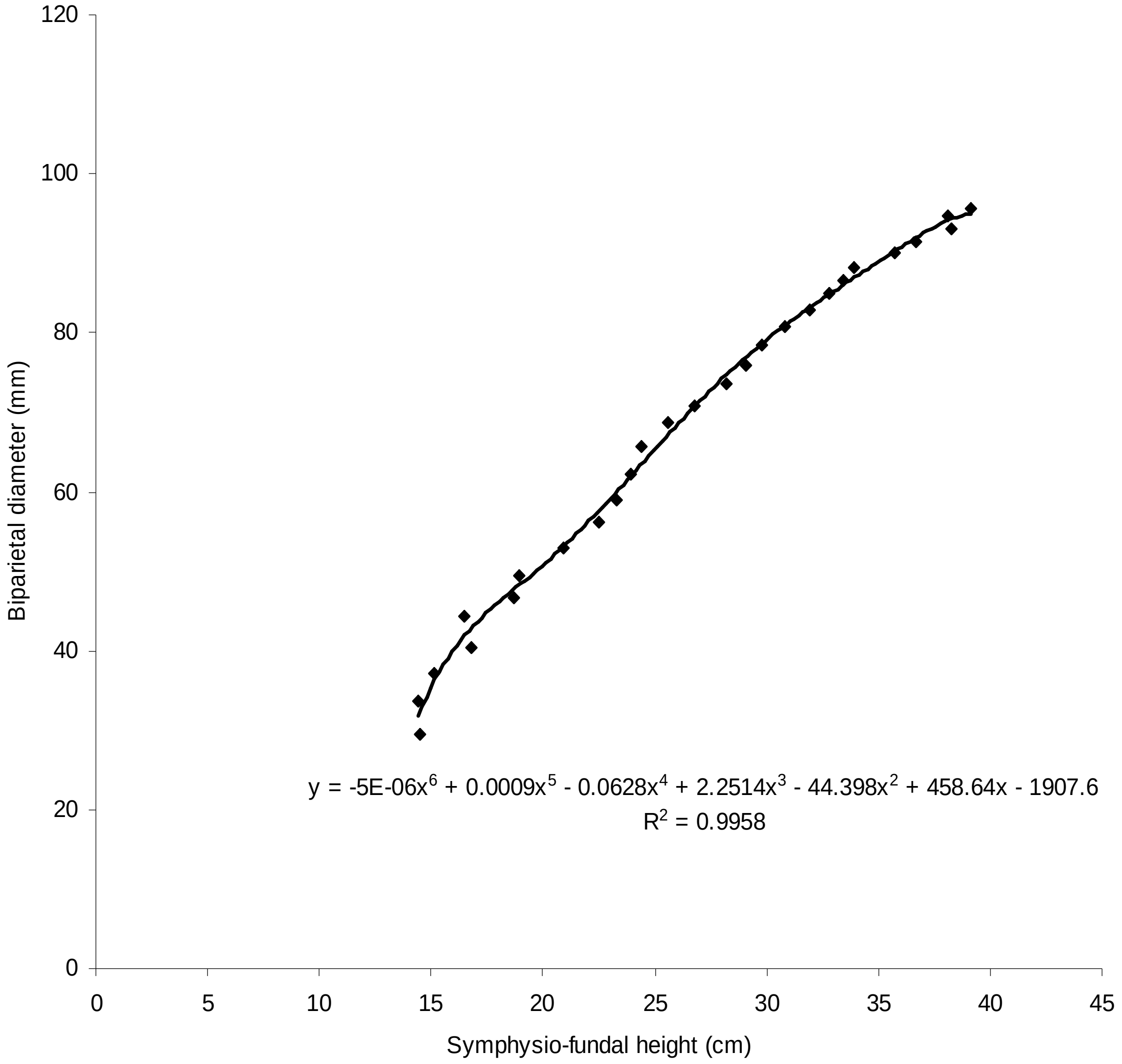

Figure 38. Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against symphysio-fundal height.

Centile values for 5th, 50th and 95th are plotted as shown in figure 39. In figure 40, the 3rd, 50th and 97th of biparietal diameter are smoothened into a growth chart which can be utilized to determine growth and of course brain size development, which is strongly related to intelligence and wellness, using biparietal diameter. Figure 41 is a graphical display showing the growth rate of the measured fetal biparietal diameter. It is clear from this graph that growth rate is much higher in the early stages of development than the late ones which precede term.

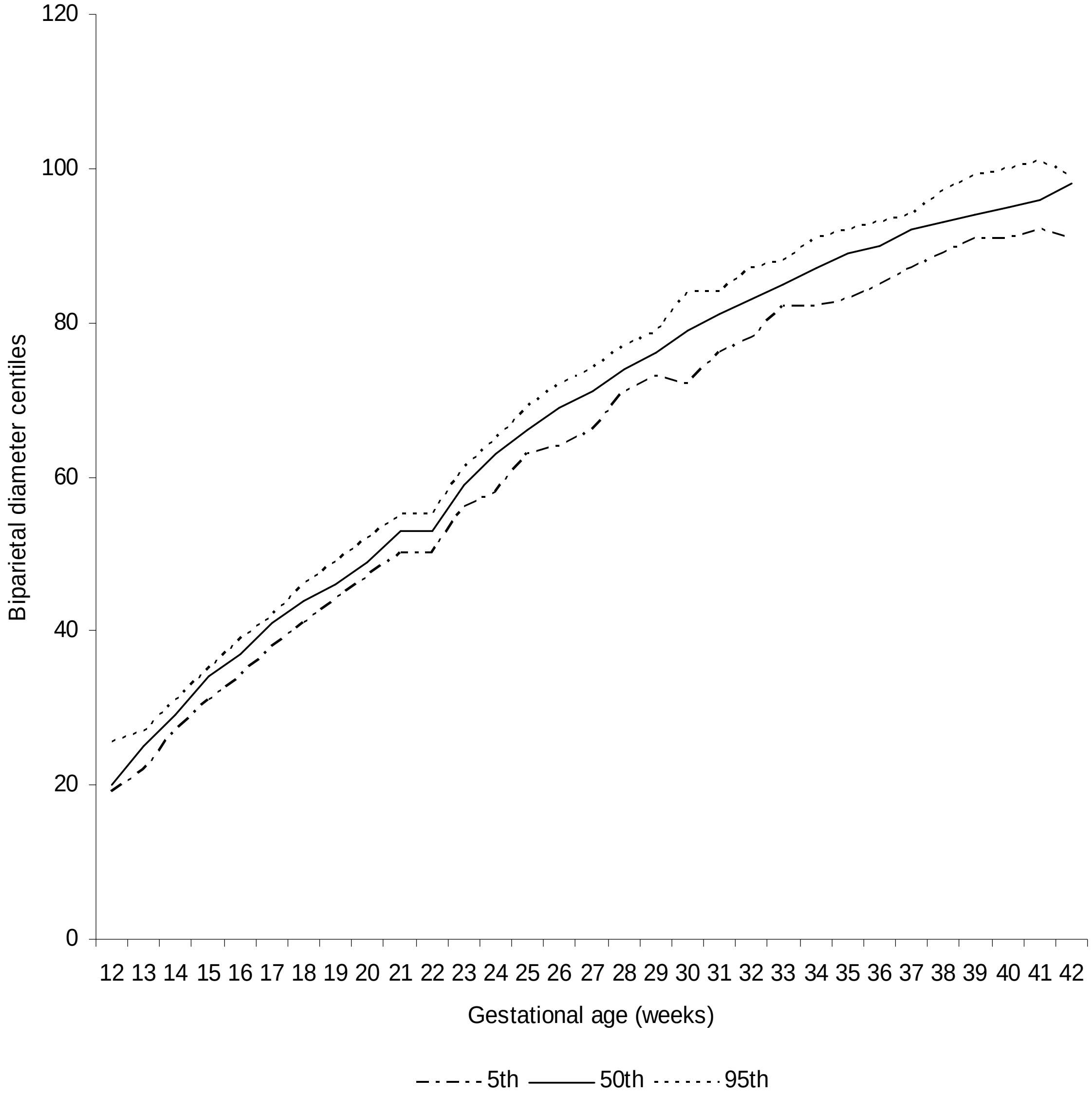

Figure 39: Fifth, 50th and 97th centiles for biparietal diameter in 13,740 fetuses at different gestational ages from 12 to 42 weeks.

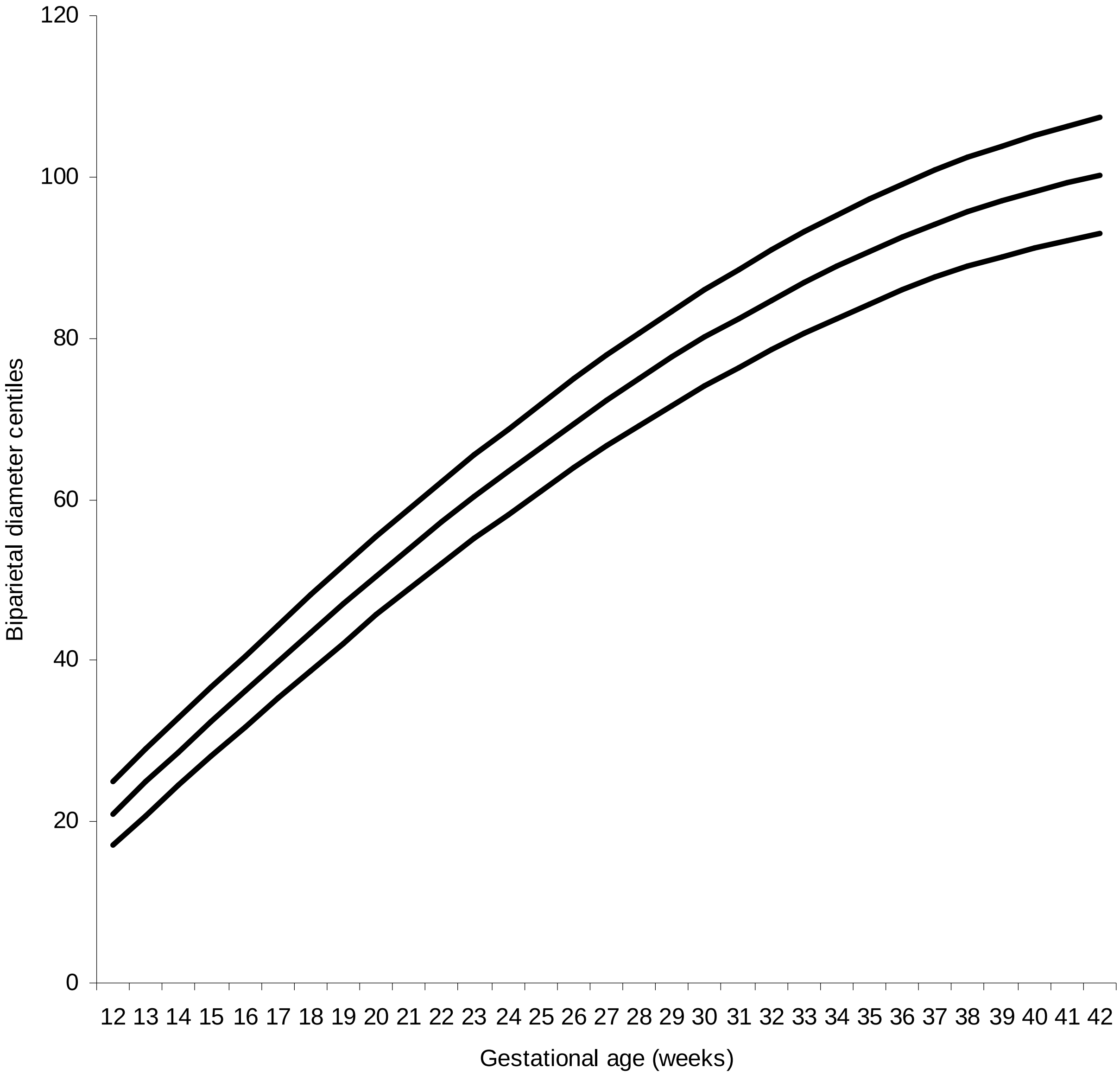

Figure 40: Curves created from 3rd, 50th and 97th fetal biparietal diameter centiles.

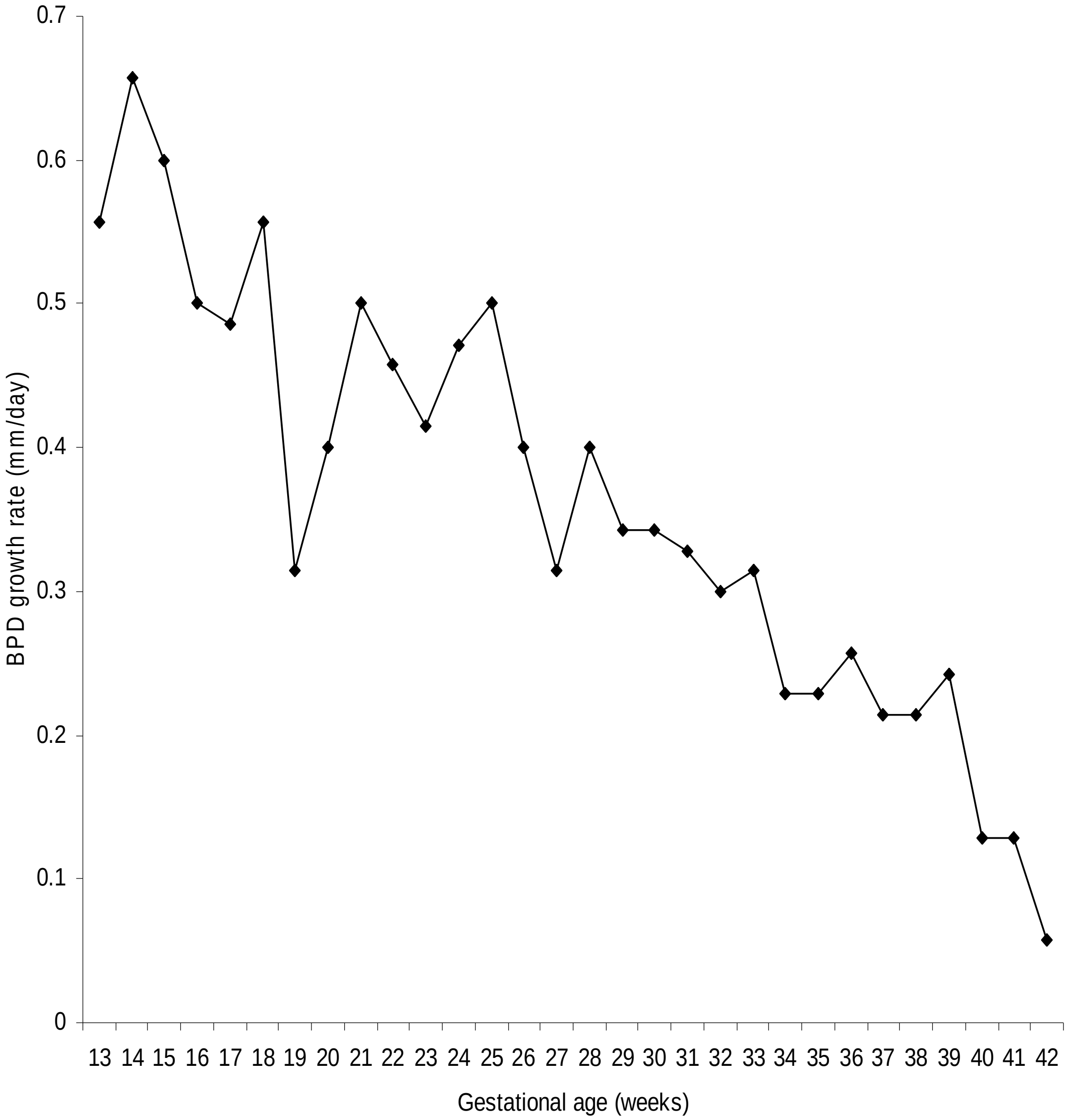

Figure 41: Growth velocity pattern of biparietal diameter in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks

4.1.3 Fetal Occipitofrontal Diameter

The mean fetal occipitofrontal diameter values at each week of gestation from 12 – 42 are as shown in table 16. This table gives the mean values of fetal occipitofrontal diameter measurements for each gestational age in weeks from 12 – 42 weeks together with their corresponding standard deviations and standard errors of mean. The highest mean value was obtained at 42 weeks while the least mean value was gotten at 12 weeks. The range of variability was 3.7 and 5.3 for the minimum and maximum values respectively. With the arithmetic mean, one has some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean occipitofrontal diameter at 19 weeks is 58.9mm plus 5.3mm or 58.9mm minus 5.3mm. This means 2 out of 3 measurements of occipitofrontal diameter at 19 weeks, approximately 188 occipitofrontal diameter measurements in a class of 282, should be between 53.6mm and 64.2mm. Since the standard error of mean at 19 weeks is 0.3mm, it is telling us that the real mean occipitofrontal diameter of fetuses in Jos at 19 weeks is probably between 58.6mm and 59.2mm (58.9mm plus or minus 0.3mm). It can also be seen that the standard error of mean for each week of gestation from 12 – 42 is very small suggesting that the sample mean is very close to the population mean. For example, at 13 weeks gestation, the mean fetal occipitofrontal diameter was 94.1mm while the standard error of mean was 0.5. This means that the difference between the mean occipitofrontal diameters of the sample of fetuses at 13 weeks is just 0.5mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (table 17) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal occipitofrontal diameter measurements were not identical. Table 18 shows the mean monthly fetal occipitofrontal diameter values from 4th month to the 10th month with their corresponding standard deviations and standard error of mean.

Table 16: Frequency distribution table of fetal occipitofrontal diameter measurements showing arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.

GA (week, days)	Fetuses (n)	Mean OFD (mm)	SD	SEM
12 to 12+6	49	28	3.7	0.5
13 to 13+6	384	32.7	3.3	0.2
14 to 14+6	371	37.7	4.1	0.2
15 to 15+6	351	42.5	4.8	0.3
16 to 16+6	505	46.2	3.4	0.2
17 to 17+6	427	50.8	3.8	0.2
18 to 18+6	446	56.3	8.1	0.4
19 to 19+6	282	58.9	5.3	0.3
20 to 20+6	553	62.8	4.4	0.2
21 to 21+6	400	67.1	4.1	0.2
22 to 22+6	398	70.1	4	0.2
23 to 23+6	478	73.9	4.8	0.2
24 to 24+6	520	78.4	4.6	0.2
25 to 25+6	388	82.9	4.9	0.2
26 to 26+6	511	86.6	5.3	0.2
27 to 27+6	432	90.3	5.4	0.3
28 to 28+6	548	93.4	4.6	0.2
29 to 29+6	484	95.2	8.1	0.4
30 to 30+6	625	98.9	6	0.2
31 to 31+6	523	101.5	5.2	0.2
32 to 32+6	583	104	5.1	0.2
33 to 33+6	516	106	4.5	0.2
34 to 34+6	744	109.2	5.2	0.2
35 to 35+6	739	110.7	4.7	0.2
36 to 36+6	599	112.9	5.1	0.2
37 to 37+6	532	114.9	4.7	0.2
38 to 38+6	481	117.3	5.3	0.2
39 to 39+6	525	119	5	0.2
40 to 40+6	252	119.8	4.9	0.3
41 to 41+6	72	121.3	4.1	1.5
42 to 42+6	22	120.6	8.2	1.7
Total	**13,740**			

Table 17: Frequency distribution table of fetal occipitofrontal diameter measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.

GA (week, days)	Number of fetuses (n)	Arithmetic mean	Geometric mean	Harmonic mean
12 to 12+6	49	28.02041	27.7769	27.52186
13 to 13+6	384	32.67969	32.49849	32.30374
14 to 14+6	371	37.72507	37.5314	37.35426
15 to 15+6	351	42.54986	42.33276	42.14695
16 to 16+6	505	46.16832	46.04197	45.91577
17 to 17+6	427	50.77986	50.63799	50.49517
18 to 18+6	446	56.33184	55.87227	55.49466
19 to 19+6	282	58.88298	58.66893	58.47072
20 to 20+6	553	62.78843	62.64119	62.50017
21 to 21+6	400	67.08	66.95792	66.83591
22 to 22+6	398	70.07789	69.969	69.86189
23 to 23+6	478	73.86192	73.70367	73.54012
24 to 24+6	520	78.375	78.24005	78.10592
25 to 25+6	388	82.89433	82.74525	82.58868
26 to 26+6	511	86.55968	86.39996	86.24117
27 to 27+6	432	90.25926	90.09711	89.93079
28 to 28+6	548	93.44526	93.32742	93.20554
29 to 29+6	484	95.21694	94.65898	93.60843
30 to 30+6	625	98.8752	98.68735	98.48719
31 to 31+6	523	101.4646	101.321	101.1645
32 to 32+6	583	104.0069	103.8739	103.7304
33 to 33+6	516	106.5562	106.456	106.3478
34 to 34+6	744	109.2218	109.0918	108.9546
35 to 35+6	739	110.7172	110.6159	110.5123
36 to 36+6	599	112.8781	112.7592	112.6352
37 to 37+6	532	114.9004	114.802	114.7024
38 to 38+6	481	117.2599	117.1476	117.0403
39 to 39+6	525	119.0152	118.9098	118.8046
40 to 40+6	252	119.8294	119.7336	119.6402
41 to 41+6	72	121.2639	121.1941	121.1232
42 to 42+6	22	120.6364	120.3676	120.0943
Total	**13740**			

Table 18: Monthly mean fetal occipitofrontal diameter values

G.A (months)	Fetuses (n)	Mean (mm)	S.D	S.E
4	1660	37.4	7.3	3.3
5	1708	57.2	5.0	2.5
6	2184	74.5	6.3	2.8
7	1975	91.4	3.8	1.9
8	2247	102.6	3.1	1.5
9	3095	113	3.2	1.4
10	871	120.2	1.0	0.5
Total	13,740			

The fetal occipitofrontal diameter mean values during second and third trimesters are shown in table 19 while table 20 gives the centile values of fetal occipitofrontal diameter measurements. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal occipitofrontal diameter measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 10th percentile of occipitofrontal diameter at 20 to 20 + 6 weeks gestation is 59 millimeters. This means that 10% of the fetuses at 20 to 20 + 6 had a mean occipitofrontal diameter less than 59 millimeters, while 90% had a mean occipitofrontal diameter greater than 59 millimeters. Similarly, the 97th percentile of occipitofrontal diameter at 36 to 36 + 6 is 118 millimeters. Hence 97% of fetuses at 36 to 36 + 6 had a mean occipitofrontal diameter less than 118 millimeters while 3% had a mean occipitofrontal diameter greater than 118 millimeters. The standard score or z-score of occipitofrontal diameter measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in table 21. The z-score enables us to look at occipitofrontal diameter measurements in each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, occipitofrontal diameter measurements at 15 weeks are 0.0104 standard deviations from the mean while measurements at 37 weeks are 0.0000 standard deviations from the mean. Again, from the above z-score table, it can be seen that the occipitofrontal diameter measurements at 38 weeks gestation are – 0.0075 standard deviations from the mean.

Table 19: Trimester mean fetal occipitofrontal diameter values

Trimester	Fetuses (n)	Mean	S.D	S.E	Minimum	Maximum	Range
2nd	5552	56.3	17.3	4.6	28	82.9	54.9
3rd	8188	107.2	11.3	2.7	86.6	121.3	34.7
Total	13,740						

Table 20: Fetal occipitofrontal diameter centiles from 12 – 42 weeks

	Occipitofrontal diameter centiles (mm)						
Gestational age	3rd	5th	10th	50th	90th	95th	97th
12 to 12+6	19.0	21.0	24.0	27.0	33.0	34.0	35.0
13 to 13+6	26.0	27.0	28.0	33.0	37.0	38.0	38.0
14 to 14+6	32.0	33.0	33.0	38.0	41.0	42.0	44.0
15 to 15+6	36.0	38.0	39.0	42.0	47.0	49.0	54.0
16 to 16+6	40.0	41.0	42.0	46.0	50.0	52.0	52.0
17 to 17+6	42.8	45.0	47.0	51.0	55.0	57.0	59.0
18 to 18+6	45.0	47.0	51.0	55.0	59.6	68.0	70.0
19 to 19+6	49.0	52.0	54.3	58.0	64.0	66.9	69.5
20 to 20+6	56.0	57.0	59.0	63.0	68.0	70.0	73.0
21 to 21+6	59.0	61.0	63.0	67.0	72.0	74.0	77.0
22 to 22+6	63.0	65.0	66.0	70.0	75.0	76.1	77.0
23 to 23+6	64.0	66.0	69.0	74.0	79.0	81.0	83.0
24 to 24+6	69.0	71.0	74.0	78.0	83.0	86.0	87.0
25 to 25+6	72.1	75.0	78.0	83.0	88.0	90.6	92.0
26 to 26+6	76.0	78.0	81.0	86.0	92.0	94.0	97.0
27 to 27+6	79.9	81.0	83.3	90.0	97.0	100.0	101.0
28 to 28+6	84.0	86.0	89.0	94.0	99.0	100.0	101.0
29 to 29+6	79.8	85.3	90.0	96.0	101.0	102.0	105.0
30 to 30+6	87.0	91.0	93.0	99.0	104.0	107.0	109.2
31 to 31+6	88.0	93.0	96.0	102.0	107.0	108.0	109.0
32 to 32+6	95.0	97.0	99.0	104.0	110.0	111.0	112.0
33 to 33+6	97.0	99.0	102.0	107.0	111.0	113.0	114.0
34 to 34+6	99.0	101.0	104.0	109.0	115.0	116.0	118.0
35 to 35+6	101.0	103.0	105.0	111.0	116.0	117.0	118.0
36 to 36+6	105.0	105.0	106.0	113.0	118.0	120.0	122.0
37 to 37+6	104.0	105.0	108.3	116.0	119.7	122.0	124.0
38 to 38+6	108.0	109.0	111.0	117.0	122.0	125.0	126.0
39 to 39+6	110.0	111.0	113.6	119.0	125.0	129.0	131.0
40 to 40+6	112.0	112.7	115.0	119.0	125.0	129.4	132.8
41 to 41+6	110.0	114.0	116.0	121.0	127.0	127.0	127.8
42 to 42+6	106.0	106.0	106.0	123.0	134.0	134.0	134.0

Table 21: Standard score (z-score) of occipitofrontal diameter measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	5.52E-03
13 to 13+6	384	-6.16E-03
14 to 14+6	371	6.11E-03
15 to 15+6	351	1.04E-02
16 to 16+6	505	-9.32E-03
17 to 17+6	427	-5.30E-03
18 to 18+6	446	3.93E-03
19 to 19+6	282	-3.21E-03
20 to 20+6	553	-2.63E-03
21 to 21+6	400	-4.88E-03
22 to 22+6	398	-5.53E-03
23 to 23+6	478	-7.93E-03
24 to 24+6	520	-5.43E-03
25 to 25+6	388	-1.16E-03
26 to 26+6	511	-7.61E-03
27 to 27+6	432	-7.54E-03
28 to 28+6	548	9.84E-03
29 to 29+6	484	2.09E-03
30 to 30+6	625	-4.13E-03
31 to 31+6	523	-6.80E-03
32 to 32+6	583	-0.50846
33 to 33+6	516	-9.73E-03
34 to 34+6	744	-0.28427
35 to 35+6	739	3.66E-03
36 to 36+6	599	-4.29E-03
37 to 37+6	532	8.00E-05
38 to 38+6	481	-7.57E-03
39 to 39+6	525	3.05E-03
40 to 40+6	252	5.99E-03
41 to 41+6	72	-8.81E-03
42 to 42+6	22	4.43E-03
Total	**13,740**	

When occipitofrontal diameter data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (figure 42), it can be seen that the distribution of occipitofrontal diameter measurements has a longer "tail" to the right of the central maximum than to the left or is skewed to the right from 13 – 24, 26, 38, 39 and 40 weeks. From 12, 13, 25, 27 – 37, 41 and 42weeks, the distribution has a longer "tail" to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the occipitofrontal diameter data was subjected to kurtosis analysis (figure 43), the analysis was found to be leptokurtic at 14, 15, 18, 19, 29 and 38 weeks of gestation while mesokurtic at the other weeks of gestation. The coefficient of dispersion of occipitofrontal diameter data of 13,740 fetuses at different gestational age shows a decrease in value as gestational age advances except at 18 and 42 weeks where it peaks (figure 44).

The occipitofrontal diameter scattergram in figure 45 shows that there are very few bad data points or outliers in the occipitofrontal diameter measurements of 13,740 fetuses. The outliers are more from 26 – 42 weeks of gestation. This shows the pattern of growth recognized for neural tissue which suggests growth of brain.

In figure 46, mean occipitofrontal diameter is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of occipitofrontal diameter data demonstrated that the best-fitted regression model is as shown in figure 47. There is a positive polynomial correlation between gestational age and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order polynomial regression equation $y = -0.001x^3 + 0.0137x^2 + 4.671x - 27.99$ where y is the occipitofrontal diameter in millimeters and x is the gestational age in weeks.

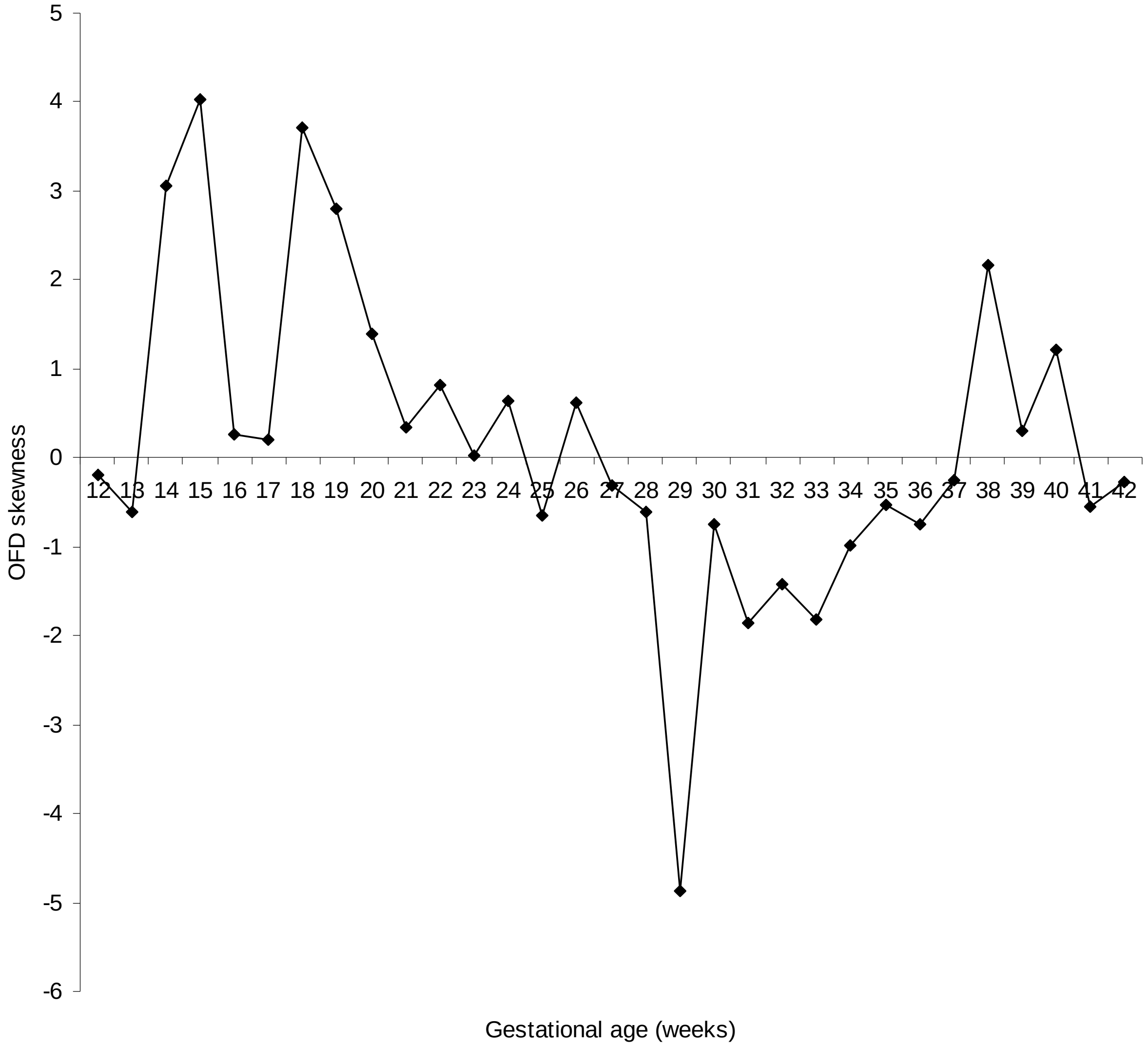

Figure 42: Occipitofrontal diameter data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.

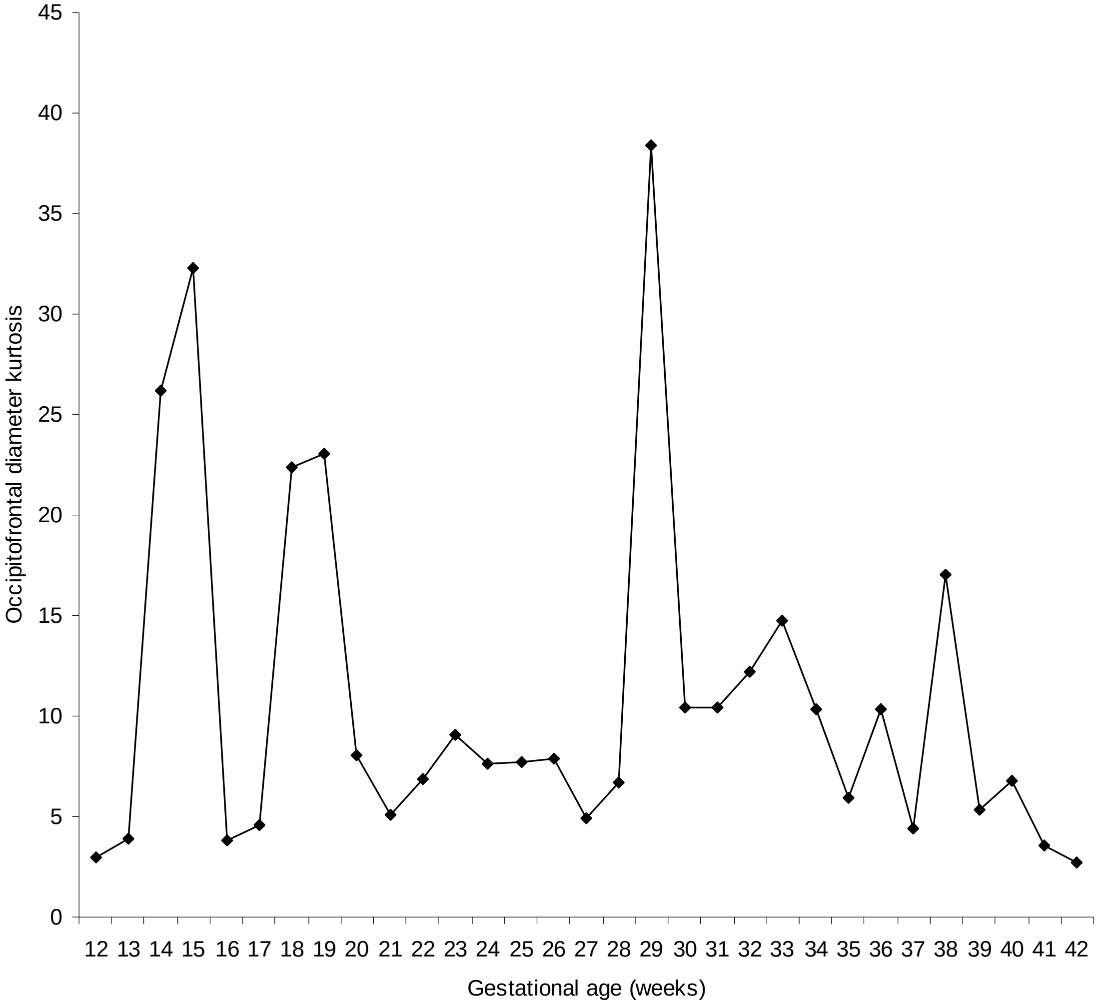

Figure 43: Occipitofrontal diameter data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.

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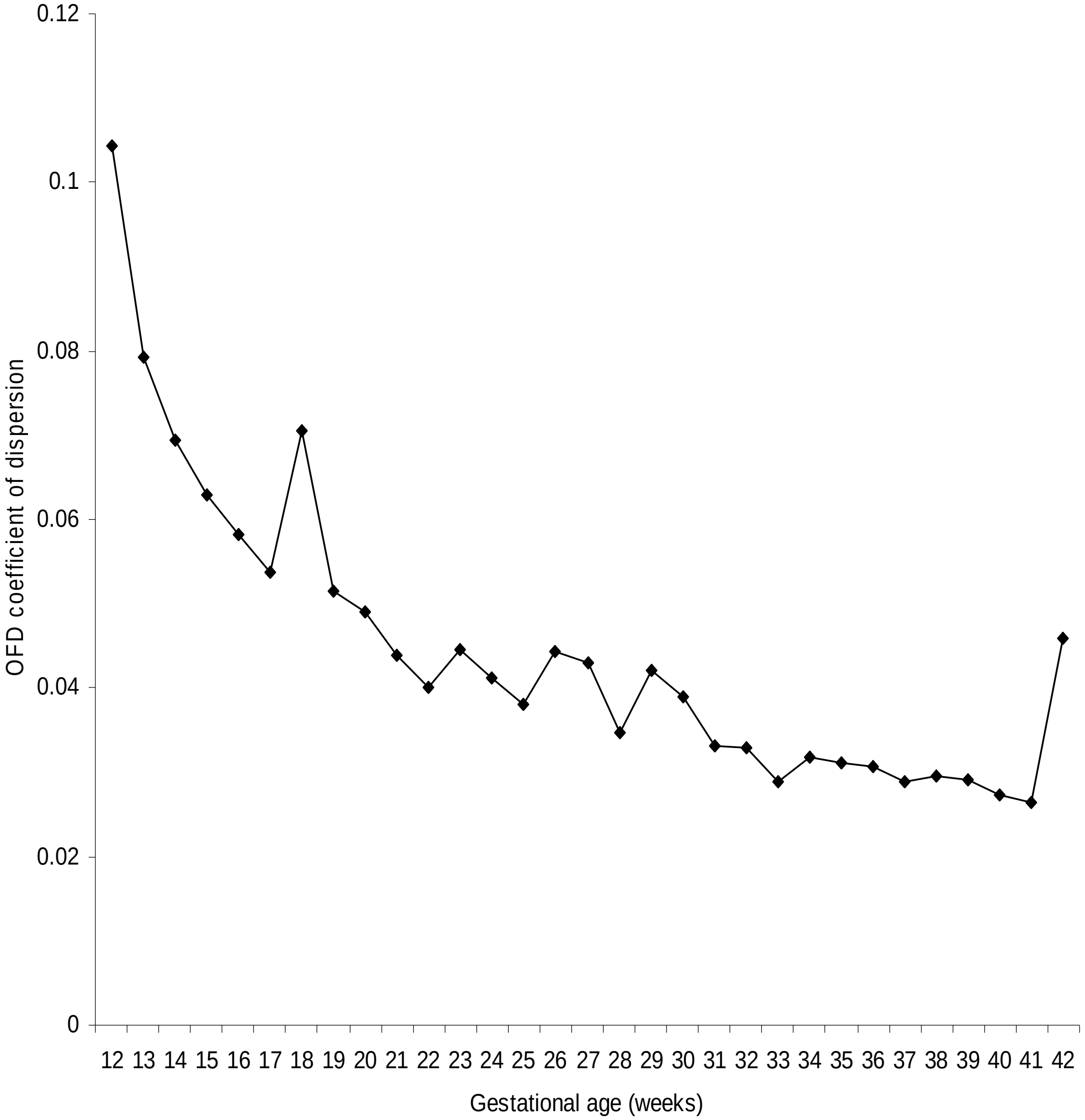

Figure 44: Occipitofrontal diameter coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.

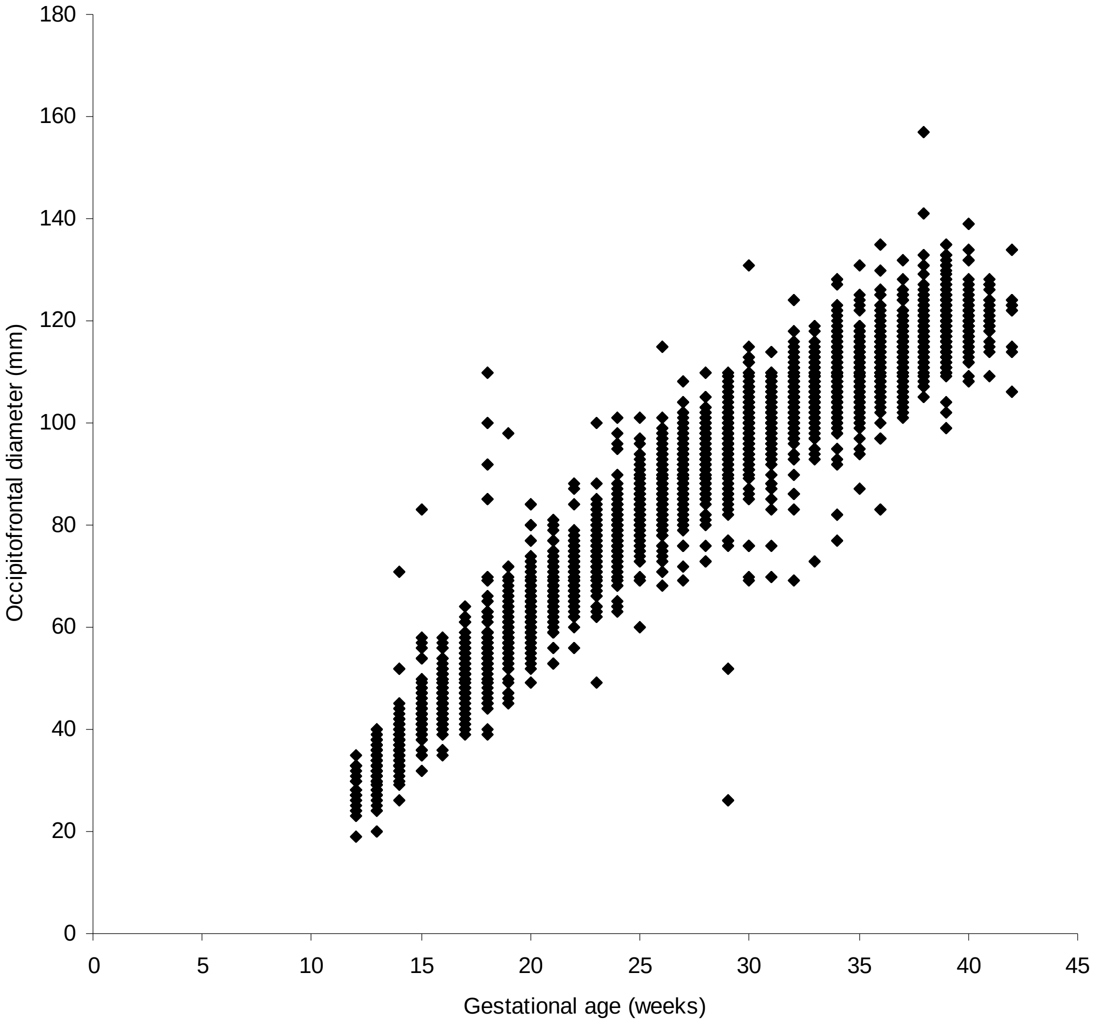

Figure 45: Scattergram of 13,740 fetal occipitofrontal diameter measurements from 12 – 42 weeks gestation.

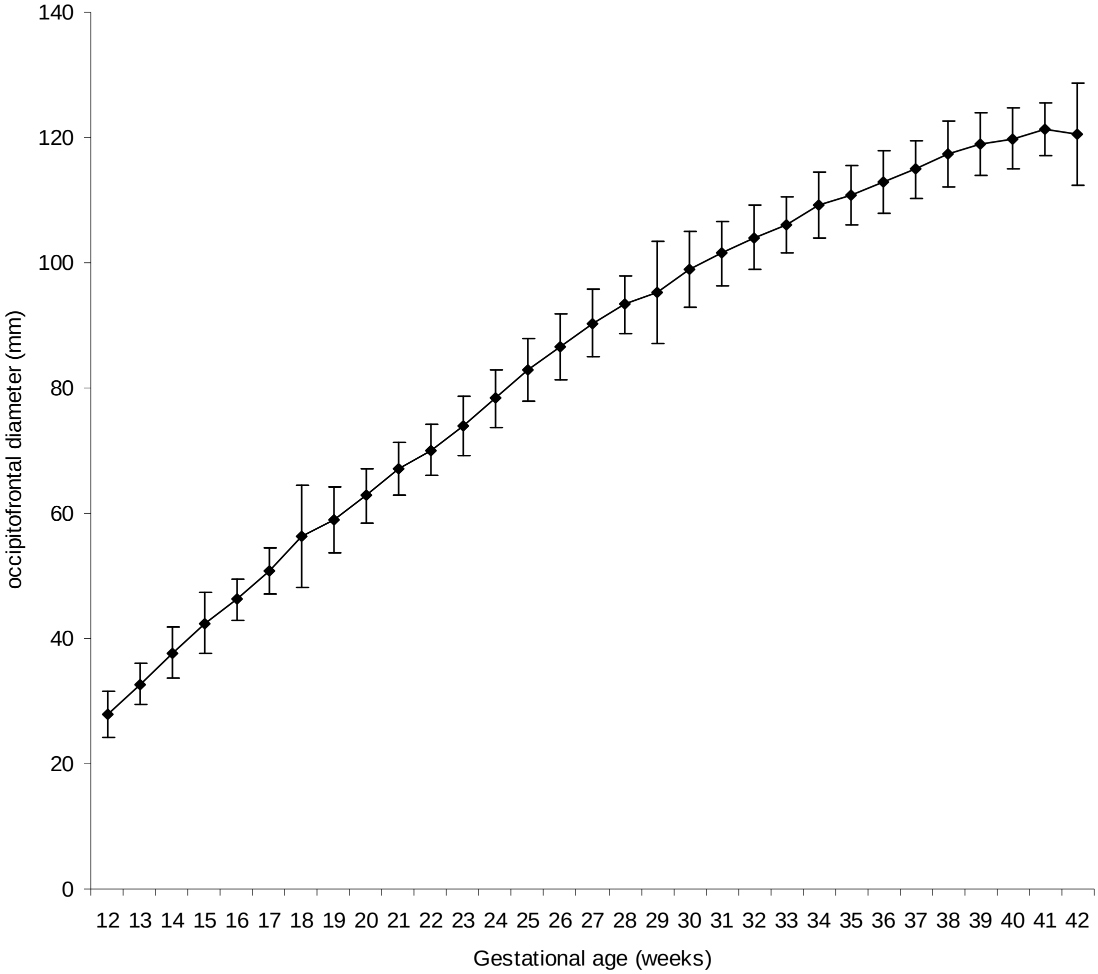

Figure 46: Mean fetal occipitofrontal diameter values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.

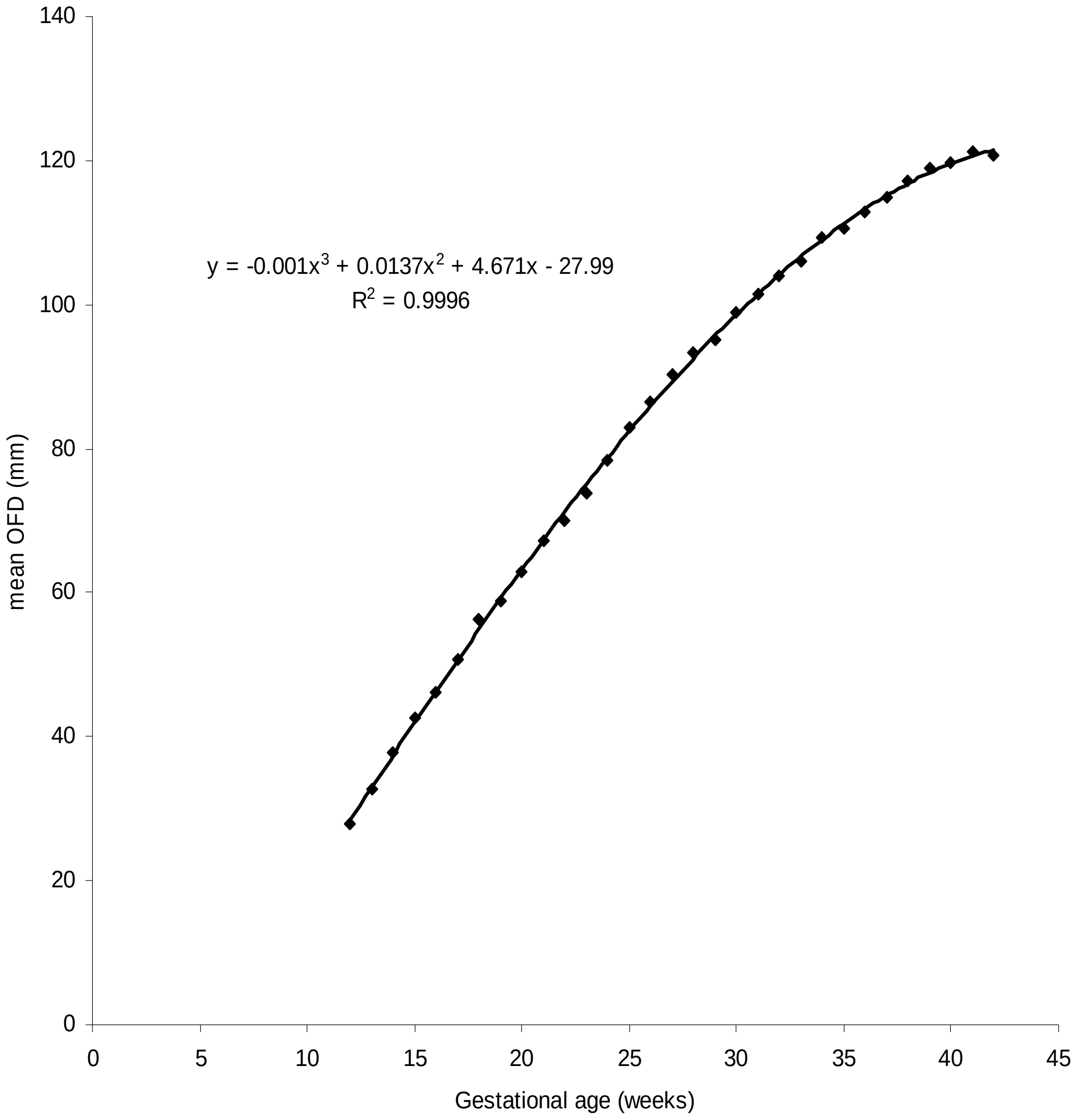

Figure 47: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks

When monthly mean values of occipitofrontal diameter in are plotted against gestational age in months, a positive polynomial correlation between gestational age and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 48). The relationship is best described by the second order polynomial regression equation $y = -1.2964x^2 + 32.011x - 70.179$ where y is the occipitofrontal diameter in millimeters and x is the gestational age in months. Figure 49 shows histogram of monthly mean values of occipitofrontal diameter. Figure 50 shows histogram of mean values for 2nd and 3rd trimesters.

When other fetal anthropometric parameters like head circumference, biparietal diameter, abdominal circumference, femur length and weight are plotted against occipitofrontal diameter certain hidden relationships can be forced out. For example, figure 51 shows the relationship of occipitofrontal diameter with biparietal diameter. From the graph, it can be seen that there is a positive linear correlation between biparietal diameter and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 0.8046x - 0.9072$ where y is the biparietal diameter in millimeters and x is the occipitofrontal diameter in millimeters. Figure 52 shows relationship of occipitofrontal diameter with head circumference which has regression equation of $y = 2.882x + 0.1487$; $r^2 = 1$ ($P<0.0001$). Figure 53 shows the relationship between cephalic index and occipitofrontal diameter. From this graph, it can be seen that there is a positive polynomial correlation between cephalic index and occipitofrontal diameter with a correlation of determination of $r^2 = 0.809$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the sixth order polynomial regression equation $y = 1E\text{-}10x^6 - 5E\text{-}08x^5 + 7E\text{-}06x^4 - 0.0002x^3 - 0.0164x^2 + 1.5205x + 47.619$ where y is the cephalic index and x is the occipitofrontal diameter in millimeters.

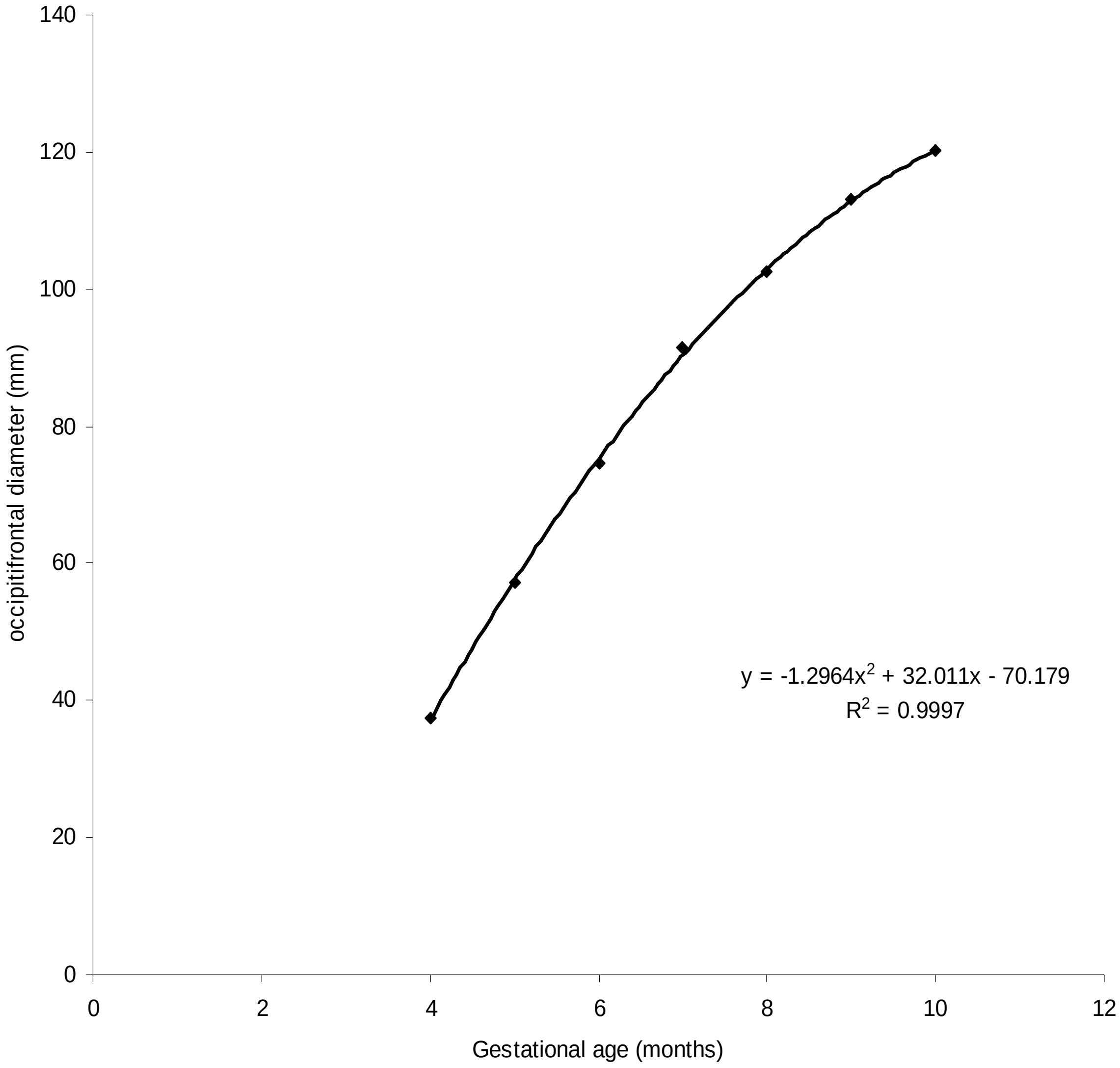

Figure 48: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months

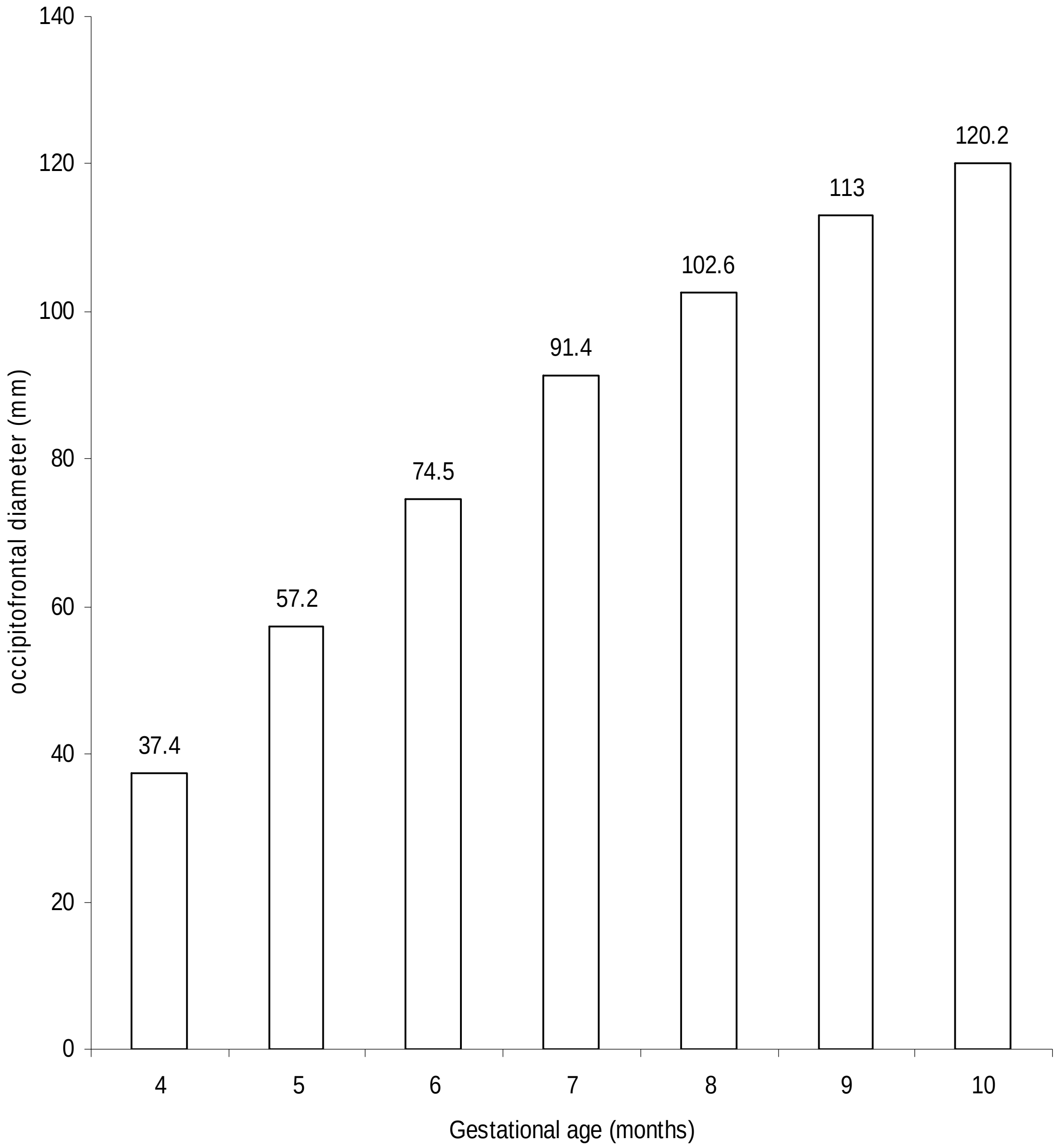

Figure 49: Histogram showing mean occipitofrontal diameter values in 13,740 occipitofrontal diameter data of fetuses in women of gestational ages from 4 to 10 months

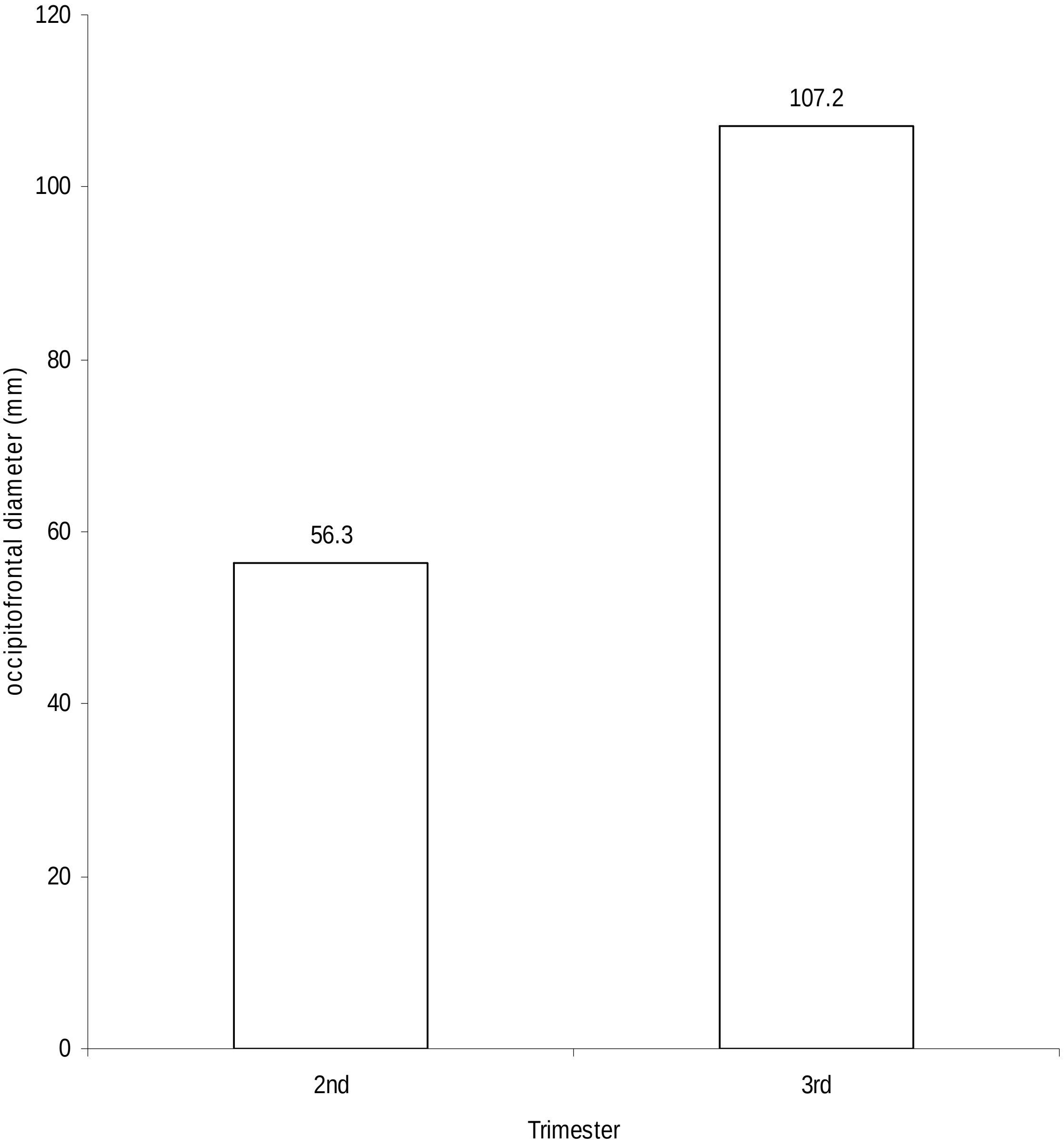

Figure 50: Histogram showing mean occipitofrontal diameter values in 13,740 occipitofrontal diameter data of fetuses in women of gestational ages from 4 to 10 months divided into two trimesters

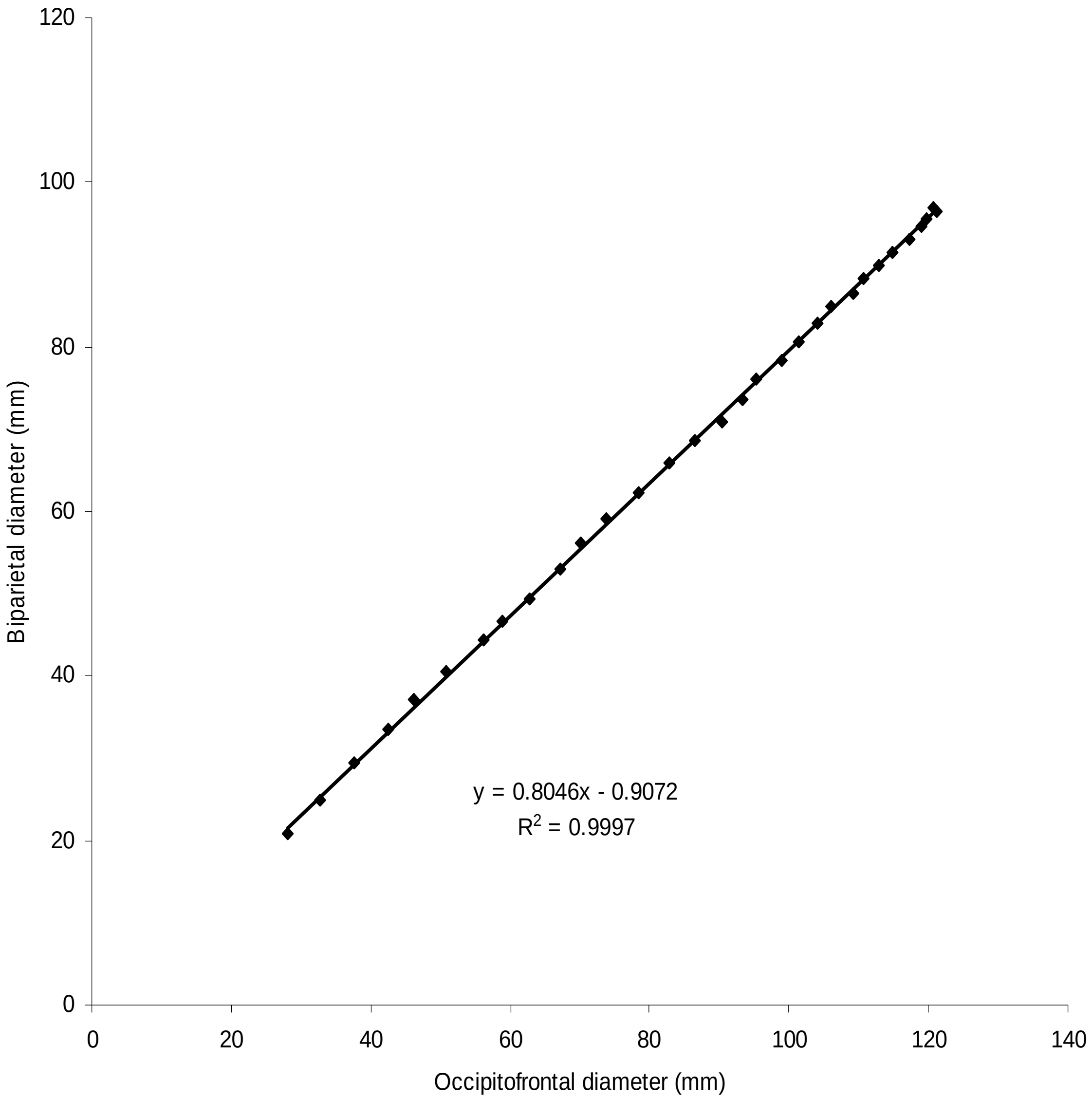

Figure 51: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter

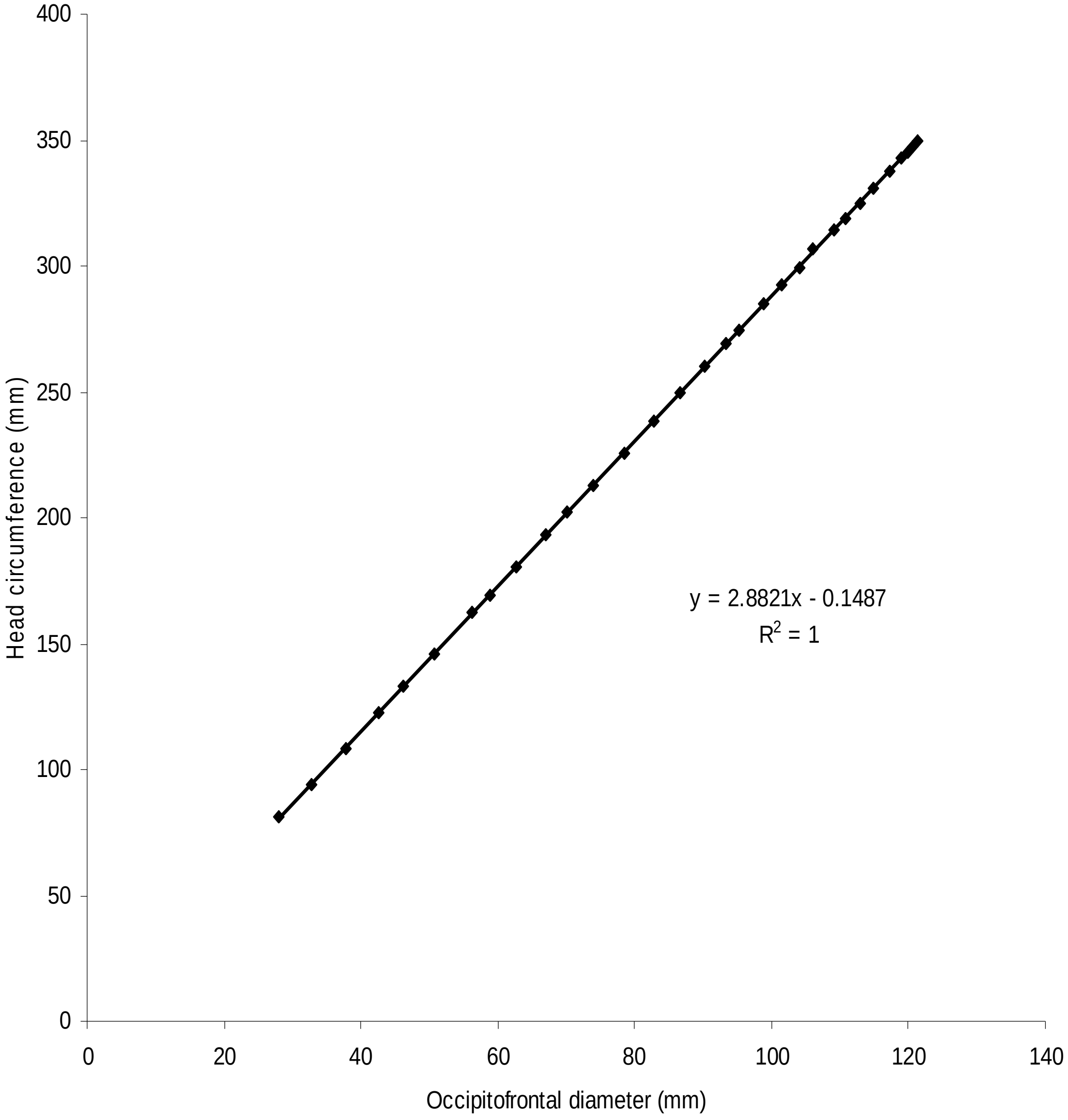

Figure 52: Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter

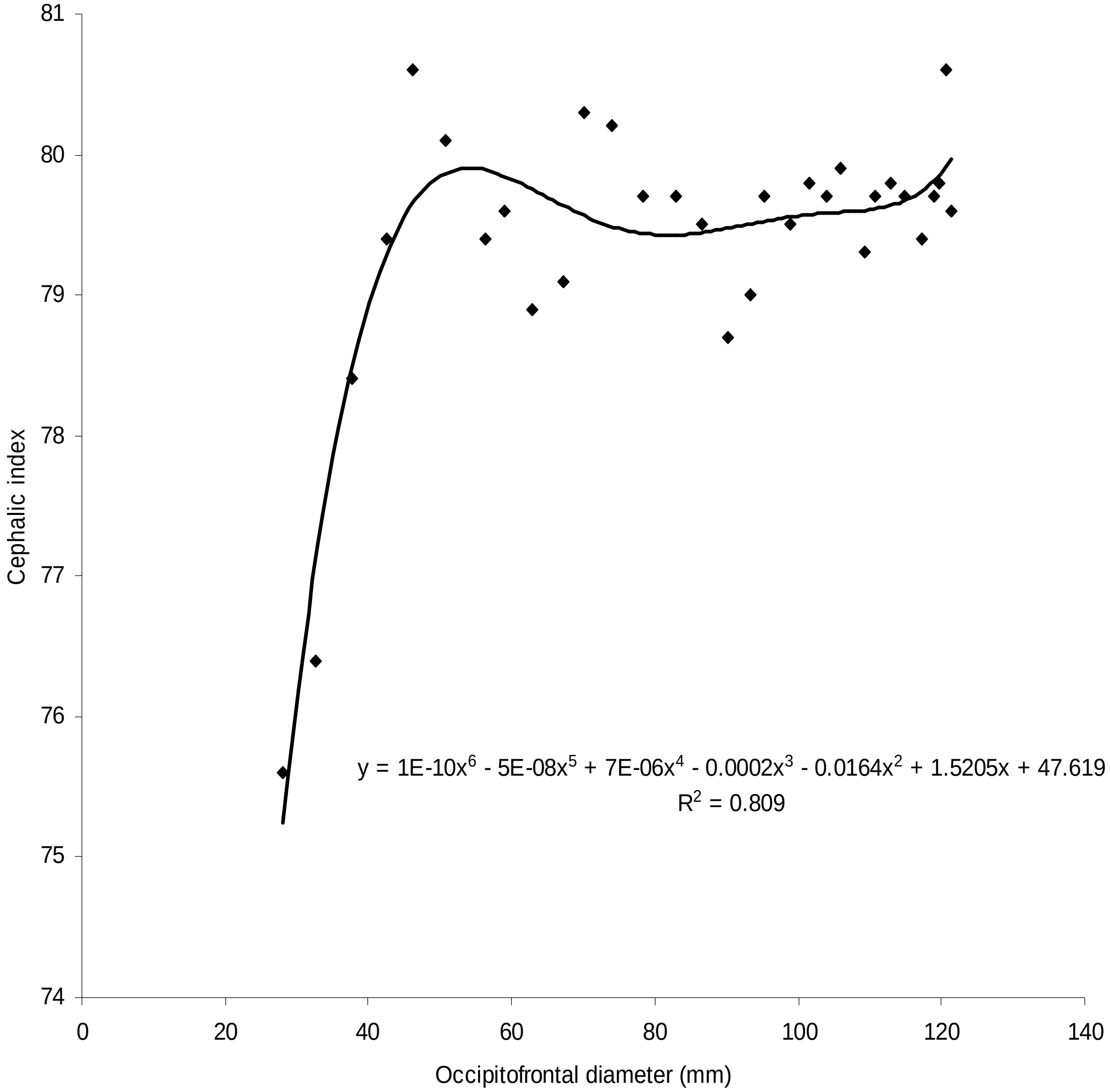

Figure 53: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against cephalic index.

Figure 54 shows relationship of occipitofrontal diameter with abdominal circumference. From the graph, it can be seen that there is a positive polynomial correlation between abdominal circumference and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9993$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = 0.0092x^2 + 1.6208x + 19.582$ where y is the abdominal circumference in millimeters and x is the occipitofrontal diameter in millimeters.

Figure 55 shows relationship between femur length and occipitofrontal diameter. There is a positive polynomial correlation between femur length and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9945$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = 0.0025x^2 + 0.3313x + 1.5192$ where y is the femur length in millimeters and x is the occipitofrontal diameter in millimeters. Figure 56 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and occipitofrontal diameter. The graph shows that there is a positive polynomial correlation between fetal weight and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9989$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order regression equation $y = 0.0071x^3 – 1.0218x^2 + 57.868x – 925.93$ where y is the fetal weight in grams and x is the occipitofrontal diameter in millimeters.

When the relationship between occipitofrontal diameter and symphysio-fundal height was determined (Figure 57), it was found that there is a positive polynomial correlation between symphysio-fundal height and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9954$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the sixth order polynomial regression equation $y = – 8E\text{-}06x^6 + 0.0013x^5 – 0.0917x^4 + 3.2678x^3 – 63.988x^2 + 655.77x – 2708.8$ where y is the occipitofrontal diameter in millimeters and x is the symphysio-fundal height in centimeters.

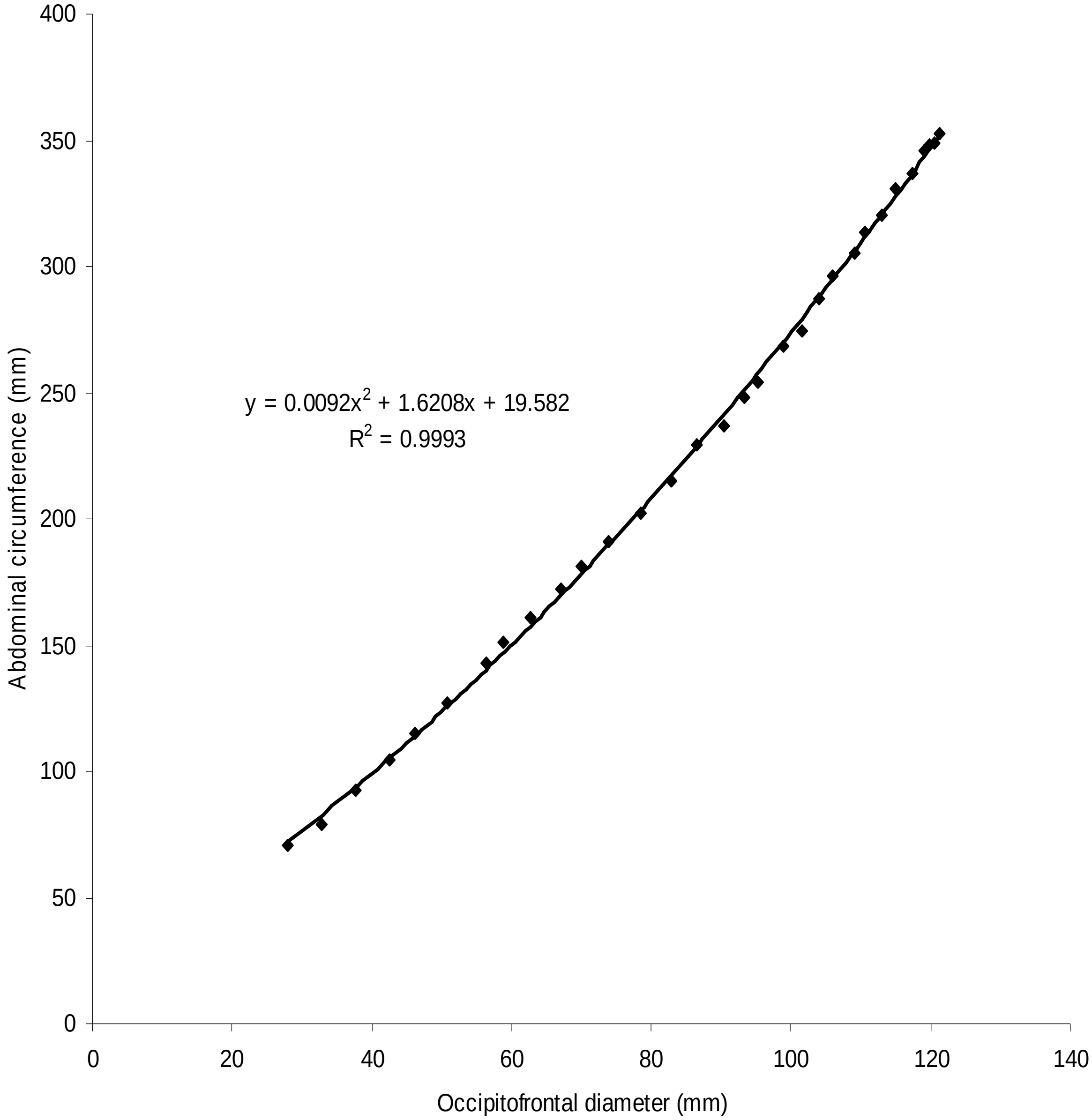

Figure 54: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference.

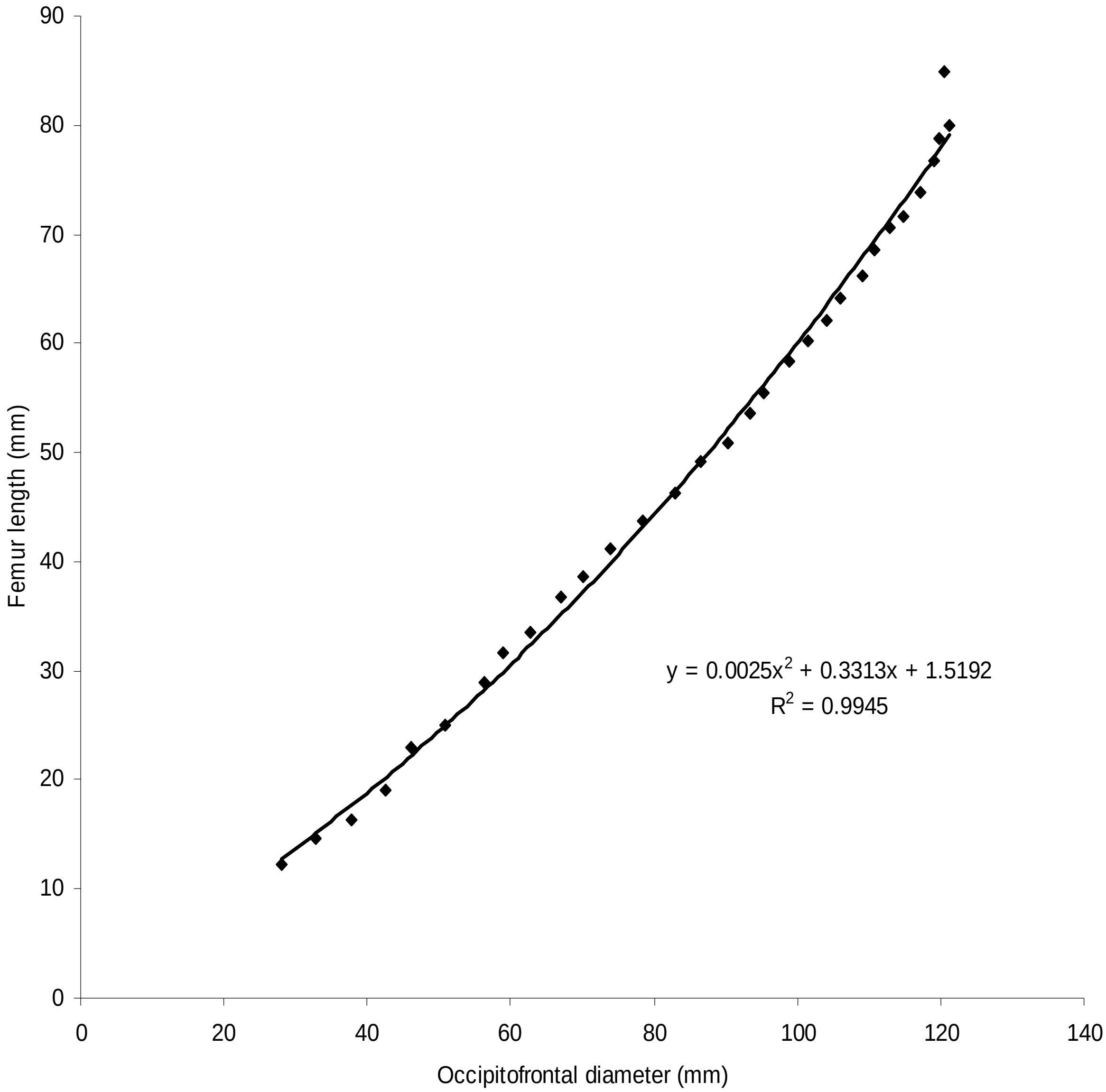

Figure 55: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against femur length.

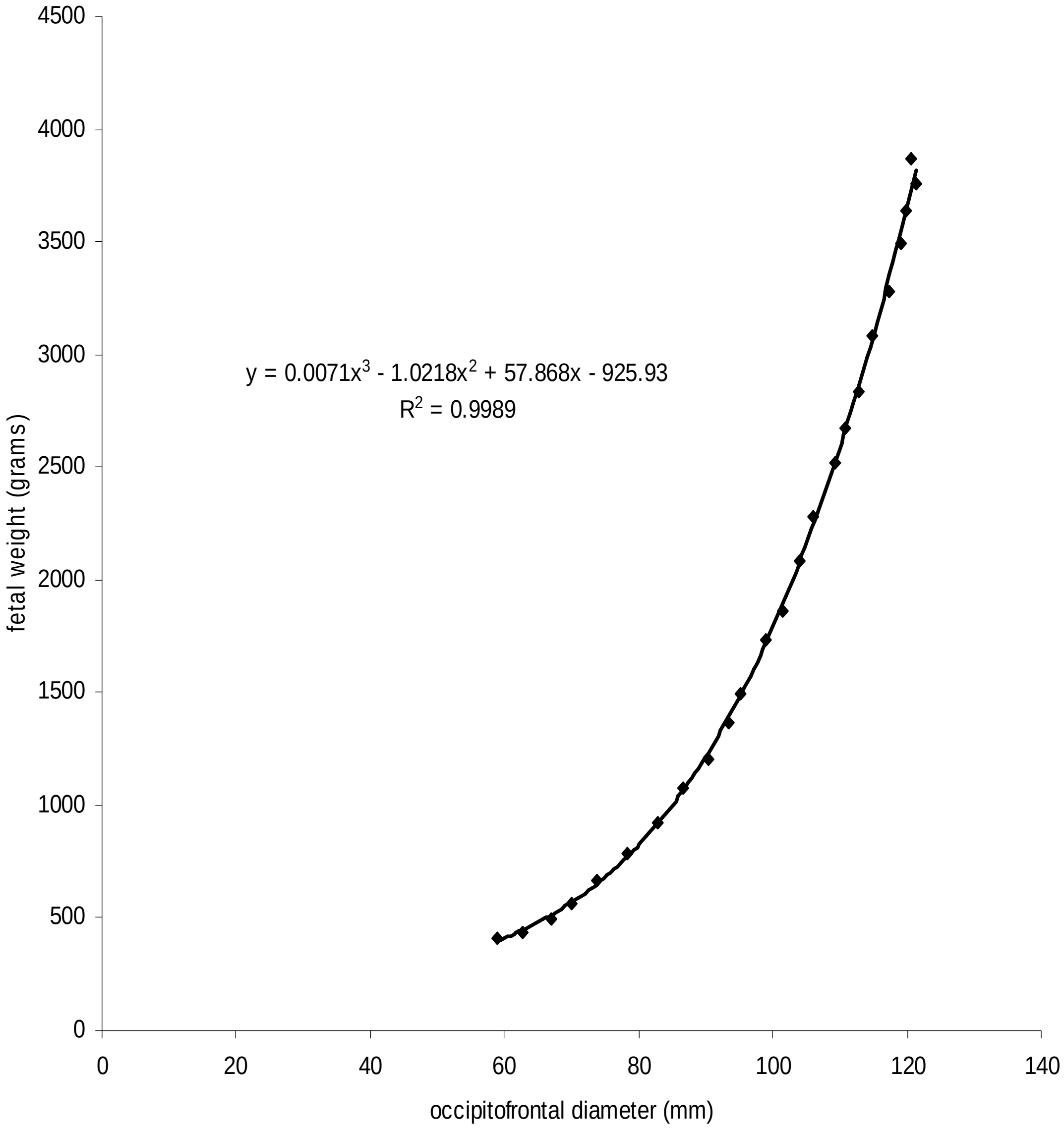

Figure 56: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against fetal weight

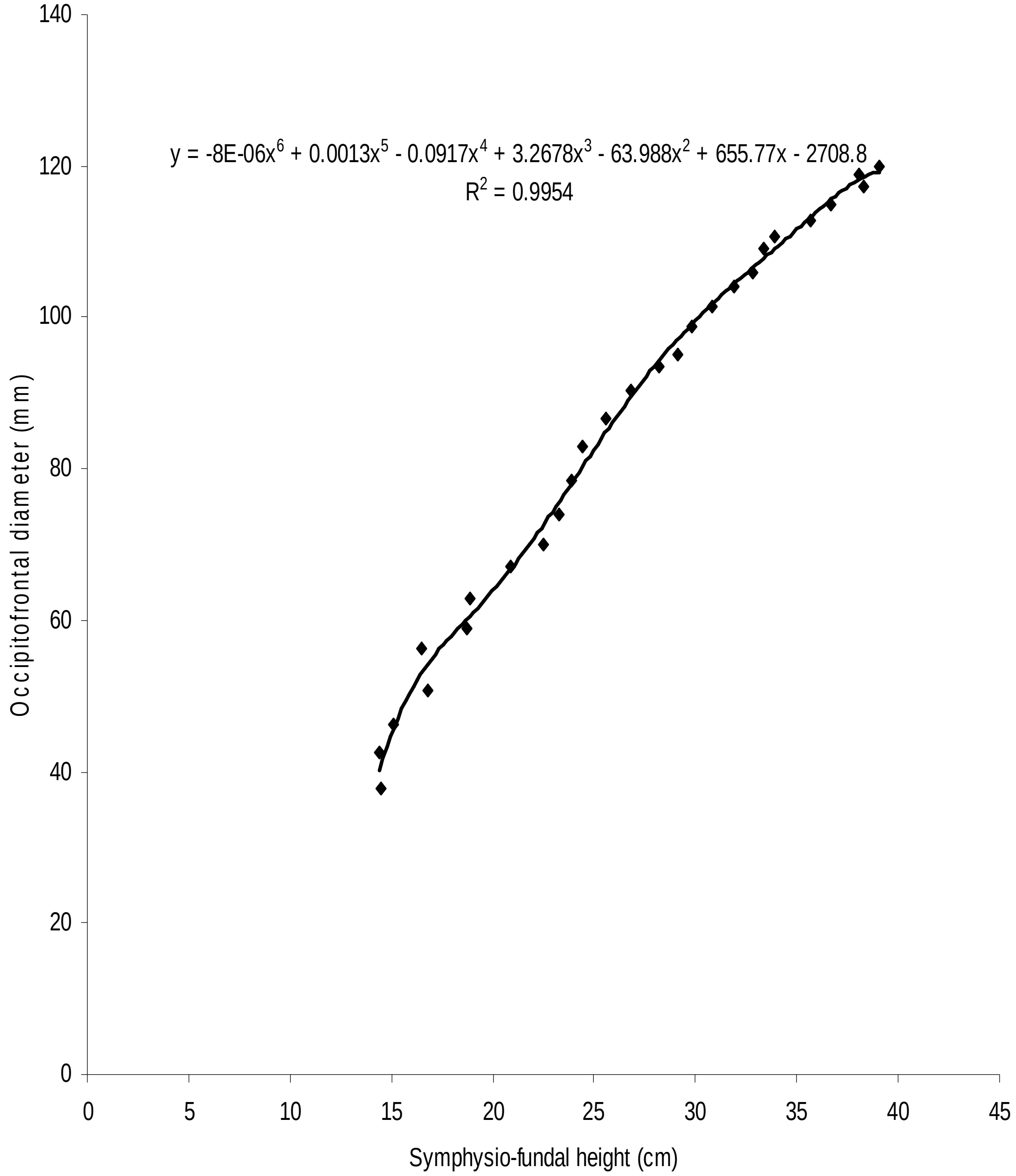

Figure 57: Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against symphysio-fundal height.

Occipitofrontal diameter centile values for 5^{th}, 50^{th} and 95^{th} are plotted as shown in figure 58. In figure 59, the 3rd, 50^{th} and 97^{th} are smoothened into a growth chart which can be utilized to determine occipitofrontal diameter growth and of course brain size development, which is strongly related to intelligence and wellness, using occipitofrontal diameter.

Figure 60 is a graphical display showing the growth rate of the measured fetal occipitofrontal diameter at gestational age ranging from 12 – 42 weeks. It is clear from this graph that growth rate is much higher in the early stages of development than the late ones which precede term.

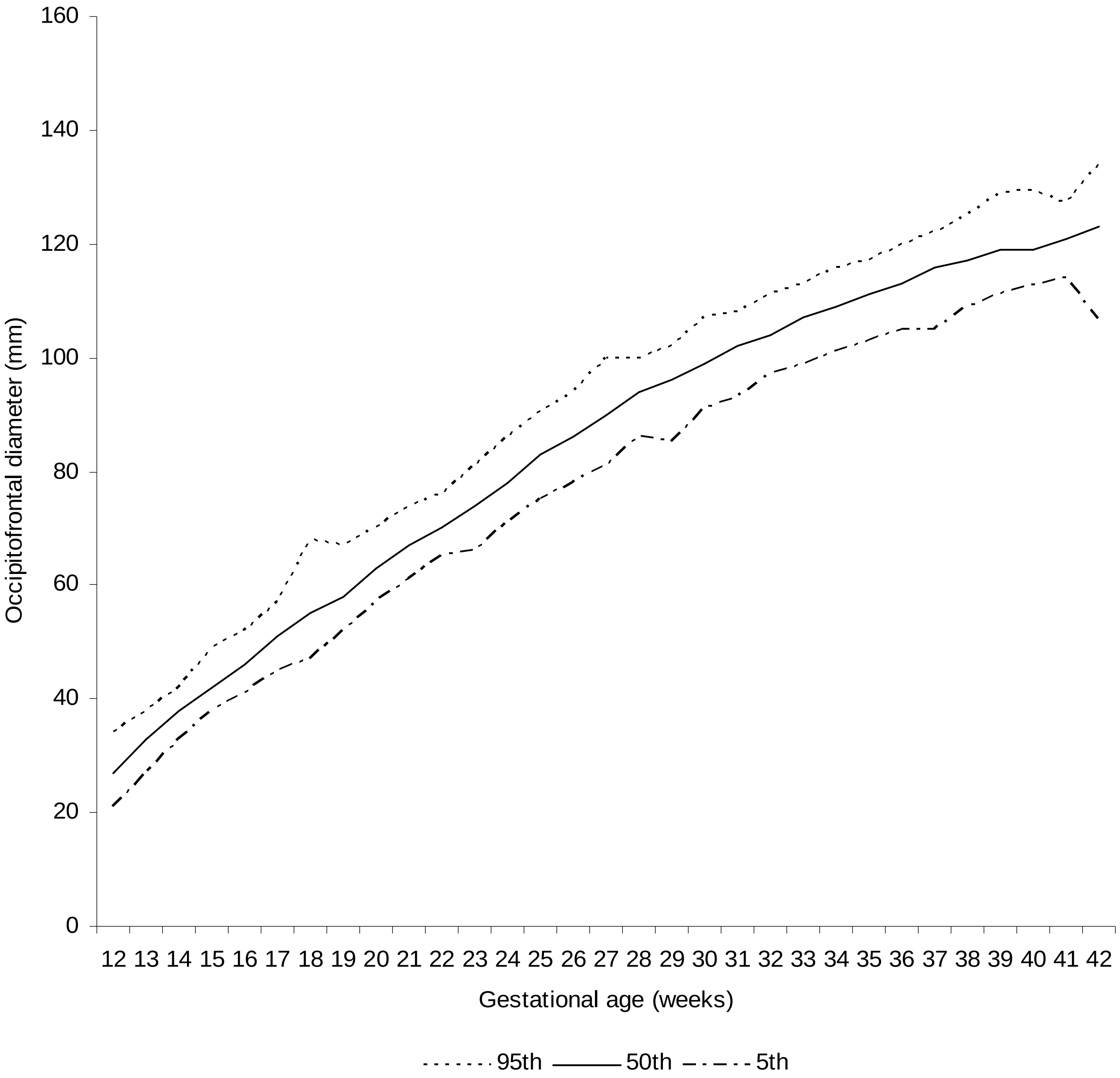

Figure 58: Fifth, 50th and 97th centiles for occipitofrontal diameter in 13,740 fetuses at different gestational ages from 12 to 42 weeks.

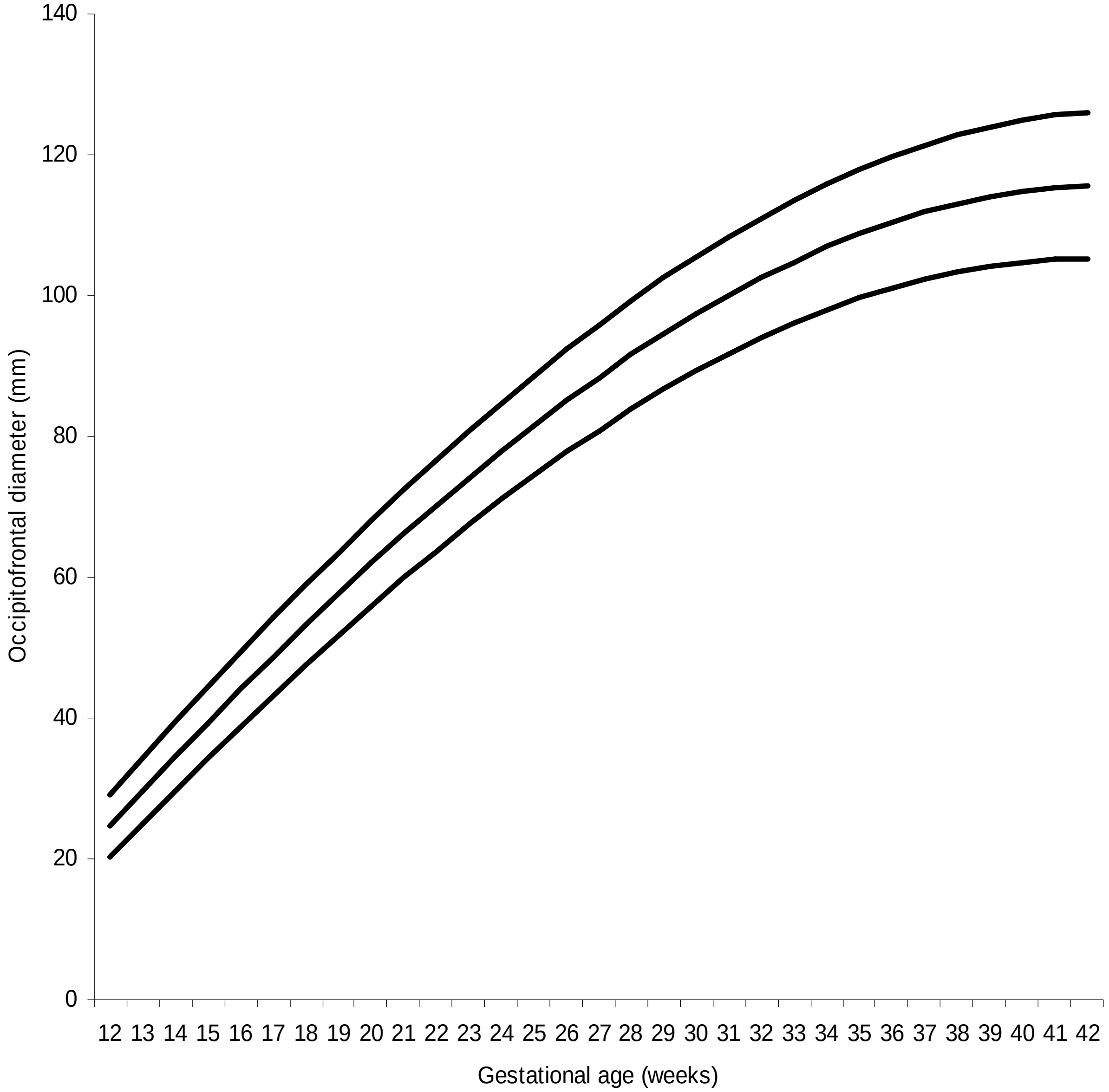

Figure 59: Curves created from 3rd, 50th and 97th fetal occipitofrontal diameter centiles.

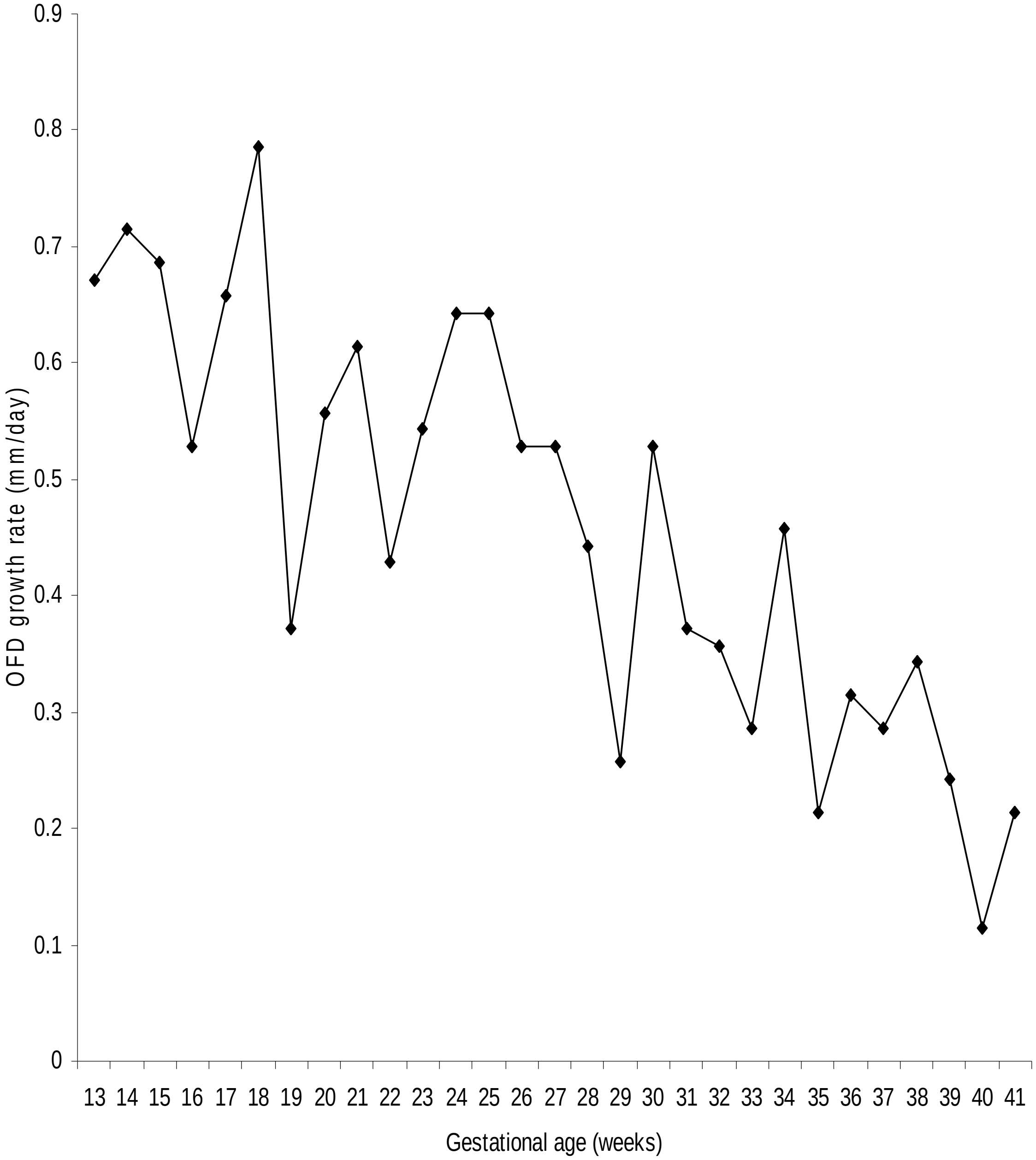

Figure 60: Growth velocity pattern of occipitofrontal diameter in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks

4.1.4 Fetal Abdominal Circumference

The mean fetal abdominal circumference values at each week of gestation from 12 – 42 are as shown in table 22. This table gives the mean values of fetal abdominal circumference measurements for each gestational age in weeks from 12 – 42 weeks together with their corresponding standard deviations and standard errors of mean.

Variation in the measurements of fetal abdominal circumference was found to be 2mm and above at weeks 18, 21, 31, 35, 39 and 42. The highest mean abdominal circumference was achieved at 42 weeks and the lowest mean abdominal circumference was at 12 weeks. With the arithmetic mean, one has some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean abdominal circumference at 36 weeks is 320.0mm plus 1.8mm or 320.0mm minus 1.8mm. This means 2 out of 3 measurements of abdominal circumference at 36 weeks, approximately 399 abdominal circumference measurements in a class of 599, should be between 318.2mm and 321.8mm. Since the standard error of mean at 36 weeks is 0.0mm, it is telling us that the real mean abdominal circumference of fetuses in Jos at 41 weeks is 320.0mm (320.0mm plus or minus 0.0mm). It can also be seen that the standard error of mean for each week of gestation from 12 – 42 is very small suggesting that the sample mean is very close to the population mean. For example, at 13 weeks gestation, the mean fetal abdominal circumference was 79.2mm while the standard error of mean was 1.2. This means that the difference between the mean abdominal circumferences of the sample of fetuses at 13 weeks is just 1.2mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (table 23) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal abdominal circumference measurements were not identical.

Table 22: Frequency distribution table of fetal abdominal circumference measurements showing the arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.

GA (week, days)	Fetuses (n)	Mean AC (mm)	SD	SE
12 to 12+6	49	70.4	1.5	0.2
13 to 13+6	384	79.2	1.2	0.0
14 to 14+6	371	92.5	1.2	0.0
15 to 15+6	351	104.8	1.3	0.0
16 to 16+6	505	115.3	1.3	0.0
17 to 17+6	427	127.4	1.7	0.0
18 to 18+6	446	142.7	2.4	0.1
19 to 19+6	282	151.1	1.7	0.1
20 to 20+6	553	160.7	1.6	0.0
21 to 21+6	400	172.5	2.3	0.1
22 to 22+6	398	181.2	1.5	0.1
23 to 23+6	478	190.7	1.8	0.0
24 to 24+6	520	202.0	1.6	0.0
25 to 25+6	388	215.4	1.7	0.0
26 to 26+6	511	229.3	1.8	0.0
27 to 27+6	432	236.7	2.0	0.0
28 to 28+6	548	248.0	1.7	0.0
29 to 29+6	484	254.3	1.9	0.0
30 to 30+6	625	268.7	1.9	0.0
31 to 31+6	523	274.7	2.0	0.0
32 to 32+6	583	287.1	1.6	0.0
33 to 33+6	516	296.0	1.9	0.0
34 to 34+6	744	305.0	1.9	0.0
35 to 35+6	739	313.2	2.0	0.0
36 to 36+6	599	320.0	1.8	0.0
37 to 37+6	532	330.5	1.8	0.1
38 to 38+6	481	336.8	1.7	0.0
39 to 39+6	525	345.6	2.2	0.0
40 to 40+6	252	348.4	1.9	0.1
41 to 41+6	72	352.4	1.3	0.2
42 to 42+6	22	349.0	2.2	0.5
Total	**13,740**			

Table 23: Frequency distribution table of fetal abdominal circumference measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.

GA (week, days)	Number of fetuses (n)	Arithmetic mean	Geometric mean	Harmonic mean
12 to 12+6	49	7.042857	6.900781	6.770617
13 to 13+6	384	7.923438	7.82983	7.733103
14 to 14+6	371	9.249057	9.171251	9.087093
15 to 15+6	351	10.47692	10.40627	10.34549
16 to 16+6	505	11.5299	11.46782	11.41118
17 to 17+6	427	12.737	12.65461	12.57686
18 to 18+6	446	14.26883	14.11921	13.99722
19 to 19+6	282	15.11277	15.02775	14.94986
20 to 20+6	553	16.06546	15.98812	15.91212
21 to 21+6	400	17.2465	17.11336	16.98076
22 to 22+6	398	18.11658	18.05408	17.99383
23 to 23+6	478	19.06862	18.97901	18.8767
24 to 24+6	520	20.20365	20.13879	20.0751
25 to 25+6	388	21.53918	21.47404	21.40784
26 to 26+6	511	22.92955	22.86071	22.79436
27 to 27+6	432	23.6669	23.58506	23.50435
28 to 28+6	548	24.79635	24.74141	24.68774
29 to 29+6	484	25.42975	25.34406	25.23957
30 to 30+6	625	26.86768	26.80438	26.74241
31 to 31+6	523	27.474	27.39667	27.31487
32 to 32+6	583	28.70892	28.66116	28.6117
33 to 33+6	516	29.60368	29.54634	29.48943
34 to 34+6	744	30.50054	30.43813	30.37043
35 to 35+6	739	31.31651	31.25593	31.19619
36 to 36+6	599	31.99683	31.94766	31.89678
37 to 37+6	532	33.04906	32.99531	32.93646
38 to 38+6	481	33.68129	33.63824	33.59433
39 to 39+6	525	34.55905	34.48941	34.41487
40 to 40+6	252	34.83611	34.78634	34.73609
41 to 41+6	72	35.23889	35.2147	35.19038
42 to 42+6	22	34.90454	34.83539	34.7663
Total	**13740**			

Table 24 shows the monthly fetal abdominal circumference mean values from 4th month to the 10th month with their corresponding standard deviations and standard errors of mean. The fetal abdominal circumference mean values during second and third trimesters are shown in table 25 while table 26 gives the centile values of fetal abdominal circumference measurements. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal abdominal circumference measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 5th percentile of abdominal circumference at 26 to 26 + 6 weeks gestation is 20.7 centimeters. This means that 5% of the fetuses at 26 to 26 + 6 had a mean abdominal circumference less than 20.7 centimeters, while 95% had a mean abdominal circumference greater than 20.7 centimeters. Similarly, the 90th percentile of abdominal circumference at 33 to 33 + 6 weeks is 31.6 centimeters. Hence 90% of fetuses at 33 to 33 + 6 weeks had a mean abdominal circumference less than 31.6 centimeters while 10% had a mean abdominal circumference greater than 31.6 centimeters.

The standard score or z-score of abdominal circumference measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in table 27. The z-score enables one to look at abdominal circumference measurements at each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, abdominal circumference measurements at 28 weeks are – 0.0215 standard deviations from the mean while measurements at 36 weeks are – 0.0175 standard deviations from the mean. Again, from the above z-score table, it can be seen that the abdominal circumference measurements at 38 weeks gestation are 0.00758 standard deviations from the mean.

Table 24: Monthly mean fetal abdominal circumference values (in mm) in a Nigerian population

G.A (months)	Fetuses (n)	Mean (mm)	S.D	S.E
4	1660	92.4	18.3	8.2
5	1708	145.5	14.1	7.1
6	2184	192.4	16.9	7.6
7	1975	242.1	11.2	5.6
8	2247	281.6	12.3	6.1
9	3095	321.1	12.8	5.7
10	871	348.9	2.8	1.4
Total	13,740			

Table 25: Trimester mean fetal abdominal circumference values

Trimester	Fetuses (n)	Mean	S.D	S.E	Minimum	Maximum	Range
2nd	5552	143.3	46.5	12.4	70.4	215.4	145.0
3rd	8188	299.7	41.9	10.2	229.3	352.4	123.1
Total	13,740						

Table 26: Fetal abdominal circumference centiles from 12 – 42 weeks

	Abdominal circumference centiles (cm)						
Gestational age	3rd	5th	10th	50th	90th	95th	97th
12 to 12+6	5.3	5.4	5.4	6.5	9.5	10.1	10.1
13 to 13+6	5.8	5.9	6.2	7.9	9.5	9.9	10.1
14 to 14+6	7.1	7.5	8.0	9.2	10.7	11.2	11.8
15 to 15+6	8.7	9.1	9.3	10.3	11.8	12.4	13.3
16 to 16+6	9.9	10.0	10.2	11.3	13.1	13.5	14.3
17 to 17+6	10.4	10.7	11.3	12.4	14.5	15.8	16.8
18 to 18+6	11.6	12.0	12.6	13.8	15.8	17.9	19.1
19 to 19+6	12.4	12.9	13.7	14.9	16.9	17.8	18.2
20 to 20+6	13.4	13.6	14.3	15.9	18.0	19.0	19.4
21 to 21+6	14.9	14.9	15.3	17.0	19.1	20.0	20.8
22 to 22+6	15.9	16.2	16.5	17.9	20.0	20.8	21.4
23 to 23+6	15.9	16.6	17.2	19.0	21.3	21.8	22.8
24 to 24+6	17.0	17.6	18.5	20.0	22.1	23.0	23.7
25 to 25+6	18.7	19.2	19.4	21.4	23.7	24.5	25.1
26 to 26+6	20.0	20.7	21.0	22.6	25.1	26.1	26.8
27 to 27+6	20.4	20.9	21.6	23.5	26.2	27.3	28.2
28 to 28+6	21.8	22.6	23.0	24.6	26.7	27.9	28.5
29 to 29+6	22.5	22.6	23.3	25.4	27.8	28.3	28.5
30 to 30+6	23.9	24.1	24.7	26.7	29.1	29.8	30.2
31 to 31+6	22.9	24.1	25.5	27.6	29.7	30.0	30.5
32 to 32+6	25.9	26.3	26.8	28.6	30.5	31.1	31.9
33 to 33+6	26.1	26.4	27.4	29.6	31.6	32.0	32.9
34 to 34+6	27.3	27.8	28.4	30.5	32.6	33.2	33.9
35 to 35+6	28.1	28.3	29.0	31.3	33.4	34.2	35.5
36 to 36+6	29.1	29.4	29.9	32.0	34.0	35.0	35.4
37 to 37+6	29.5	30.2	31.0	33.2	35.1	35.9	36.6
38 to 38+6	30.9	31.2	31.8	33.6	35.9	36.4	36.9
39 to 39+6	30.5	31.0	32.3	34.7	36.9	38.2	38.8
40 to 40+6	30.5	31.4	33.1	34.6	37.8	38.4	38.5
41 to 41+6	32.3	32.9	33.7	35.1	37.0	37.3	37.3
42 to 42+6	30.9	30.9	31.5	34.9	38.7	38.7	38.7

Table 27: Standard score (z-score) of abdominal circumference measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	-2.71565
13 to 13+6	384	-1.75942
14 to 14+6	371	-7.86E-03
15 to 15+6	351	-2.37E-02
16 to 16+6	505	-7.62E-04
17 to 17+6	427	-2.00E-02
18 to 18+6	446	-4.86E-03
19 to 19+6	282	1.63E-02
20 to 20+6	553	-2.84E-02
21 to 21+6	400	-2.47E-02
22 to 22+6	398	-2.28E-02
23 to 23+6	478	-7.67E-03
24 to 24+6	520	2.28E-02
25 to 25+6	388	-4.85E-03
26 to 26+6	511	-2.50E-03
27 to 27+6	432	-1.55E-02
28 to 28+6	548	-2.15E-02
29 to 29+6	484	-1.30E-03
30 to 30+6	625	-1.22E-02
31 to 31+6	523	2.00E-02
32 to 32+6	583	-6.75E-03
33 to 33+6	516	1.94E-02
34 to 34+6	744	2.83E-03
35 to 35+6	739	-1.75E-02
36 to 36+6	599	-1.76E-02
37 to 37+6	532	0.272556
38 to 38+6	481	7.58E-03
39 to 39+6	525	-4.54E-03
40 to 40+6	252	-2.05E-02
41 to 41+6	72	-8.55E-03
42 to 42+6	22	2.07E-02
Total	**13,740**	

When abdominal circumference data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (figure 61), it can be seen that the distribution of abdominal circumference measurements has a longer “tail” to the right of the central maximum than to the left or is skewed to the right from 12, 14, 15, 18, 19, 20, 21, 22 and 39 weeks. In the remaining weeks, the distribution has a longer “tail” to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the abdominal circumference data was subjected to kurtosis analysis (figure 62), the analysis was found to be leptokurtic at 15, 18, 19 and 21 weeks of gestation while at other weeks of gestation, the distribution was mesokurtic. The coefficient of dispersion (fig 125) of abdominal circumference data of 13,740 fetuses at different gestational age shows a relatively constant pattern except at 20 weeks where it peaks. The abdominal circumference scattergram in figure 64 shows that there are very few bad data points or outliers in the abdominal circumference measurements of 13,740 fetuses.

In figure 65, mean abdominal circumference is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of abdominal circumference data demonstrated that the best-fitted regression model is that shown in figure 66. From this graph, it can be seen that there is a positive polynomial correlation between gestational age and abdominal circumference with a correlation of determination of $r^2 = 0.9995$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = -0.0004x^4 + 0.0349x^3 - 1.2485x^2 + 30.598x - 172.02$ where y is the abdominal circumference in millimeters and x is the gestational age in weeks.

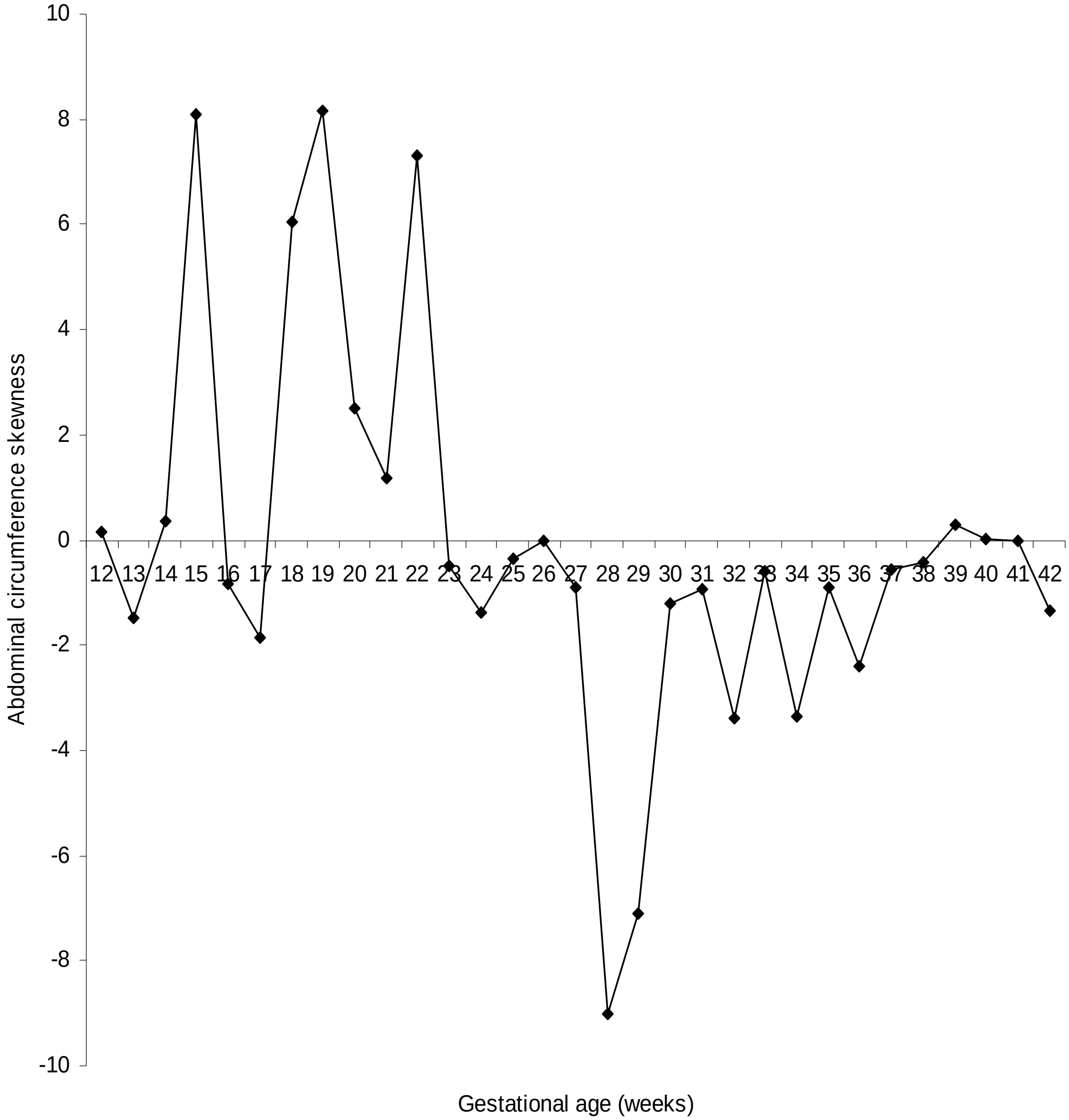

Figure 61: Abdominal circumference data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.

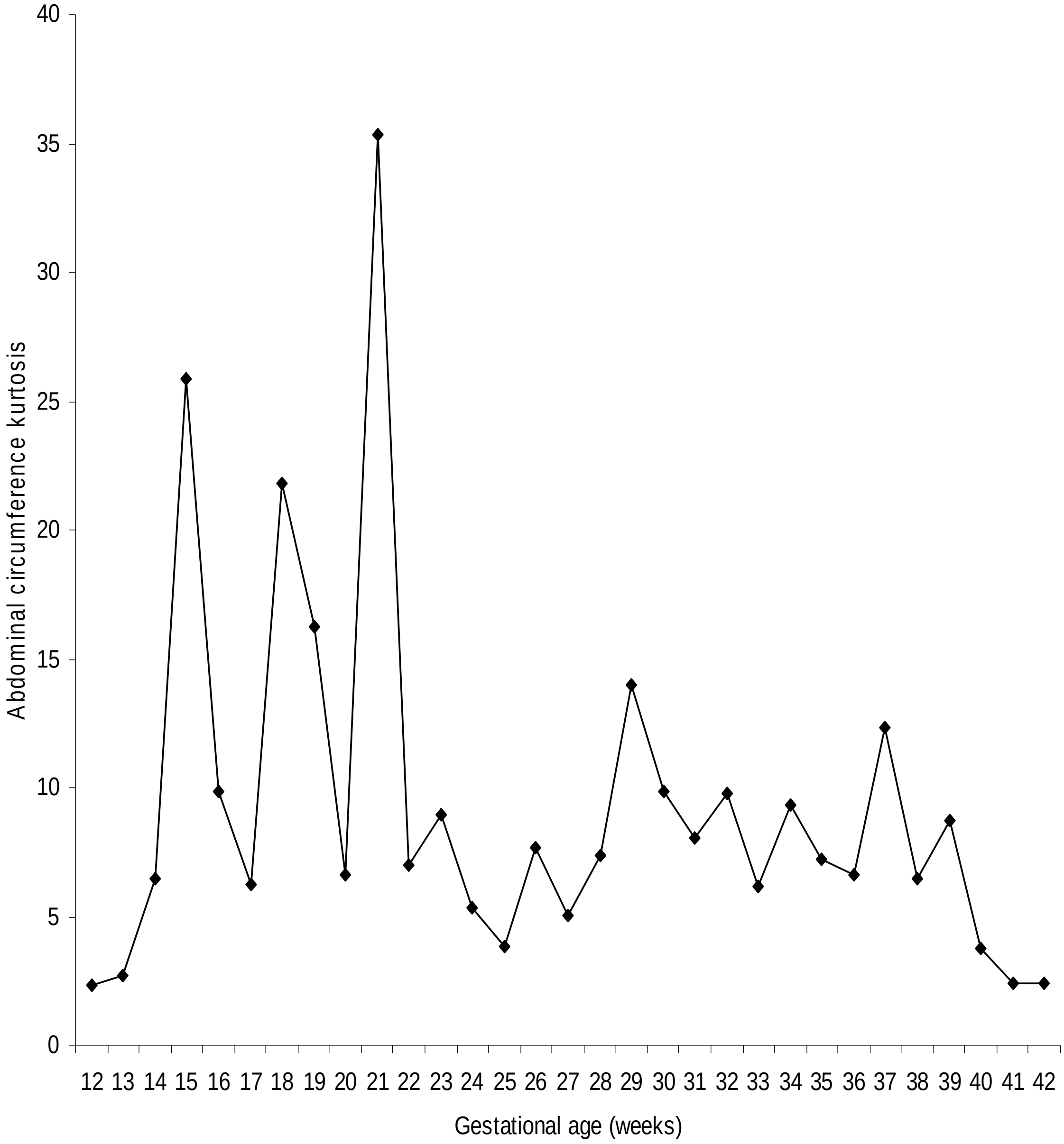

Figure 62: Abdominal circumference data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.

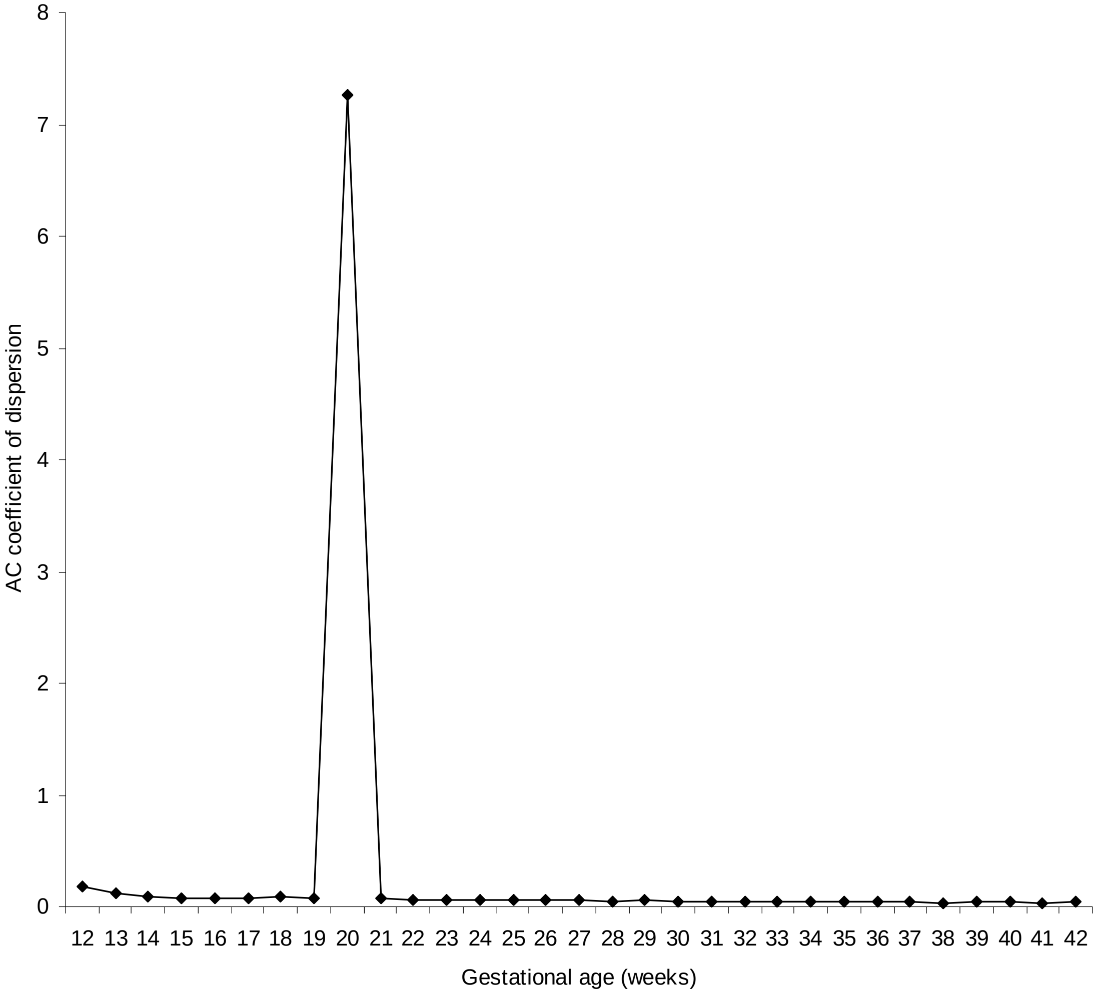

Figure 63: Abdominal circumference coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.

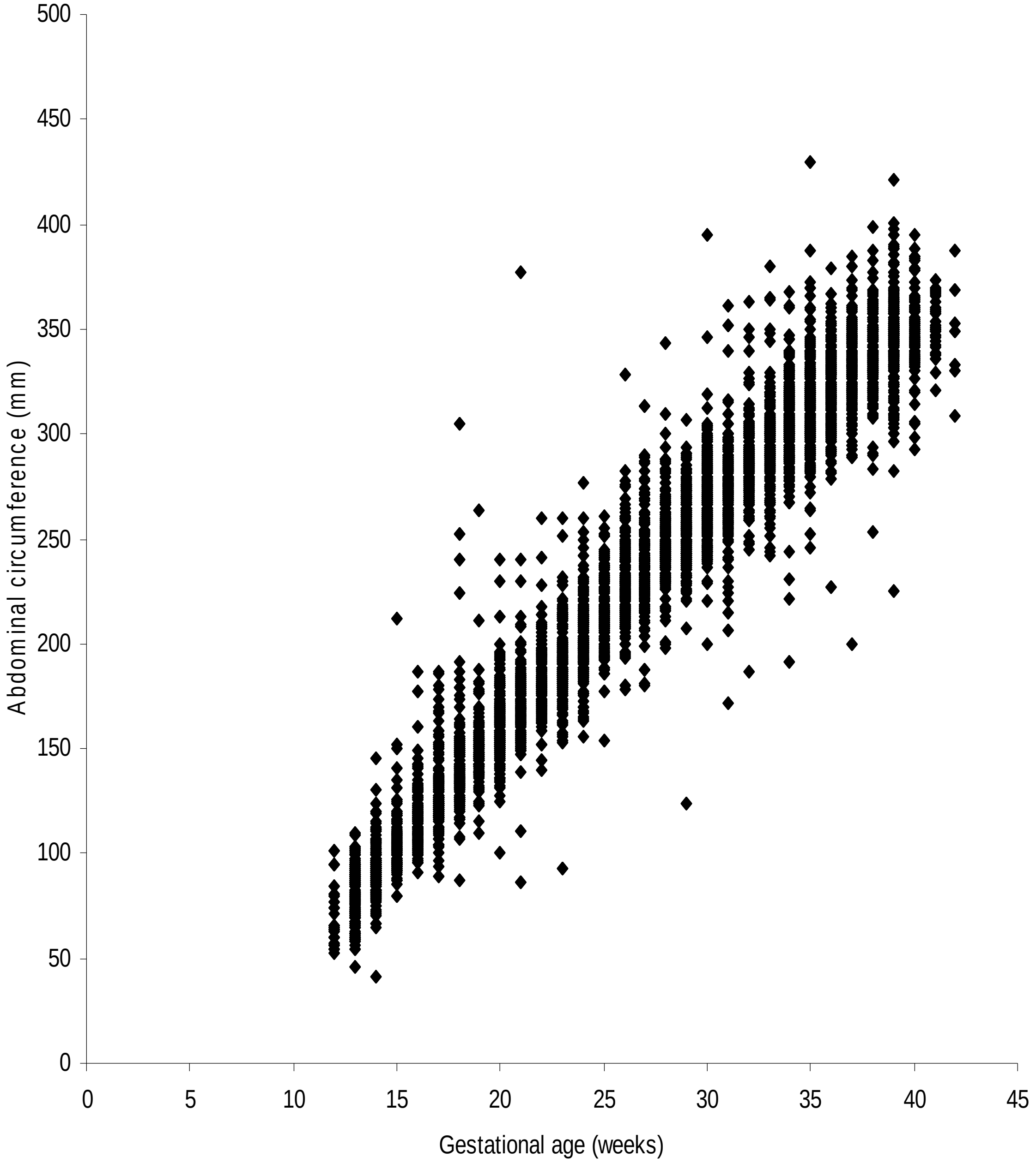

Figure 64: Scattergram of 13,740 fetal abdominal circumference measurements from 12 – 42 weeks gestation.

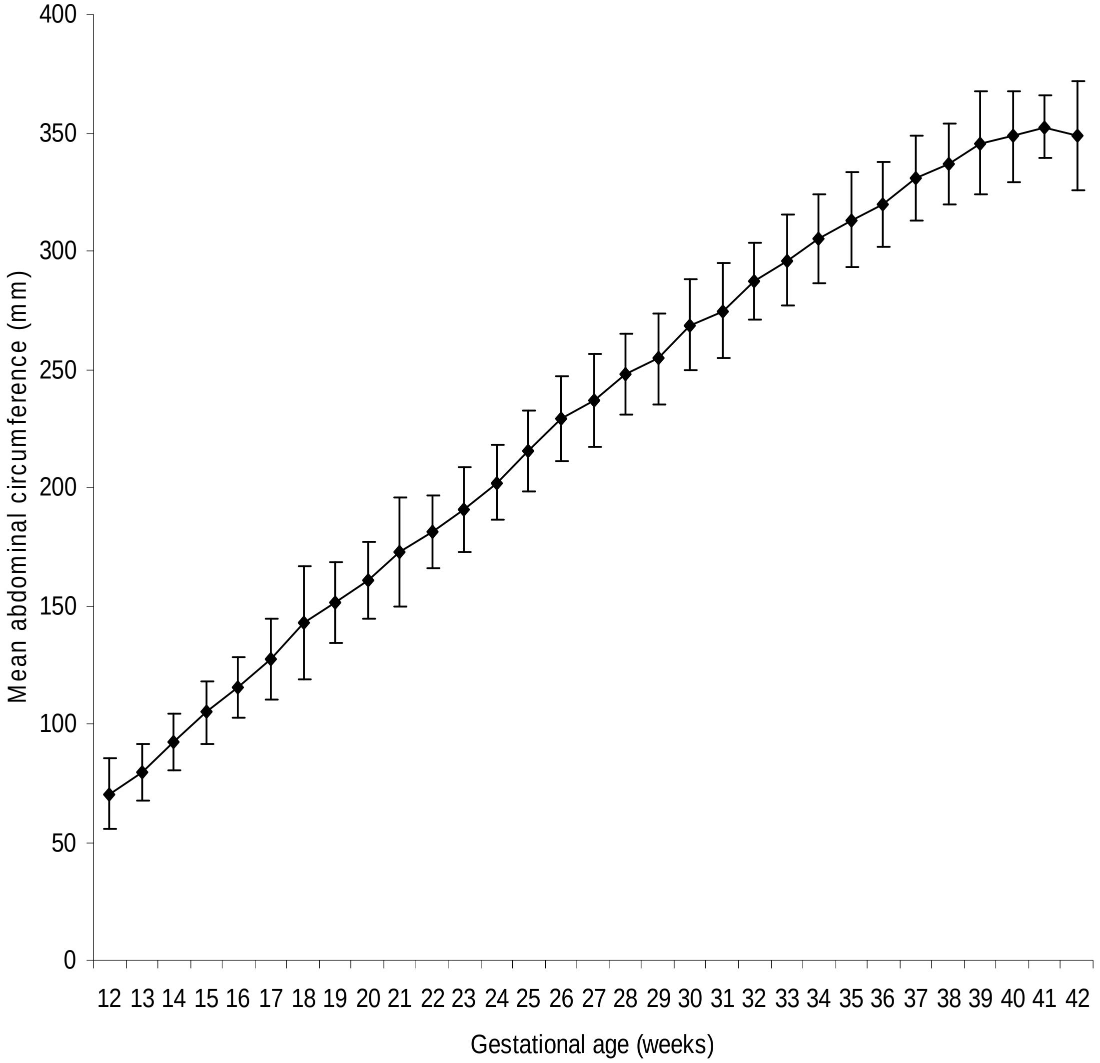

Figure 65: Mean fetal abdominal circumference values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.

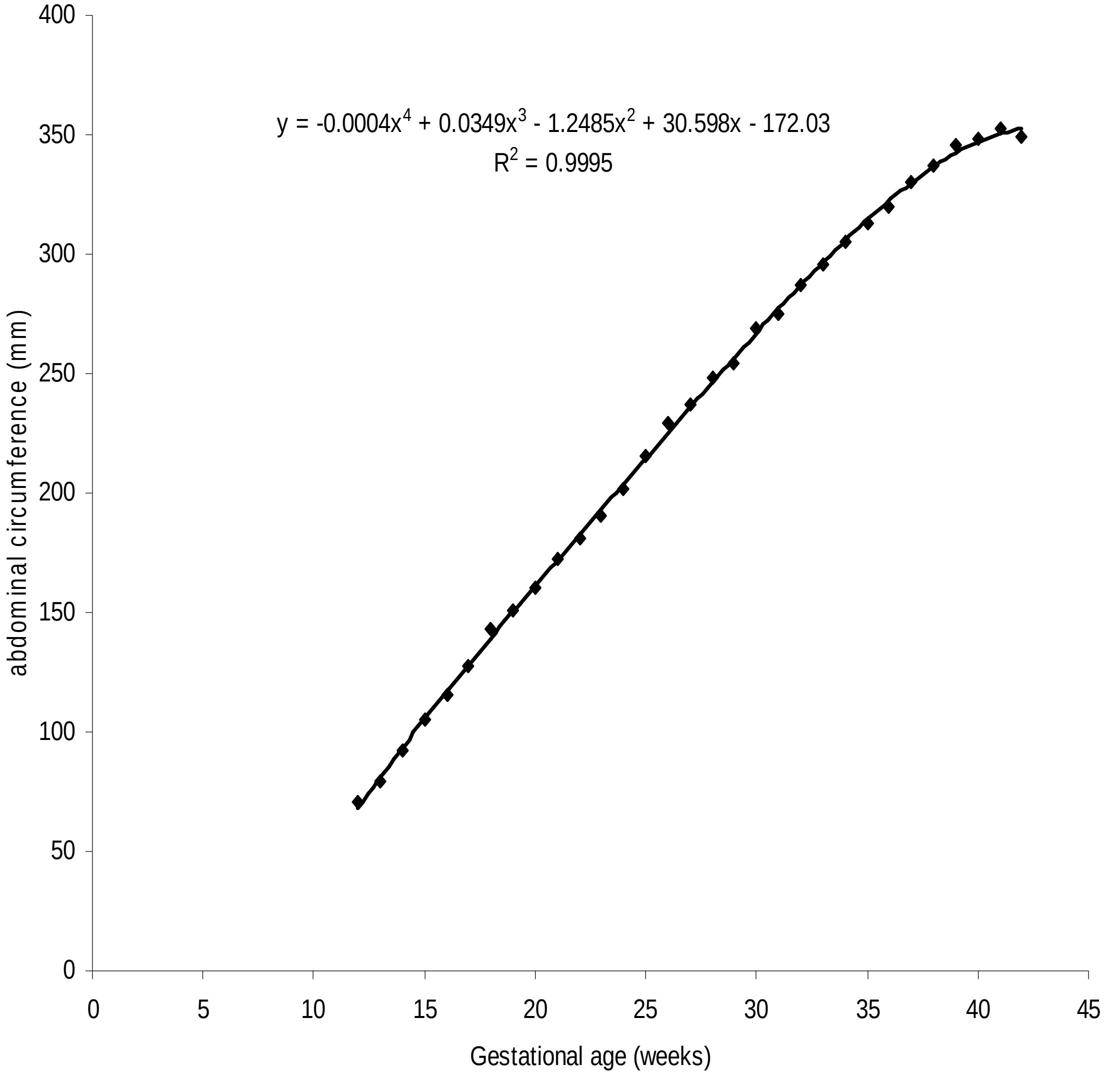

Figure 66: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks

When monthly mean values of abdominal circumference are plotted against gestational age in months, a positive polynomial correlation between gestational age and abdominal circumference with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 67). The relationship is best described by the second order polynomial regression equation $y = -2.1893x^2 + 73.861x - 168.99$ where y is the abdominal circumference in millimeters and x is the gestational age in months. Figure 68 shows histogram of monthly mean abdominal circumference from 4th month to the 10th month. Figure 69 shows histogram of abdominal circumference means for 2nd and 3rd trimesters with mean abdominal circumference doubling at 3rd trimester.

When other fetal anthropometric parameters like head circumference, biparietal diameter, occipitofrontal diameter, femur length and weight are plotted against abdominal circumference certain hidden relationships can be forced out. For example, figure 70 shows the relationship of abdominal circumference with biparietal diameter. From the graph, it can be seen that there is a positive polynomial correlation between biparietal diameter and abdominal circumference with a correlation of determination of $r^2 = 0.9995$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = -0.0003x^2 + 0.3777x - 3.6302$ where y is the biparietal diameter in millimeters and x is the abdominal circumference in millimeters. Figure 71 shows relationship of abdominal circumference with occipitofrontal diameter. From the graph, it can be seen that there is a positive polynomial correlation between occipitofrontal diameter and abdominal circumference with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = -0.0003x^2 + 0.4671x - 3.1666$ where y is the biparietal diameter in millimeters and x is the abdominal circumference in millimeters.

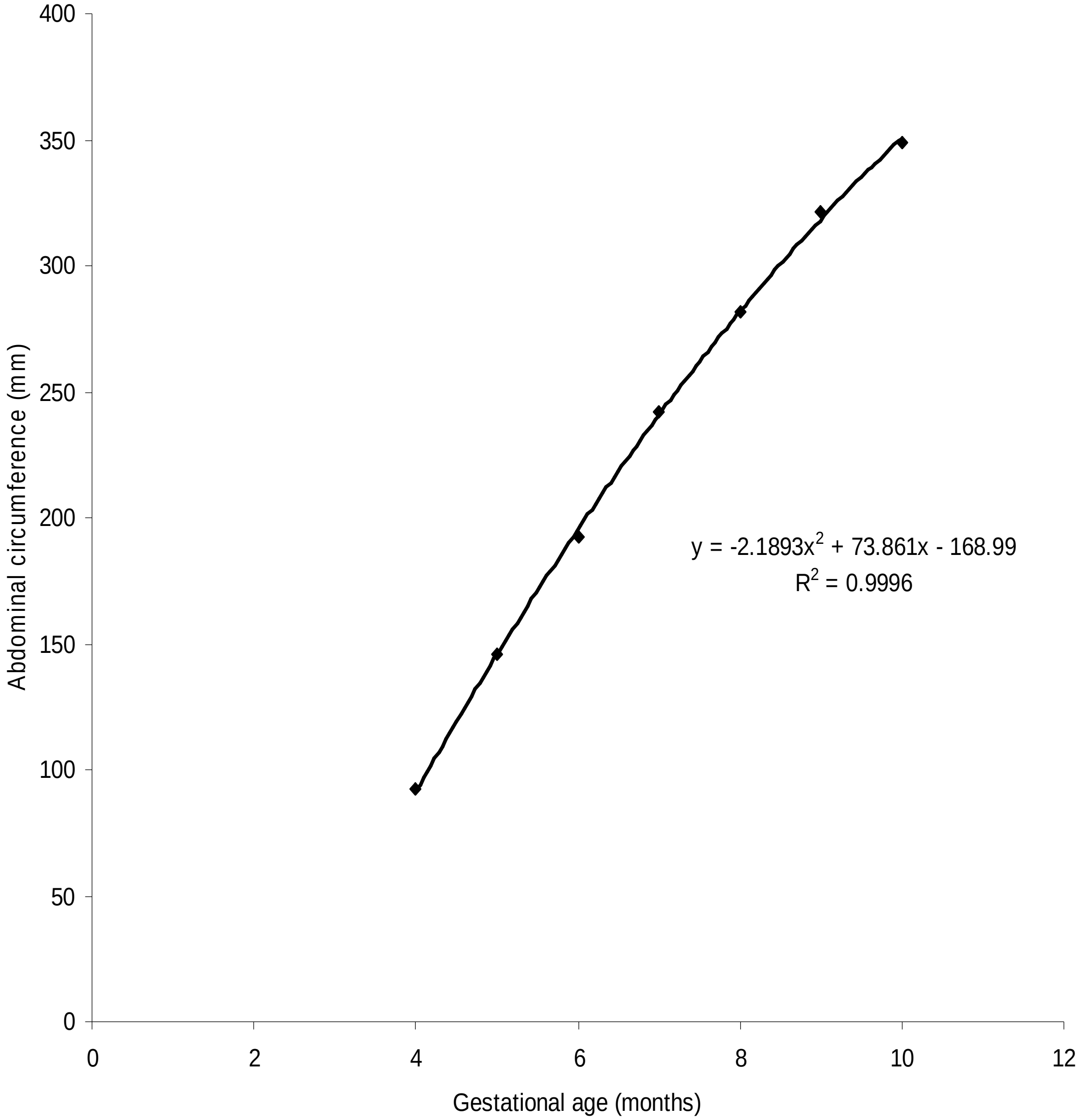

Figure 67: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months

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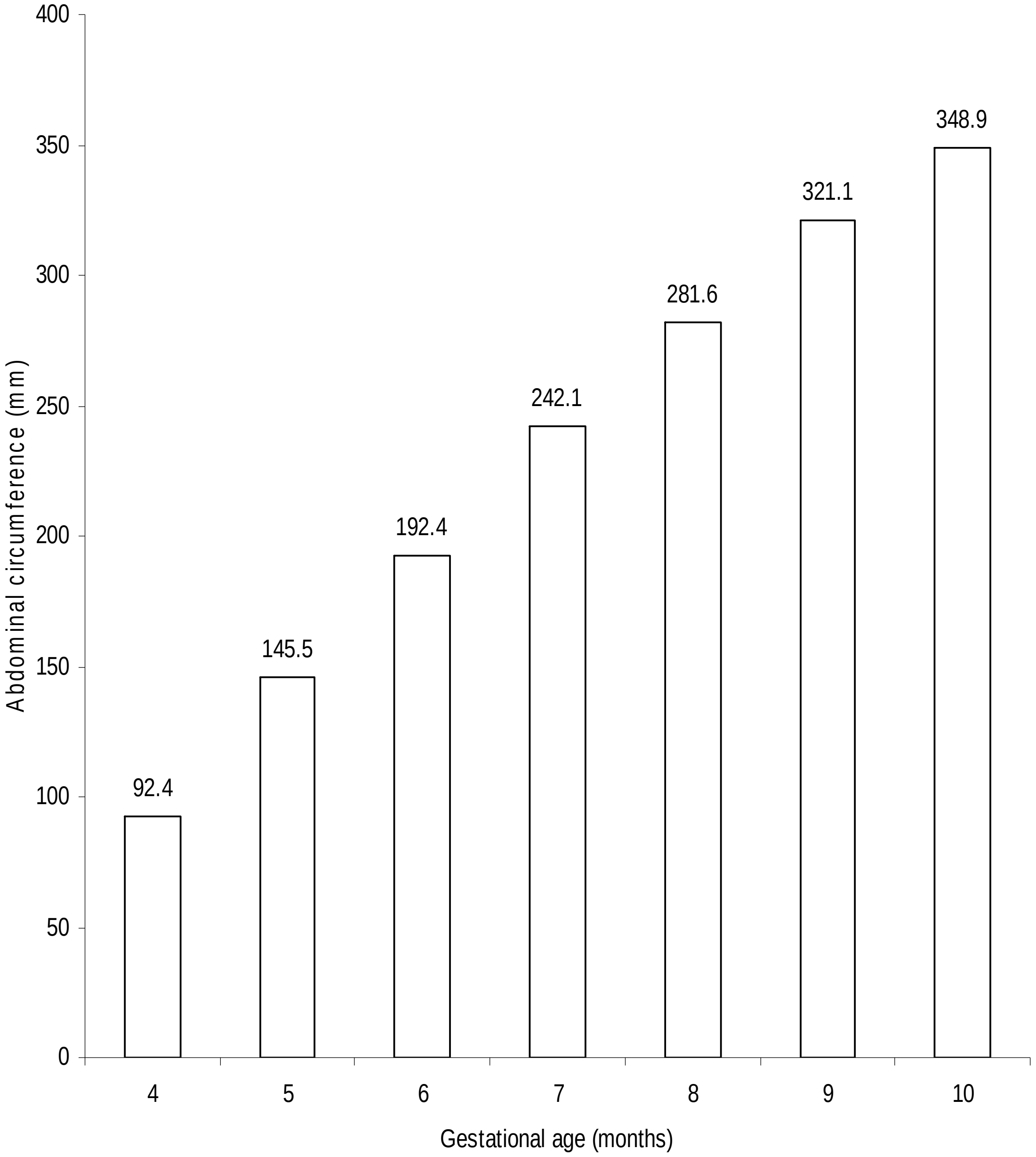

Figure 68: Histogram showing mean abdominal circumference values in 13,740 abdominal circumference data of fetuses in women of gestational ages from 4 to 10 months.

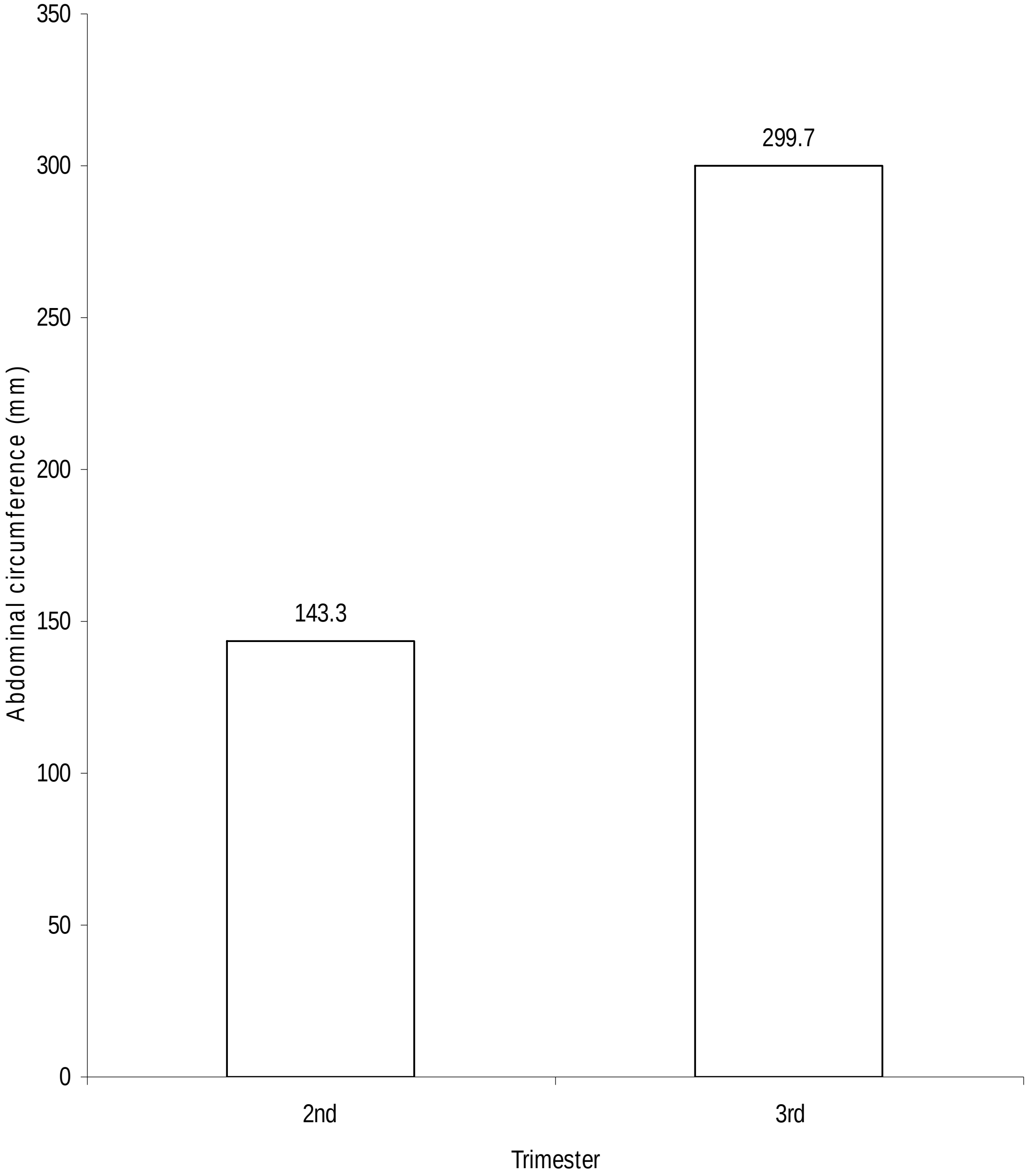

Figure 69: Histogram showing mean abdominal circumference values in 13,740 abdominal circumference data of fetuses in women of gestational ages from 4 to 10 months divided into two trimesters

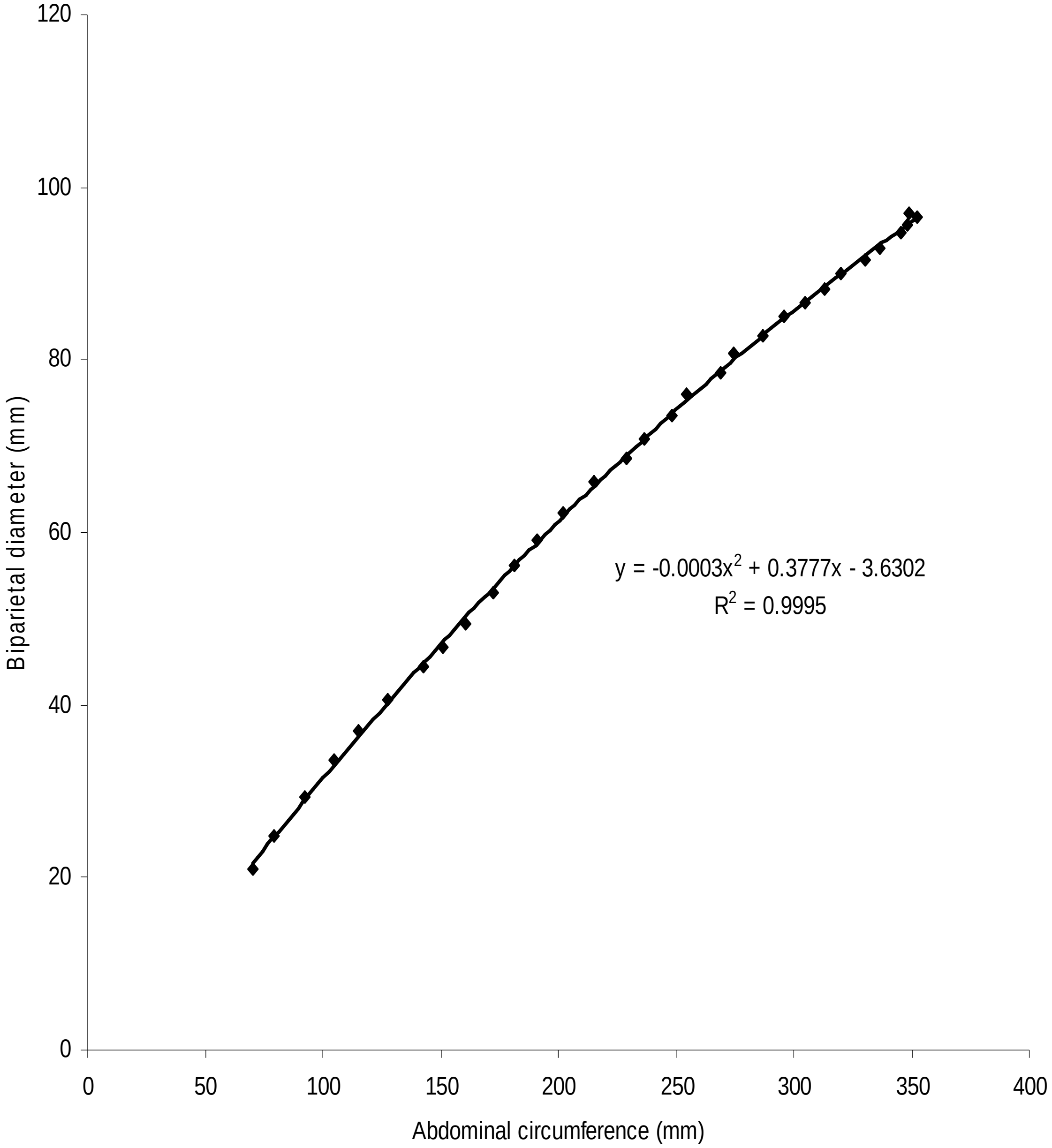

Figure 70: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter

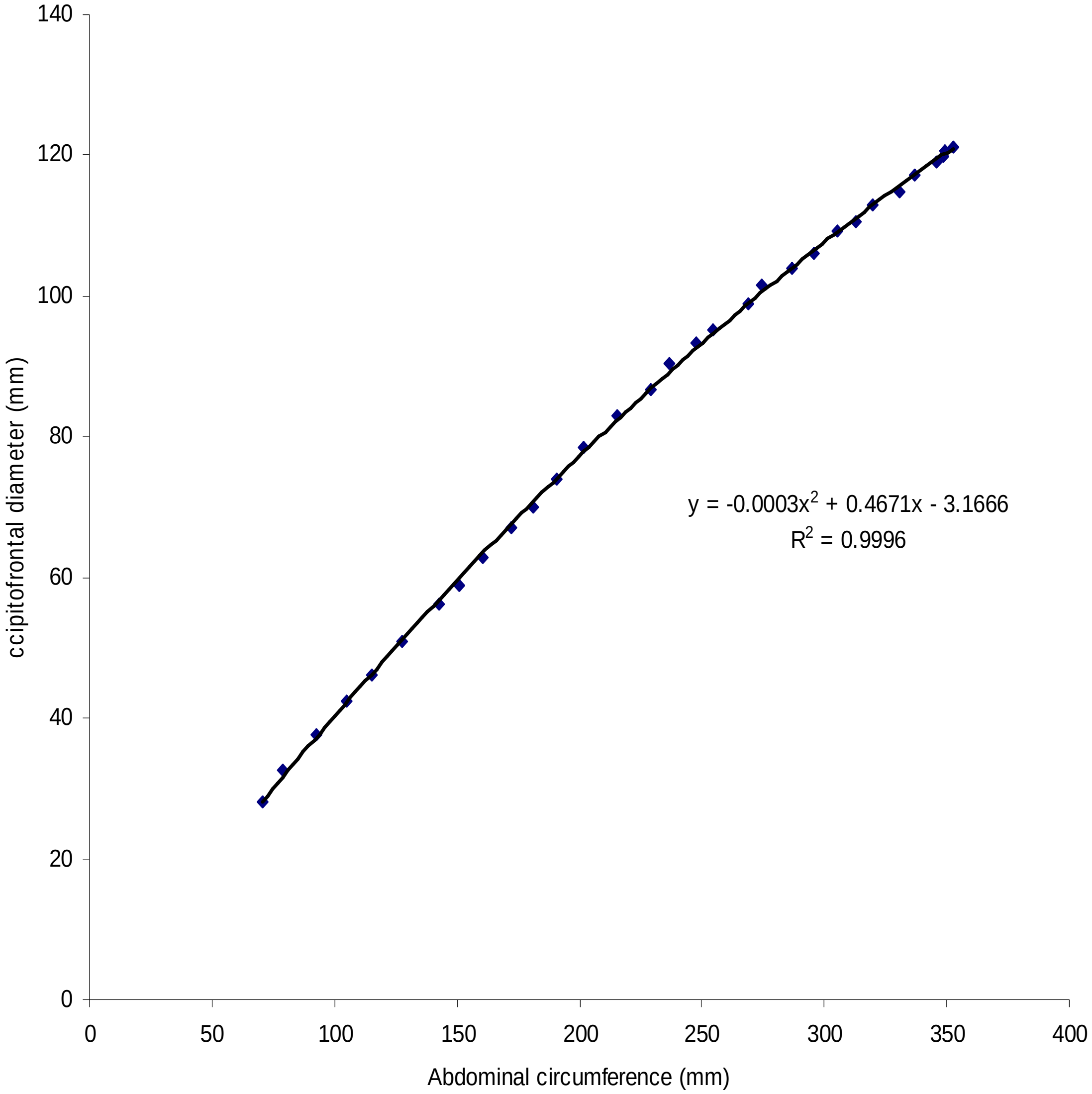

Figure 71: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter

Figure 72 shows the relationship between cephalic index and abdominal circumference. There is a positive polynomial correlation between cephalic index and abdominal circumference with a correlation of determination of $r^2 = 0.8227$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fifth order polynomial regression equation $y = 8E\text{-}11x^5 - 1E\text{-}07x^4 + 4E\text{-}05x^3 - 0.01x^2 + 1.0676x + 36.349$ where y is the cephalic index and x is the abdominal circumference in millimeters.

Figure 73 shows relationship of abdominal circumference with head circumference. From the graph, it can be seen that there is a positive polynomial correlation between abdominal circumference and head circumference with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = -0.0009x^2 + 1.3431x - 9.0021$ where y is the head circumference in millimeters and x is the abdominal circumference in millimeters. Figure 74 shows relationship between femur length and abdominal circumference. There is a positive linear correlation between femur length and abdominal circumference with a correlation of determination of $r^2 = 0.9952$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 0.2381x - 5.0199$ where y is the femur length in millimeters and x is the abdominal circumference in millimeters.

Figure 75 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and abdominal circumference. From this graph, it can be seen that there is a positive polynomial correlation between fetal weight and abdominal circumference with a correlation of determination of $r^2 = 0.9982$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the second order regression equation $y = 0.065x^2 - 16.072x + 1355.5$ where y is the fetal weight in grams and x is the abdominal circumference in millimeters.

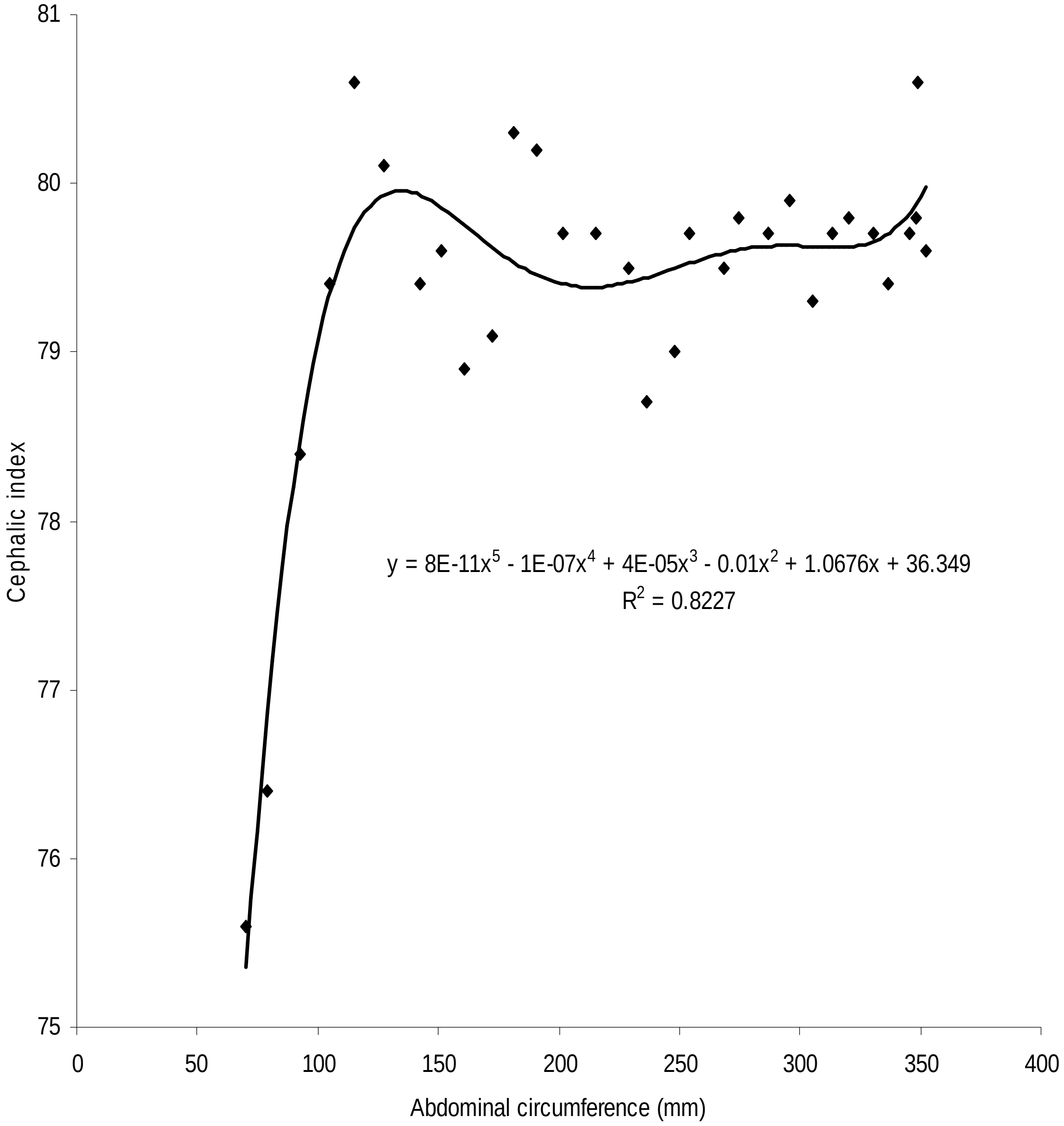

Figure 72: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against cephalic index.

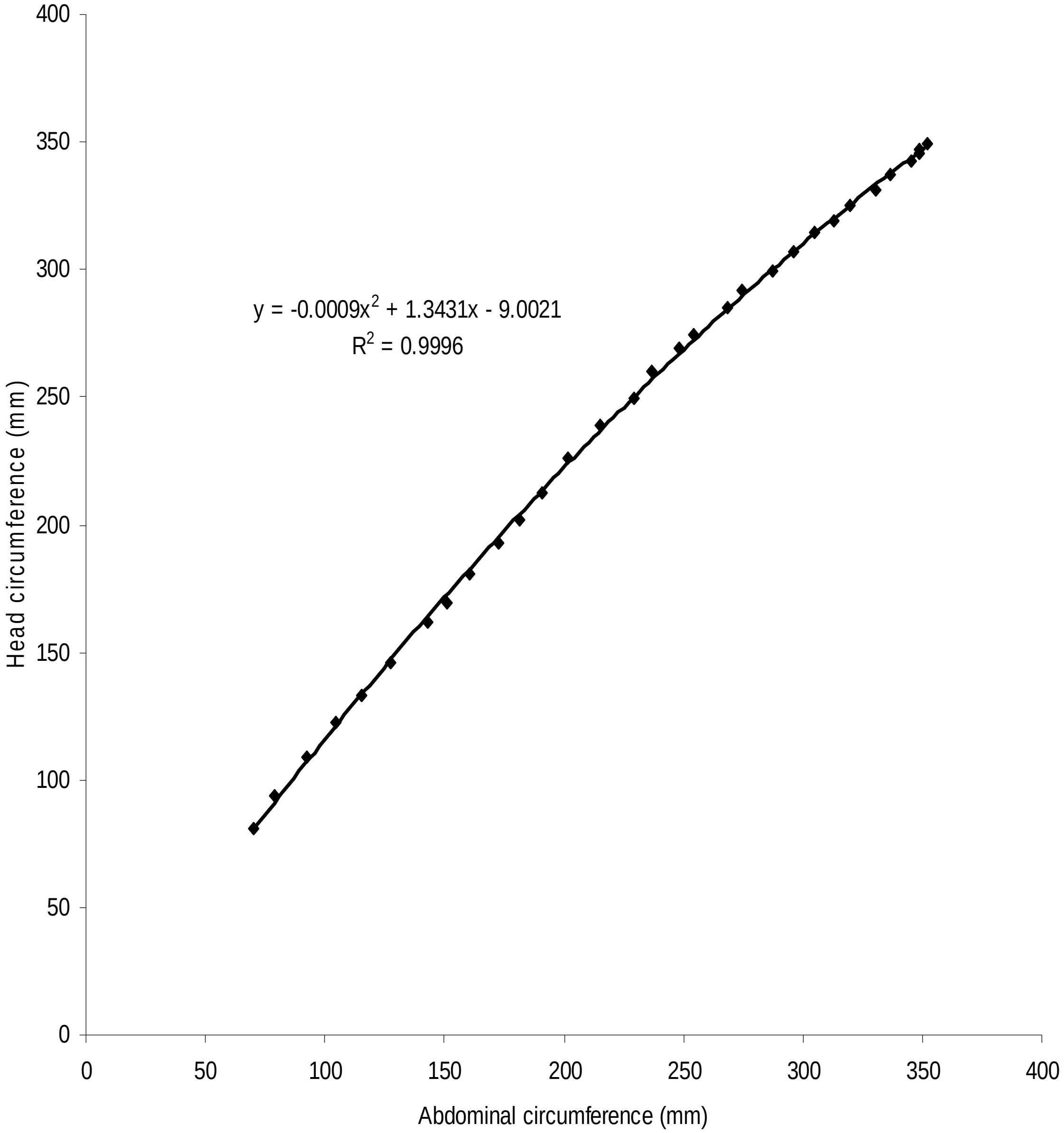

Figure 73: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference

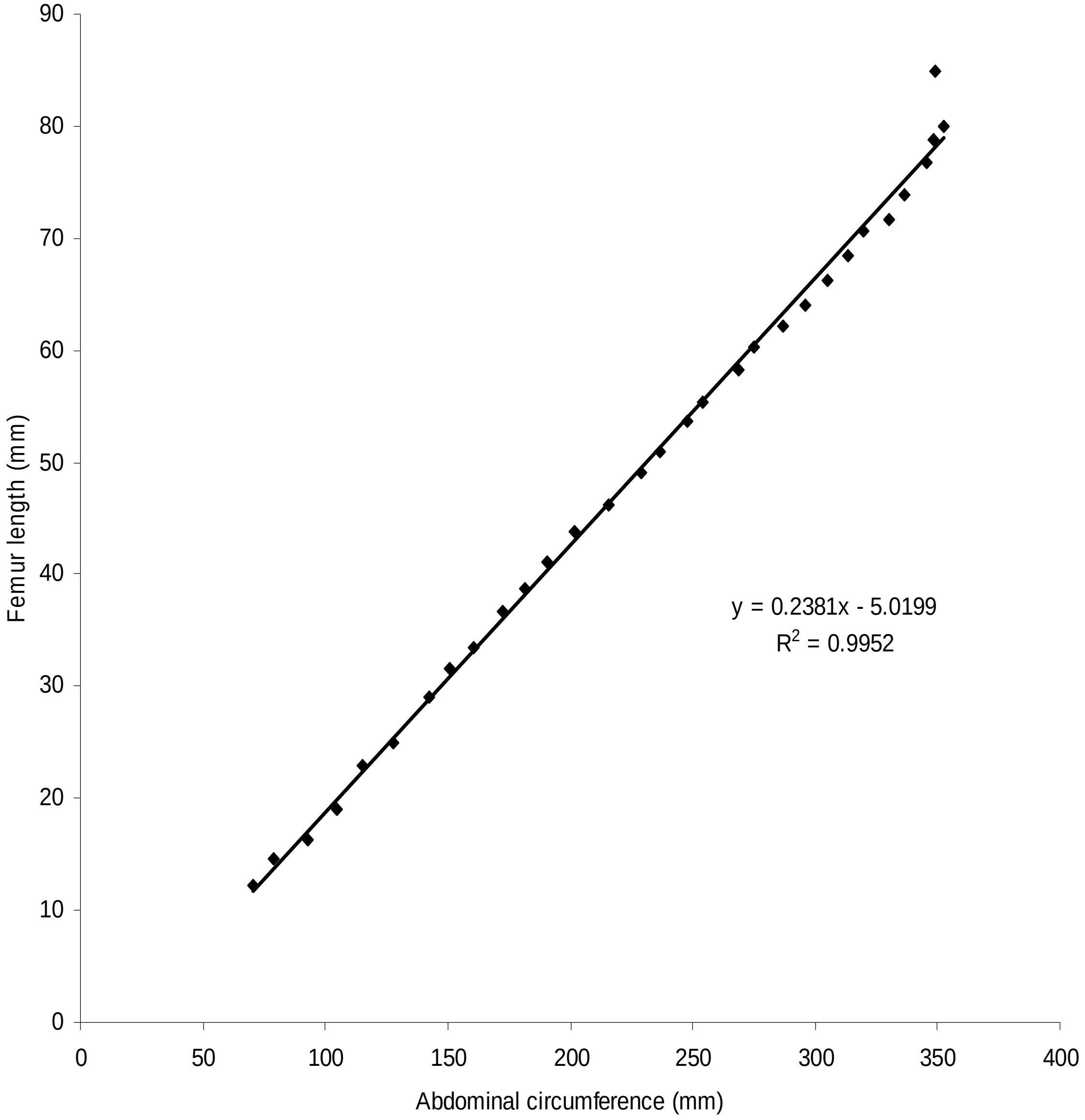

Figure 74: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against femur length.

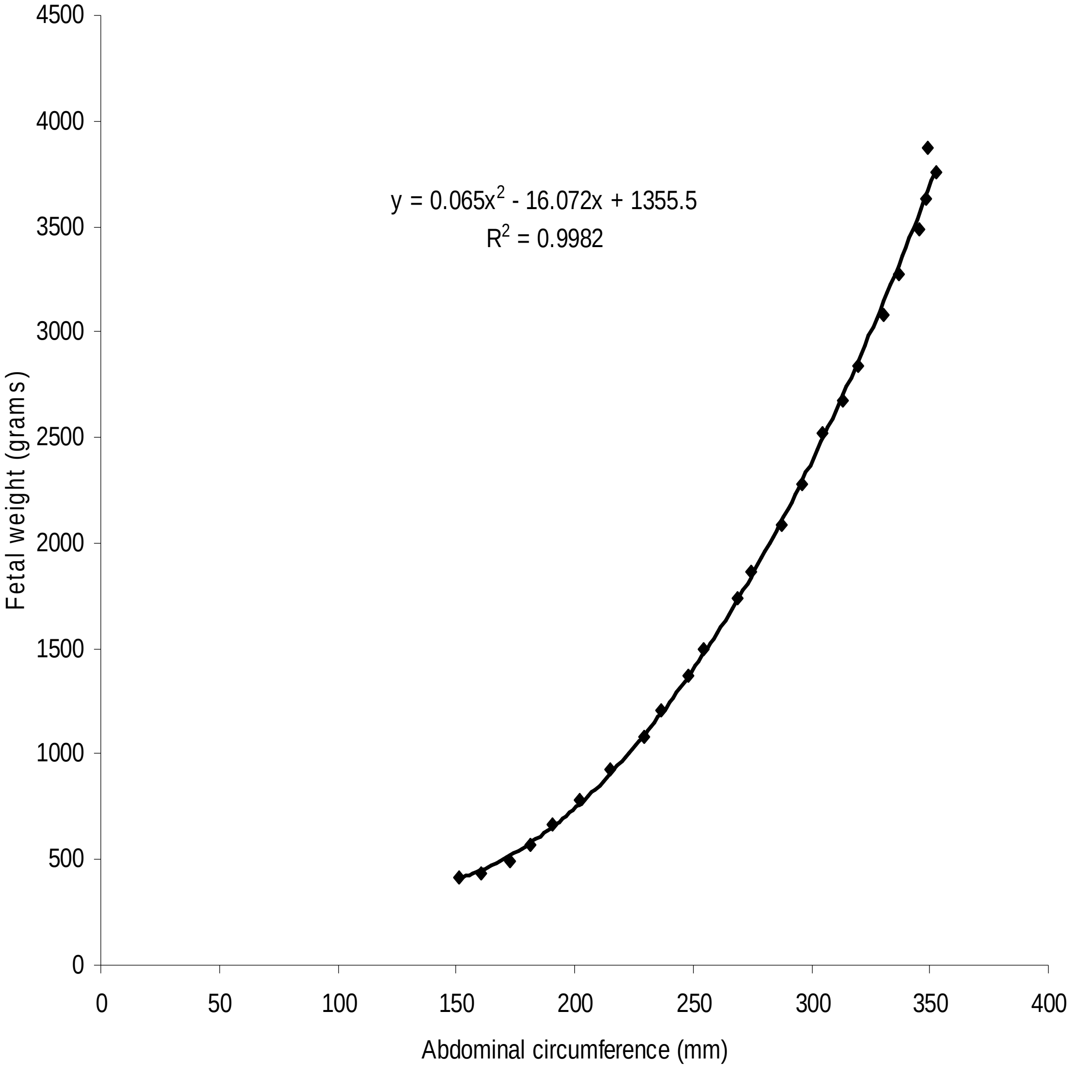

Figure 75: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against fetal weight

When the relationship between abdominal circumference and symphysio-fundal height was determined, it was found that there is a positive polynomial correlation between symphysio-fundal height and abdominal circumference with a correlation of determination of $r^2 = 0.9942$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = -0.054x^2 + 12.926x - 71.554$ where y is the abdominal circumference in millimeters and x is the symphysio-fundal height in centimeters (figure 76). Abdominal circumference centile values for 5th, 50th and 95th centiles are plotted as shown in figure 77. In figure 78, 3rd, 50th, and 97th centiles are smoothened into a growth chart which can be utilized to determine growth of fetal abdominal circumference. Figure 79 is a graphical display showing the growth rate of the measured fetal abdominal circumference. It is clear from this graph that growth rate fluctuates throughout the period of intrauterine life.

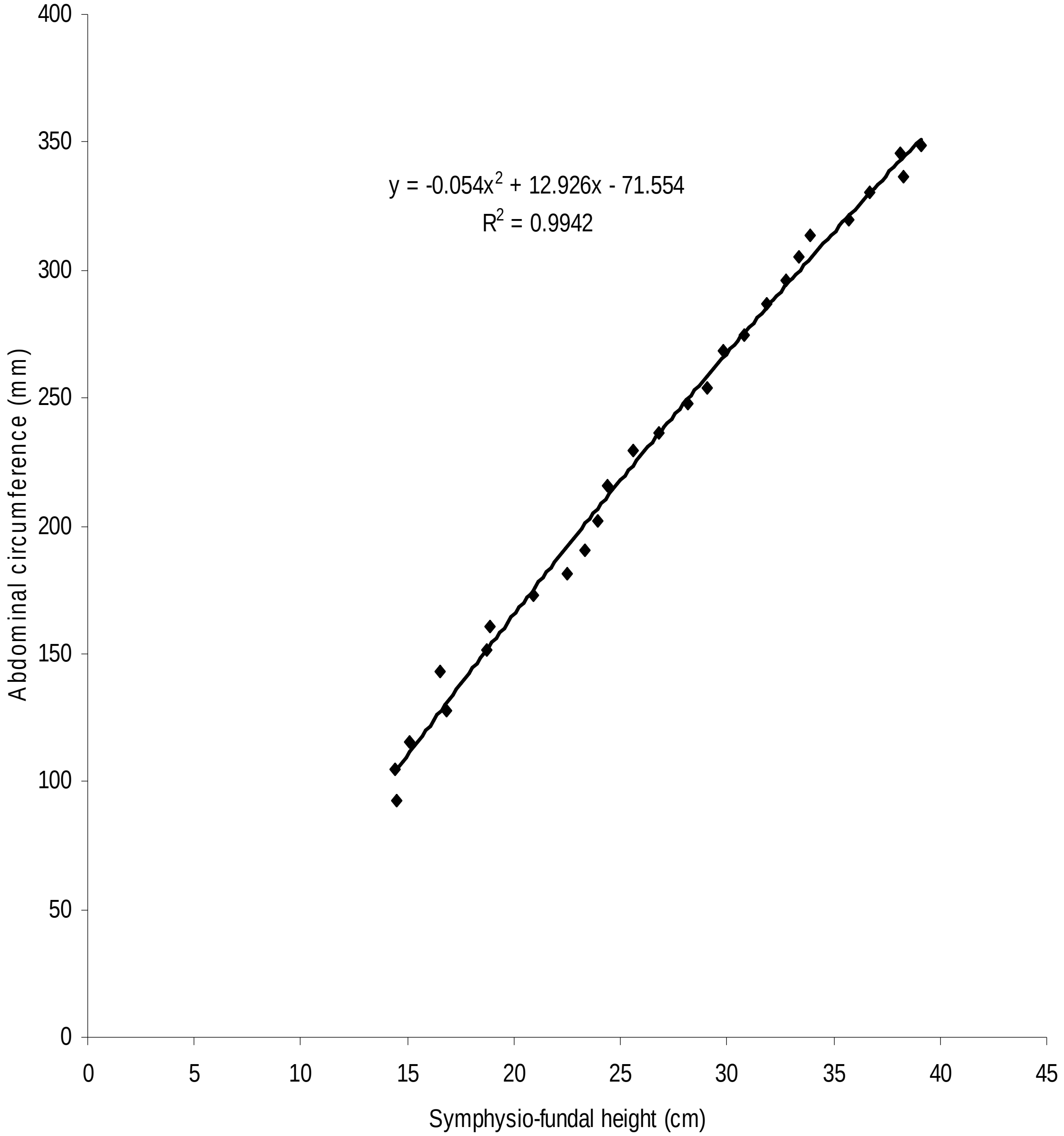

Figure 76: Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against symphysio-fundal height.

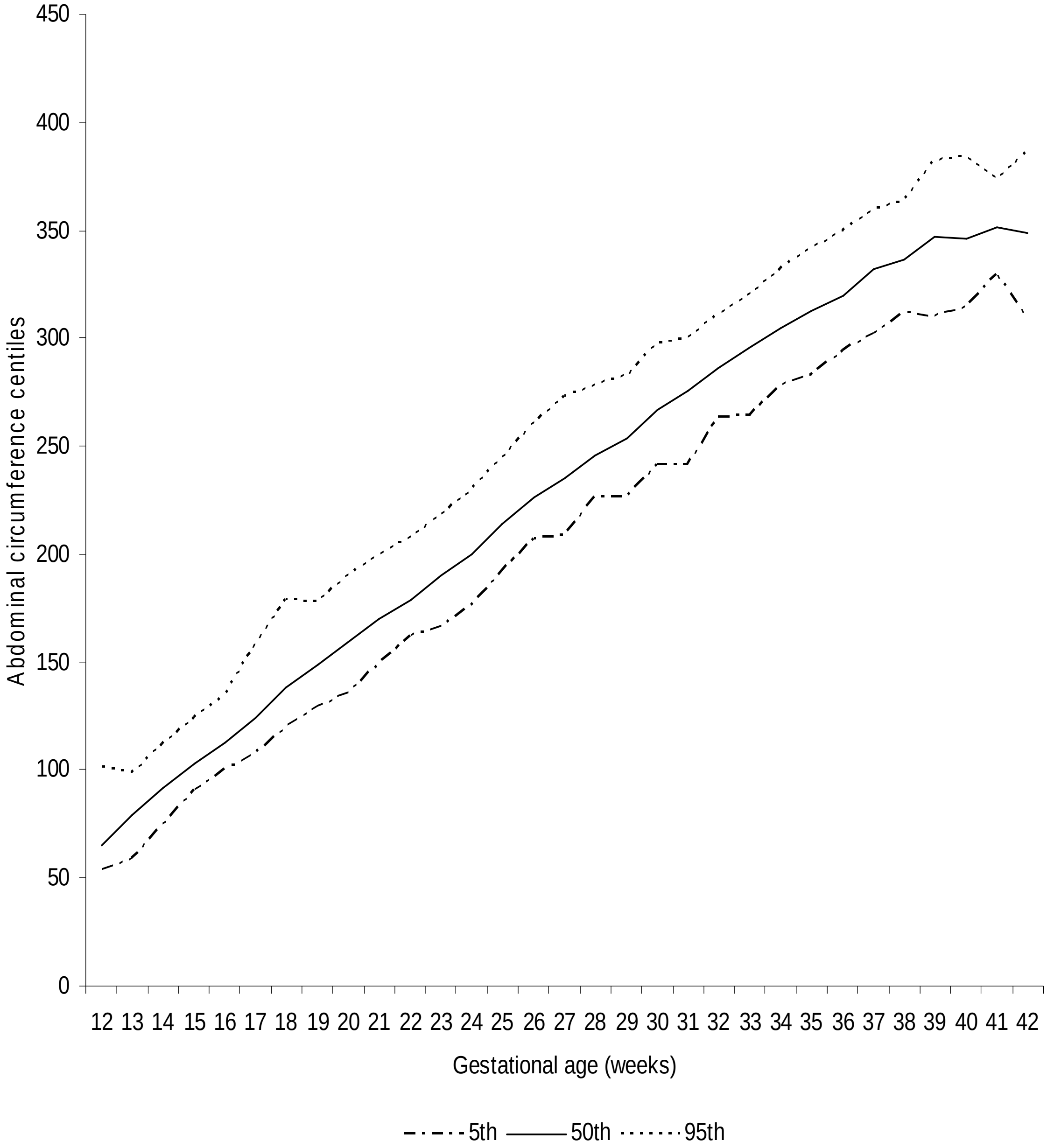

Figure 77: Fifth, 50th and 95th centiles for abdominal circumference in 13,740 fetuses at different gestational ages from 12 to 42 weeks.

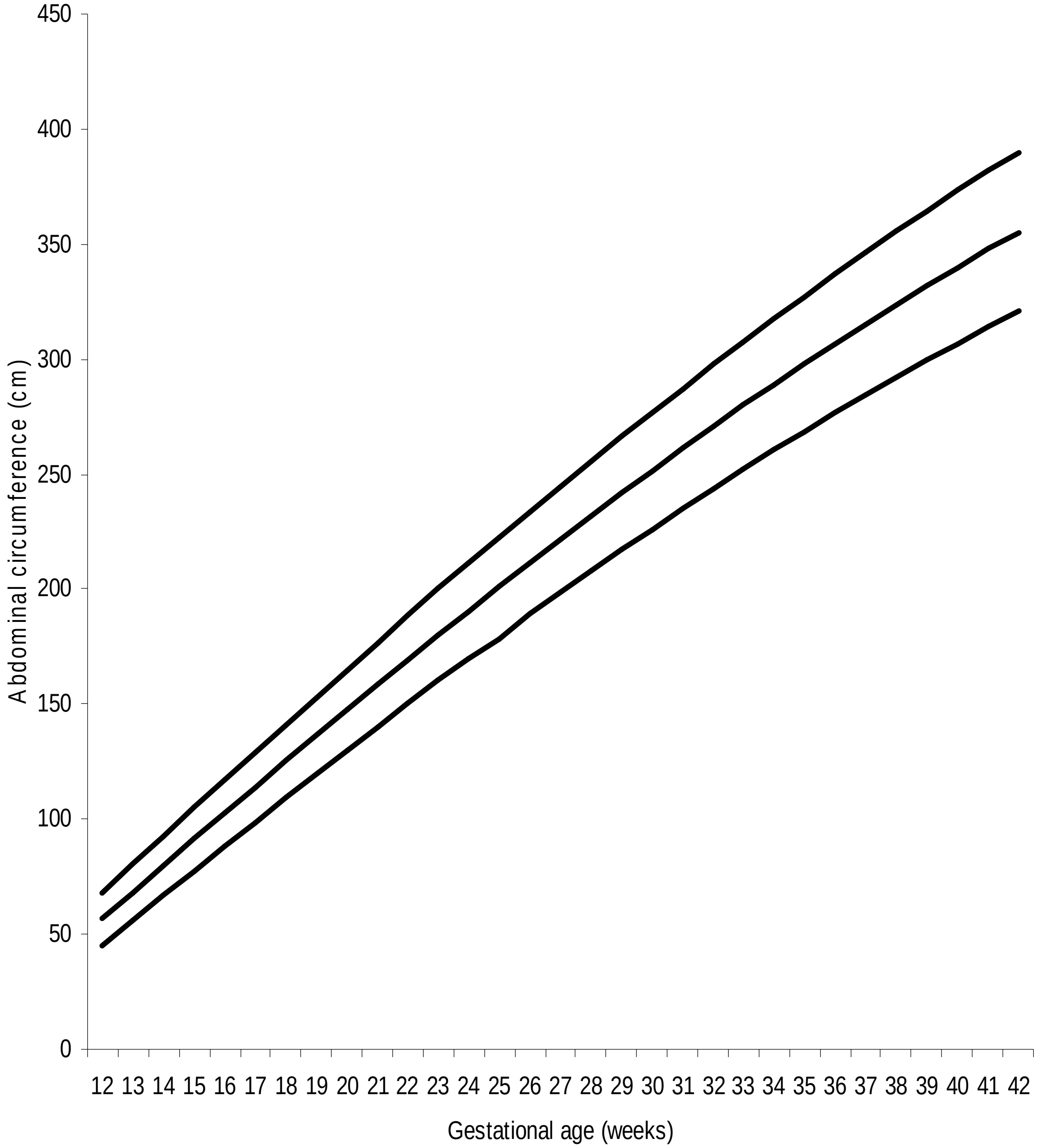

Figure 78: Curves created from 3rd, 50th and 97th fetal abdominal circumference centiles.

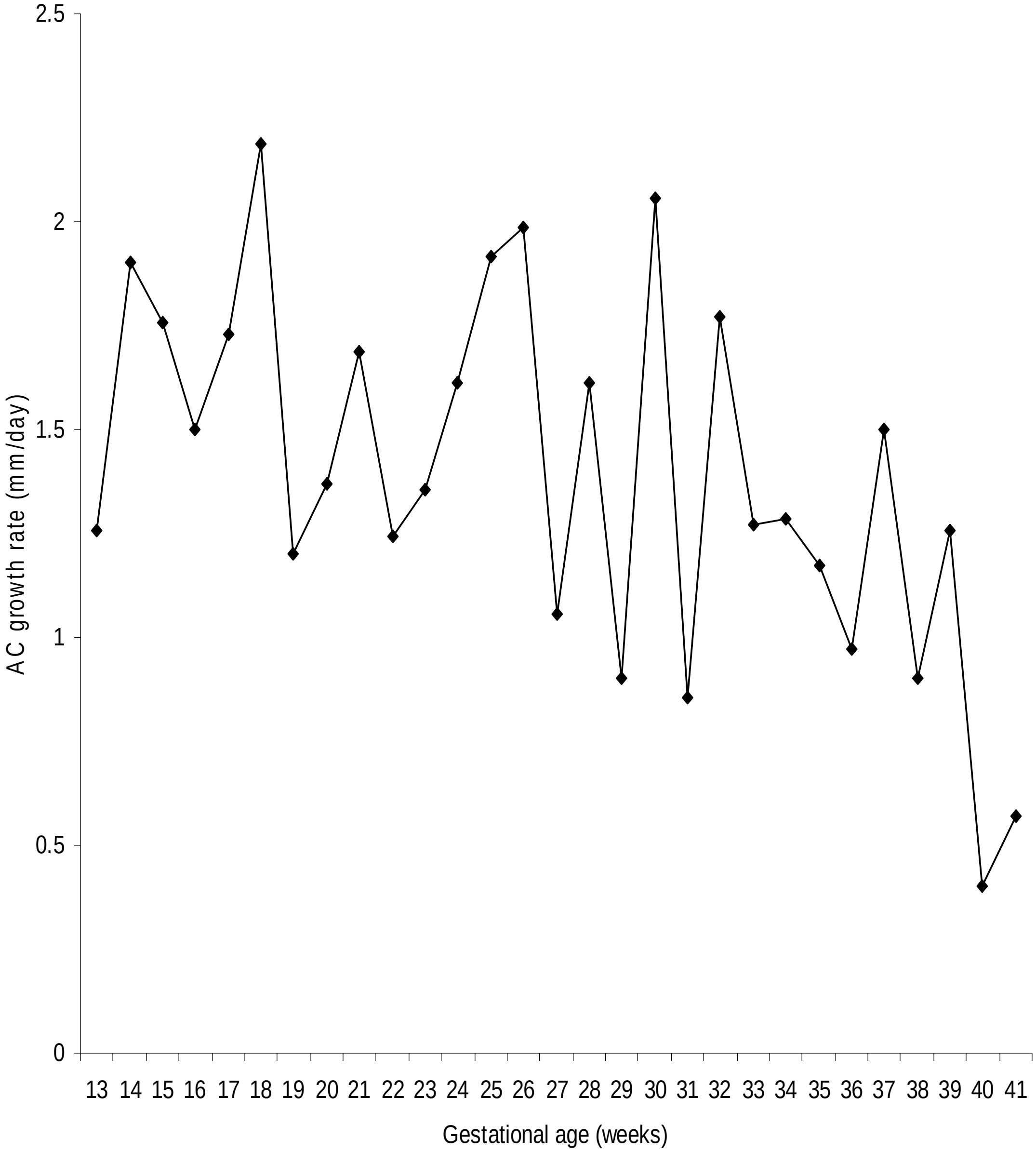

Figure 79: Growth velocity pattern of abdominal circumference in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks

4.1.5 Fetal Femur Length

Fetal femur length measurements were classified into thirty one groups. The mean values at each week of gestation from 12 – 42 are as shown in table 28. This table gives the mean values of fetal femur length measurements for each gestational age in weeks from 12 – 42 weeks together with their corresponding standard deviations and standard errors of mean. Variability of measurements was marked at weeks 16, 18, 37, 38 and 41 with the highest at 16 weeks. The standard error is found to be less than 1 throughout the period of gestation except at 42 weeks where it is 2.6 millimeters. With the arithmetic mean, one has some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean femur length at 28 weeks is 53.6mm plus 3.4mm or 53.6mm minus 3.4mm. This means 2 out of 3 measurements of femur length at 28 weeks, approximately 365 femur length measurements in a class of 548, should be between 50.2mm and 57.0mm. Since the standard error of mean at 28 weeks is 0.1mm, it is telling us that the real mean femur length of fetuses in Jos at 28 weeks is probably between 53.5mm and 53.7mm (53.6mm plus or minus 0.1mm). It can also be seen that the standard error of mean for each week of gestation from 12 – 42 is very small suggesting that the sample mean is very close to the population mean. For example, at 33 weeks gestation, the mean fetal femur length was 64.1mm while the standard error of mean was 2.4. This means that the difference between the mean femur length of the sample of fetuses at 33 weeks is just 2.4mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (table 29) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal femur length measurements were not identical. Table 30 shows the monthly fetal femur length mean values from 4th month to the 10th month with their corresponding standard deviations and standard error of mean.

Table 28: Frequency distribution table of fetal femur length measurements showing the arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.

GA (wk, days)	Fetuses (n)	Mean FL (mm)	SD	SE
12 to 12+6	49	12.2	2.1	0.3
13 to 13+6	384	14.6	8	0.4
14 to 14+6	371	16.3	4.8	0.2
15 to 15+6	351	19.0	3.1	0.2
16 to 16+6	505	22.9	6.3	0.3
17 to 17+6	427	25.0	2.9	0.1
18 to 18+6	446	29.0	5.2	0.2
19 to 19+6	282	31.6	4.3	0.3
20 to 20+6	553	33.5	3.8	0.2
21 to 21+6	400	36.7	3.9	0.2
22 to 22+6	398	38.7	3.5	0.2
23 to 23+6	478	41.1	2.9	0.1
24 to 24+6	520	43.8	3	0.1
25 to 25+6	388	46.2	3.8	0.2
26 to 26+6	511	49.1	3.6	0.1
27 to 27+6	432	50.9	2.3	0.1
28 to 28+6	548	53.6	3.4	0.1
29 to 29+6	484	55.4	3.8	0.2
30 to 30+6	625	58.3	3.5	0.1
31 to 31+6	523	60.3	3.4	0.1
32 to 32+6	583	62.1	3.3	0.1
33 to 33+6	516	64.1	2.4	0.1
34 to 34+6	744	66.2	3.4	0.1
35 to 35+6	739	68.5	2.4	0
36 to 36+6	599	70.6	3.3	0.1
37 to 37+6	532	71.7	5.5	0.2
38 to 38+6	481	73.9	4.7	0.2
39 to 39+6	525	76.7	3	0.1
40 to 40+6	252	78.8	3.7	0.2
41 to 41+6	72	79.9	5.4	0.6
42 to 42+6	22	84.9	12	2.6
Total	**13,740**			

Table 29: Frequency distribution table of fetal femur length measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.

GA (week, days)	Number of fetuses (n)	Arithmetic mean	Geometric mean	Harmonic mean
12 to 12+6	49	12.20408	12.04776	11.9039
13 to 13+6	384	14.64063	13.85937	13.48663
14 to 14+6	371	16.34232	15.98908	15.74245
15 to 15+6	351	19.0114	18.78066	18.55452
16 to 16+6	505	22.93465	22.45429	22.13357
17 to 17+6	427	24.97424	24.80889	24.64348
18 to 18+6	446	29.00897	28.66378	28.37964
19 to 19+6	282	31.59575	31.33629	31.08744
20 to 20+6	553	33.4991	33.29572	33.09573
21 to 21+6	400	36.7075	36.50051	36.28643
22 to 22+6	398	38.72613	38.56079	38.38766
23 to 23+6	478	41.14675	41.04465	40.94054
24 to 24+6	520	43.77735	43.66936	43.5484
25 to 25+6	388	46.18299	46.00735	45.79766
26 to 26+6	511	49.08806	48.96292	48.84365
27 to 27+6	432	50.90278	50.84937	50.79458
28 to 28+6	548	53.55109	53.44577	53.34311
29 to 29+6	484	55.42355	55.26376	55.05746
30 to 30+6	625	58.2512	58.15721	58.06916
31 to 31+6	523	60.25813	60.16758	60.08173
32 to 32+6	583	62.0566	61.96439	61.86463
33 to 33+6	516	64.1376	64.08805	64.03426
34 to 34+6	744	64.1376	64.08805	64.03426
35 to 35+6	739	68.51151	68.47121	68.43069
36 to 36+6	599	70.5793	70.50031	70.41488
37 to 37+6	532	71.7124	71.26648	69.96014
38 to 38+6	481	73.88982	73.64711	73.19981
39 to 39+6	525	76.70477	76.64517	76.58453
40 to 40+6	252	78.78175	78.69141	78.59788
41 to 41+6	72	79.93056	79.76249	79.60353
42 to 42+6	22	84.90909	84.10523	83.32234
Total	**13,740**			

Table 30: Monthly mean fetal femur length values (in mm) in a Nigerian population

G.A (months)	Fetuses (n)	Mean (mm)	S.D	S.E
4	1660	17.0	4.1	1.8
5	1708	29.8	3.7	1.8
6	2184	41.3	3.8	1.7
7	1975	52.2	2.8	1.4
8	2247	61.2	2.5	1.3
9	3095	69.8	3.7	1.7
10	871	80.1	3.5	1.7
Total	13,740			

The fetal femur length values during second and third trimesters are shown in table 31 while table 32 gives the centile values of fetal femur length measurements. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal femur length measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 5th percentile of femur length at 26 to 26 + 6 weeks gestation is 44 millimeters. This means that 5% of the fetuses at 26 to 26 + 6 had a mean femur length less than 44 millimeters, while 95% had a mean femur length greater than 44 millimeters. Similarly, the 90th percentile of femur length at 33 to 33 + 6 weeks is 65 millimeters. Hence 90% of fetuses at 33 to 33 + 6 weeks had a mean femur length less than 65 millimeters while 10% had a mean femur length greater than 65 millimeters. The standard score or z-score of femur length measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in table 33. The z-score enables one to look at femur length measurements at each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, femur length measurements at 20 weeks are 0.0000 standard deviations from the mean while measurements at 36 weeks are – 0.0014 standard deviations from the mean. Again, from the above z-score table, it can be seen that the femur length measurements at 38 weeks gestation are – 0.00067 standard deviations from the mean.

When femur length data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (figure 80), it can be seen that the distribution of femur length measurements has a longer "tail" to the right of the central maximum than to the left or is skewed to the right from 13 – 21weeks and then at 26, 28, 30, 31, 32, 35, and 41weeks. From 22 – 25weeks and then at 27, 29, 33, 34, 36, 37, 38, 39 and 40weeks, the distribution has a longer "tail" to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks.

Table 31: Trimester mean fetal femur length values

Trimester	Fetuses (n)	Mean	S.D	S.E	Minimum	Maximum	Range
2nd	5552	29.3	11.2	3.0	12.2	46.2	33.9
3rd	8188	66.0	10.7	2.6	49.1	84.9	35.8
Total	13,740						

Table 32: Fetal femur length centiles from 12 – 42 weeks

	Femur Length percentiles (mm)						
GA (weeks, days	3rd	5th	10th	50th	90th	95th	97th
12 to 12+6	9.0	9.5	10.0	12.0	14.0	17.0	19.0
13 to 13+6	10.0	10.0	11.0	14.0	16.0	18.0	20.5
14 to 14+6	12.0	12.0	13.0	16.0	19.0	21.0	21.0
15 to 15+6	13.6	14.0	16.0	19.0	22.0	23.4	24.0
16 to 16+6	17.0	18.0	19.0	22.0	26.0	27.0	28.0
17 to 17+6	20.0	20.0	21.0	25.0	27.0	30.0	31.0
18 to 18+6	22.0	23.0	25.0	29.0	31.0	33.0	37.0
19 to 19+6	26.0	27.0	28.0	31.0	36.0	37.8	42.6
20 to 20+6	26.6	27.0	29.0	34.0	38.0	39.0	40.0
21 to 21+6	29.0	30.0	32.0	37.0	40.0	41.0	42.0
22 to 22+6	30.0	32.0	34.0	39.0	42.0	43.0	44.0
23 to 23+6	35.0	36.0	37.0	42.0	44.0	46.0	46.0
24 to 24+6	38.0	39.0	40.0	44.0	47.0	48.0	49.0
25 to 25+6	39.7	41.0	42.9	46.0	49.0	52.0	53.0
26 to 26+6	42.0	44.0	46.0	49.0	52.8	55.0	56.0
27 to 27+6	46.0	47.0	48.3	51.0	54.0	54.4	55.0
28 to 28+6	48.0	49.0	50.0	54.0	57.0	58.0	59.0
29 to 29+6	50.0	51.0	52.5	55.0	59.0	61.0	62.0
30 to 30+6	52.0	53.3	56.0	58.0	61.0	63.0	65.0
31 to 31+6	55.0	55.0	57.0	60.0	62.0	64.0	66.0
32 to 32+6	56.0	57.0	59.0	62.0	64.0	65.0	66.0
33 to 33+6	59.0	60.0	62.0	64.0	65.0	66.0	67.0
34 to 34+6	60.0	62.0	64.0	66.5	68.0	69.0	70.0
35 to 35+6	63.0	65.0	66.0	69.0	70.0	70.0	72.0
36 to 36+6	65.0	66.0	68.0	71.0	72.0	72.0	73.0
37 to 37+6	64.0	65.0	69.0	73.0	74.0	74.0	75.0
38 to 38+6	66.0	69.0	71.0	75.0	76.0	76.0	77.0
39 to 39+6	70.0	71.3	73.0	77.0	79.0	80.0	81.0
40 to 40+6	69.7	72.0	74.0	80.0	83.0	83.4	84.4
41 to 41+6	73.0	73.0	74.3	79.0	88.0	92.0	96.9
42 to 42+6	71.0	71.0	71.6	81.0	99.0	99.0	99.0

Table 33: Standard score (z-score) of femur length measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	3.89E-04
13 to 13+6	384	4.23E-03
14 to 14+6	371	3.59E-03
15 to 15+6	351	8.26E-04
16 to 16+6	505	3.57E-03
17 to 17+6	427	-2.36E-03
18 to 18+6	446	3.82E-04
19 to 19+6	282	-2.80E-04
20 to 20+6	553	-7.12E-05
21 to 21+6	400	6.41E-04
22 to 22+6	398	2.31E-03
23 to 23+6	478	3.49E-03
24 to 24+6	520	-1.45E-03
25 to 25+6	388	-1.22E-03
26 to 26+6	511	-7.85E-04
27 to 27+6	432	1.80E-04
28 to 28+6	548	-3.68E-03
29 to 29+6	484	1.01E-03
30 to 30+6	625	-2.87E-03
31 to 31+6	523	-2.81E-03
32 to 32+6	583	-2.95E-03
33 to 33+6	516	2.91E-03
34 to 34+6	744	2.44E-03
35 to 35+6	739	8.52E-04
36 to 36+6	599	-1.41E-03
37 to 37+6	532	9.06E-04
38 to 38+6	481	-6.75E-04
39 to 39+6	525	3.31E-04
40 to 40+6	252	-1.29E-03
41 to 41+6	72	2.59E-03
42 to 42+6	22	3.90E-04
Total	**13,740**	

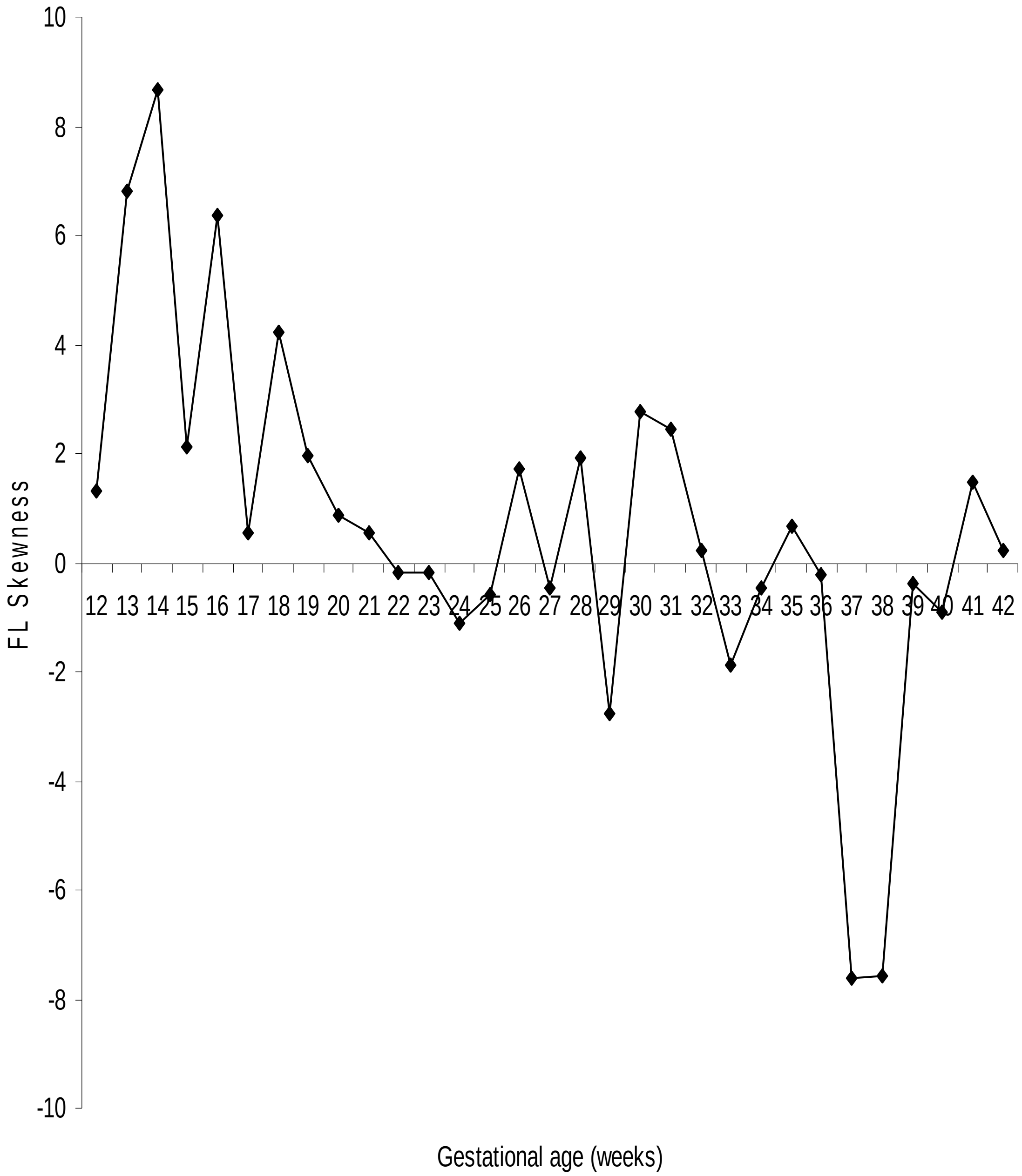

Figure 80: Femur length data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.

When the femur length data was subjected to kurtosis analysis (figure 81), the distribution was found to be leptokurtic at 13, 14, 16, 37 and 38 weeks of gestation while at other weeks of gestation, the distribution was mesokurtic. The coefficient of dispersion of femur length data of 13,740 fetuses at different gestational age shows a decrease in value as gestational age advances except at term where it peaks (figure 82).

The femur length scattergram in figure 83 shows that there are very few bad data points or outliers in the femur length measurements of 13,740 fetuses. The outliers are more from 26 – 42 weeks of gestation. In figure 84, mean femur length is plotted against gestational age with error bars showing standard deviation. Arithmetic mean and standard deviation go together like star and satellite. With the mean, we have some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean ± 1 standard deviation will include about 2 out of 3 numbers in the group while the mean ± 2 standard deviations will include about 95 out of 100 numbers in the group and the mean ± 3 standard deviations will include 997 numbers out of 1,000. Mathematical modeling of data demonstrated that the best-fitted regression model (figure 85) to describe the relationship between femur length and gestational age was the second order polynomial regression equation $y = -0.017x^2 + 3.2794x - 25.282$ with a correlation of determination of $r^2 = 0.999$ ($P < 0.0001$) where y is the femur length in millimeters and x is the gestational age in weeks. When monthly mean values of femur length are plotted against gestational age in months, a positive polynomial correlation between gestational age and femur length with a correlation of determination of $r^2 = 0.9992$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 86). The relationship is best described by the second order polynomial regression equation $y = -3.667x^2 + 15.462x - 38.6$ where y is the femur length in millimeters and x is the gestational age in months.

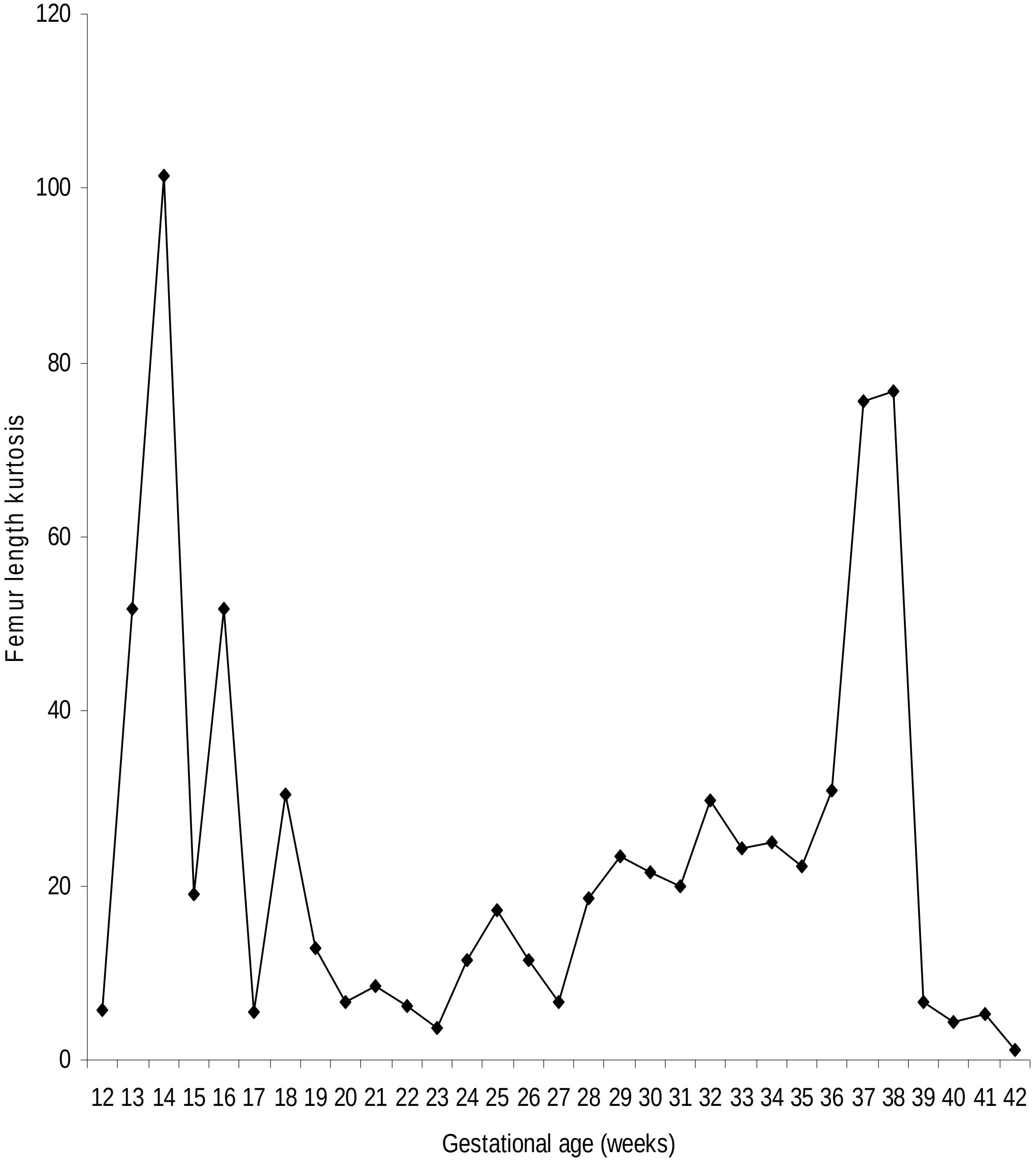

Figure 81: Femur length data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.

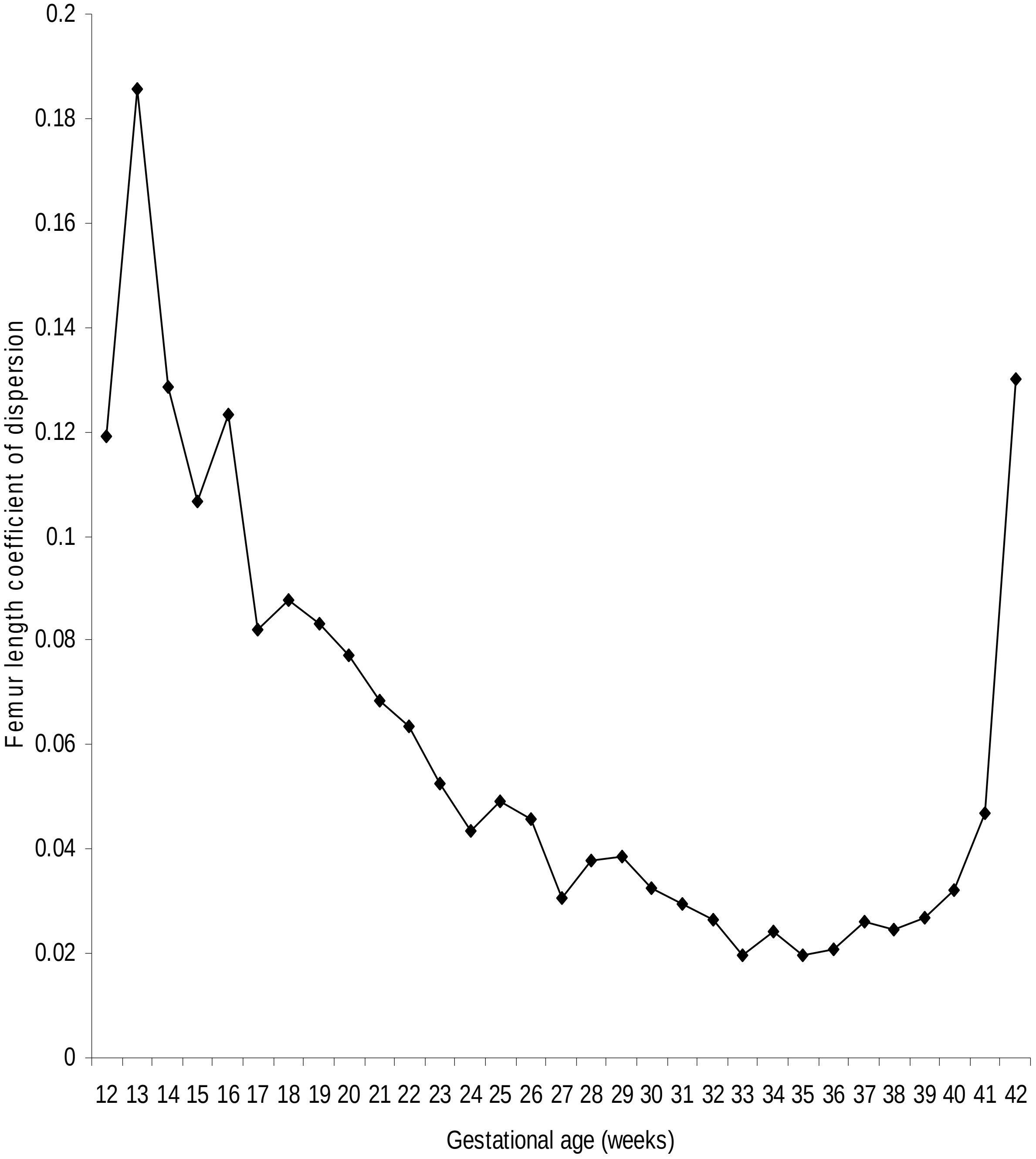

Figure 82: Femur length coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.

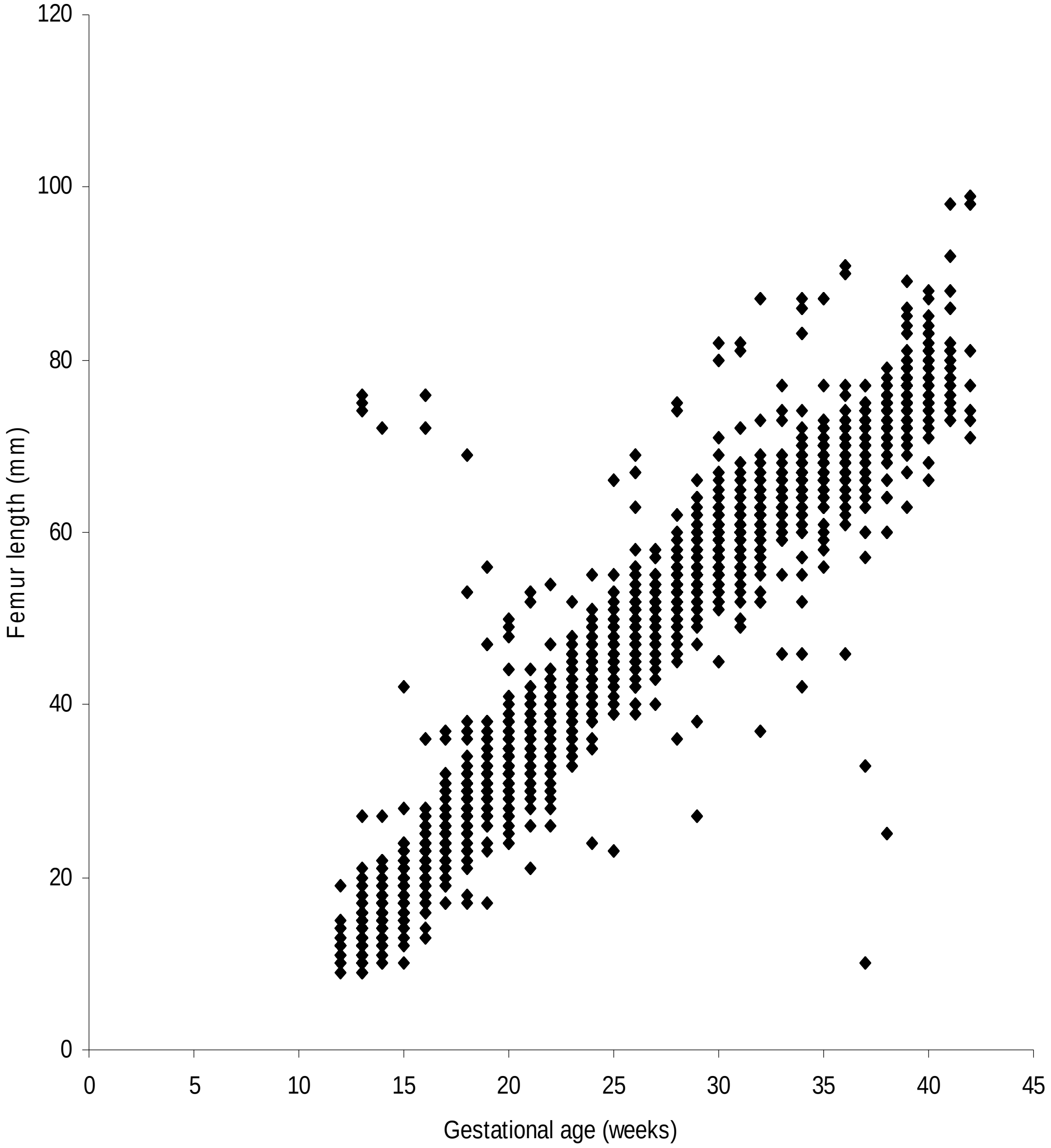

Figure 83: Scattergram of 13,740 fetal femur length measurements from 12 – 42 weeks gestation.

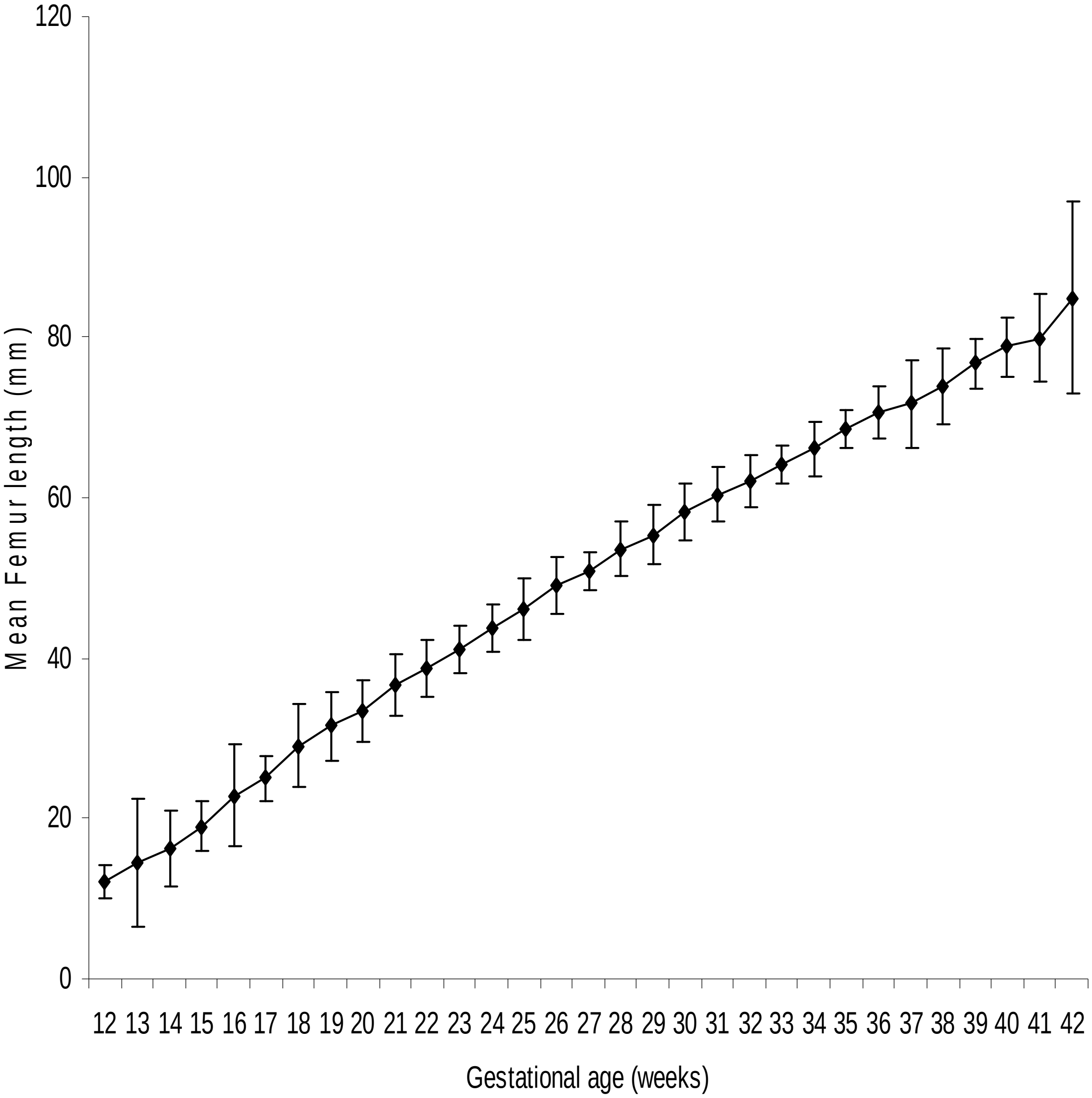

Figure 84: Mean fetal femur length values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.

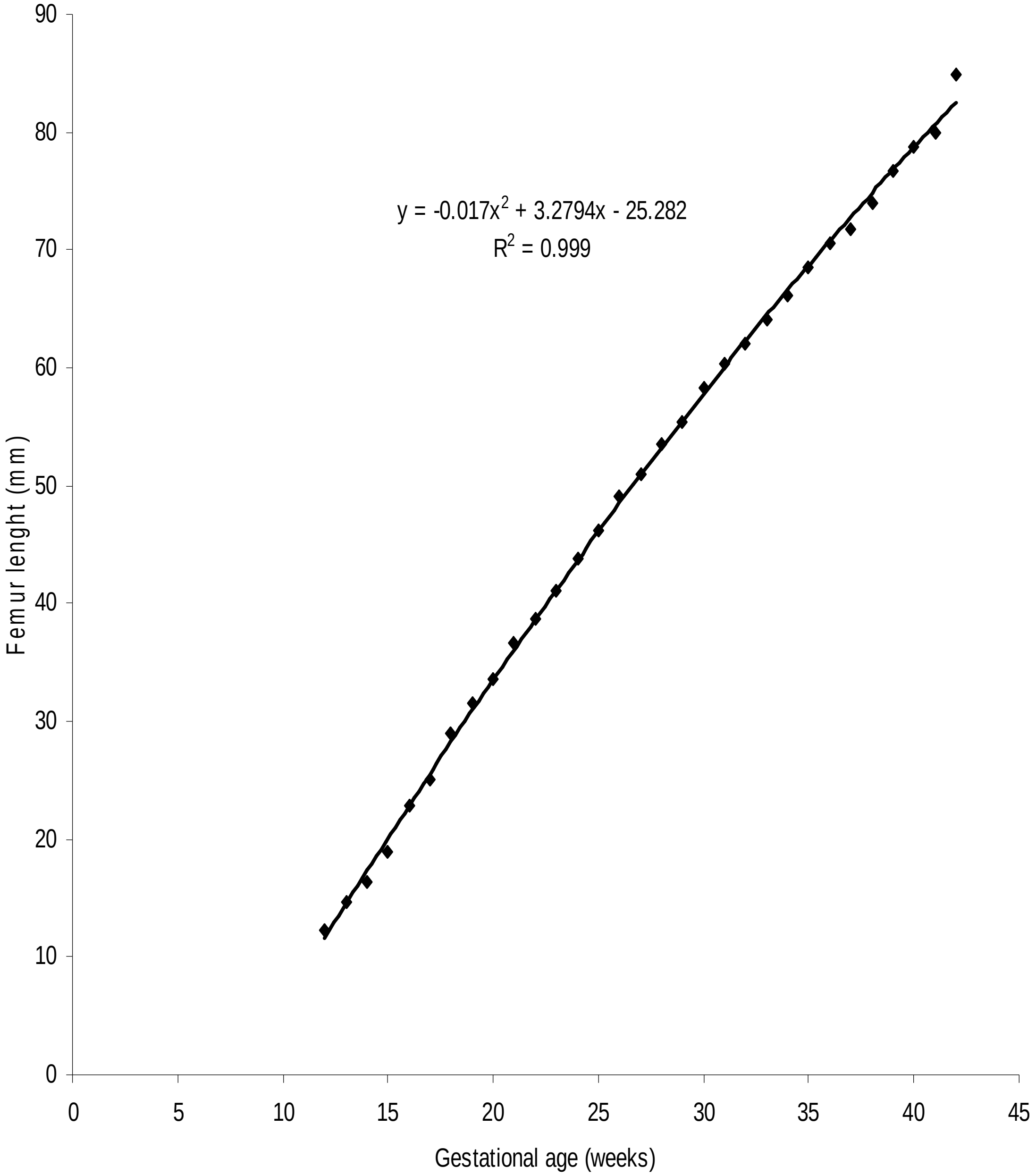

Figure 85: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks

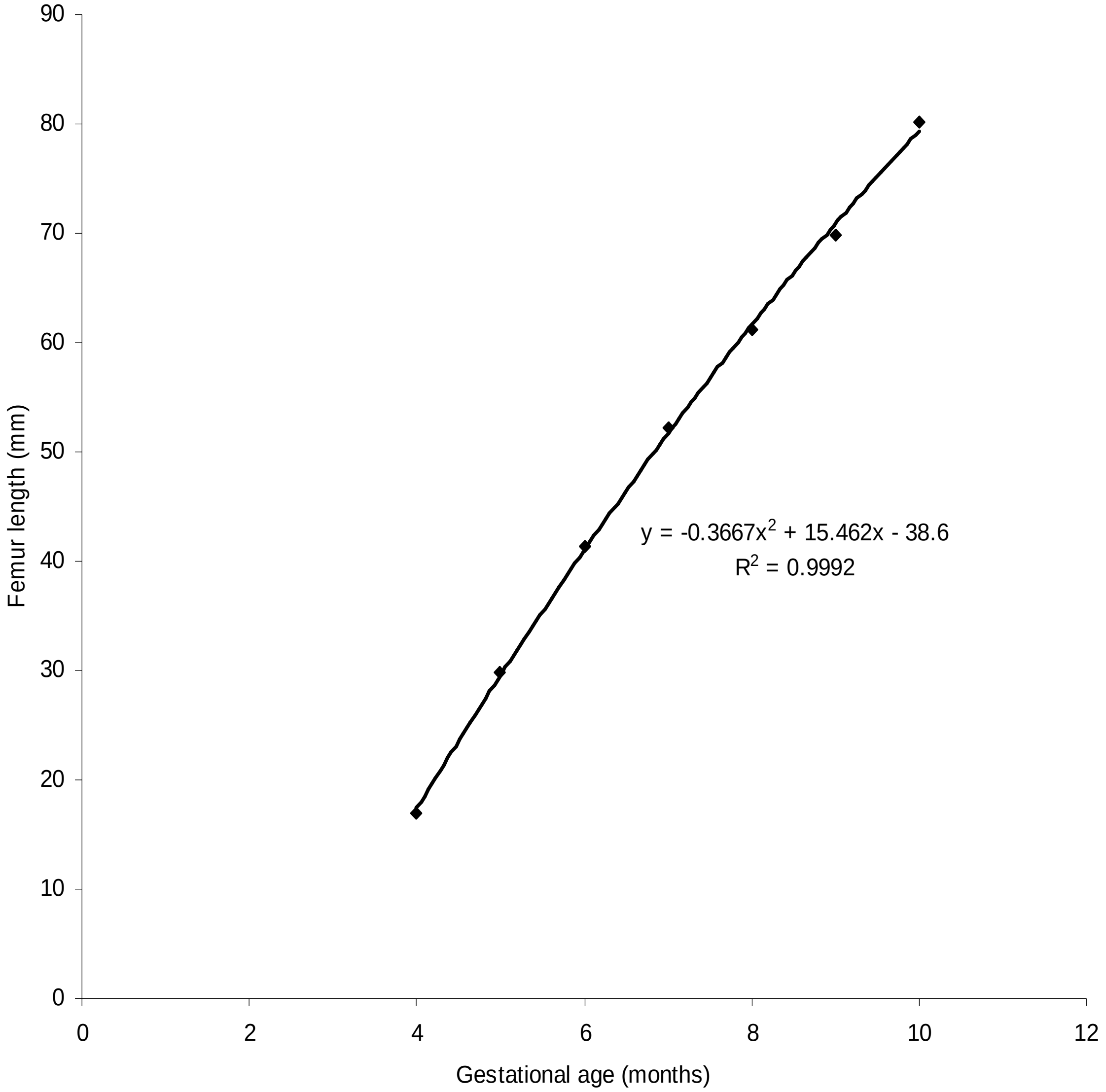

Figure 86: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months

Figure 87 shows histogram of monthly mean of femur length. Figure150 shows histogram of mean femur length at 2nd and 3rd trimesters.

When other fetal anthropometric parameters like head circumference, biparietal diameter, occipitofrontal diameter, abdominal circumference and weight are plotted against femur length certain hidden relationships can be forced out. For example, figure 89 shows the relationship of femur length with biparietal diameter. From the graph, it can be seen that there is a positive polynomial correlation between femur length and biparietal diameter with a correlation of determination of $r^2 = 0.9993$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = -4E\text{-}06x^4 + 0.0006x^3 - 0.0414x^2 + 2.3555x - 1.7905$ where y is the biparietal diameter in millimeters and x is the femur length in millimeters. Figure 90 shows relationship of femur length with occipitofrontal diameter. There is a positive polynomial correlation between femur length and biparietal diameter. The relationship is best described by the quadratic regression equation of $y = -0.007x^2 + 2.0251x + 4.2448$ with a correlation of determination of $r^2 = 0.9973$ ($P < 0.0001$) in Nigerian fetuses in Jos. Figure 91 shows the relationship between cephalic index and femur length. The relationship is best described by the fifth order polynomial regression equation $y = 1E\text{-}07x^5 - 3E\text{-}05x^4 + 0.003x^3 - 0.1448x^2 + 3.2738x + 52.171$ where y is the cephalic index and x is the femur length in millimeters; $r^2 = 0.8284$; $P<0.0001$).

Figure 92 shows relationship of femur length with abdominal circumference. From the graph, it can be seen that there is a positive linear correlation between femur length and femur length with a correlation of determination of $r^2 = 0.9952$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 4.179x + 22.077$ where y is the abdominal circumference in millimeters and x is the femur length in millimeters.

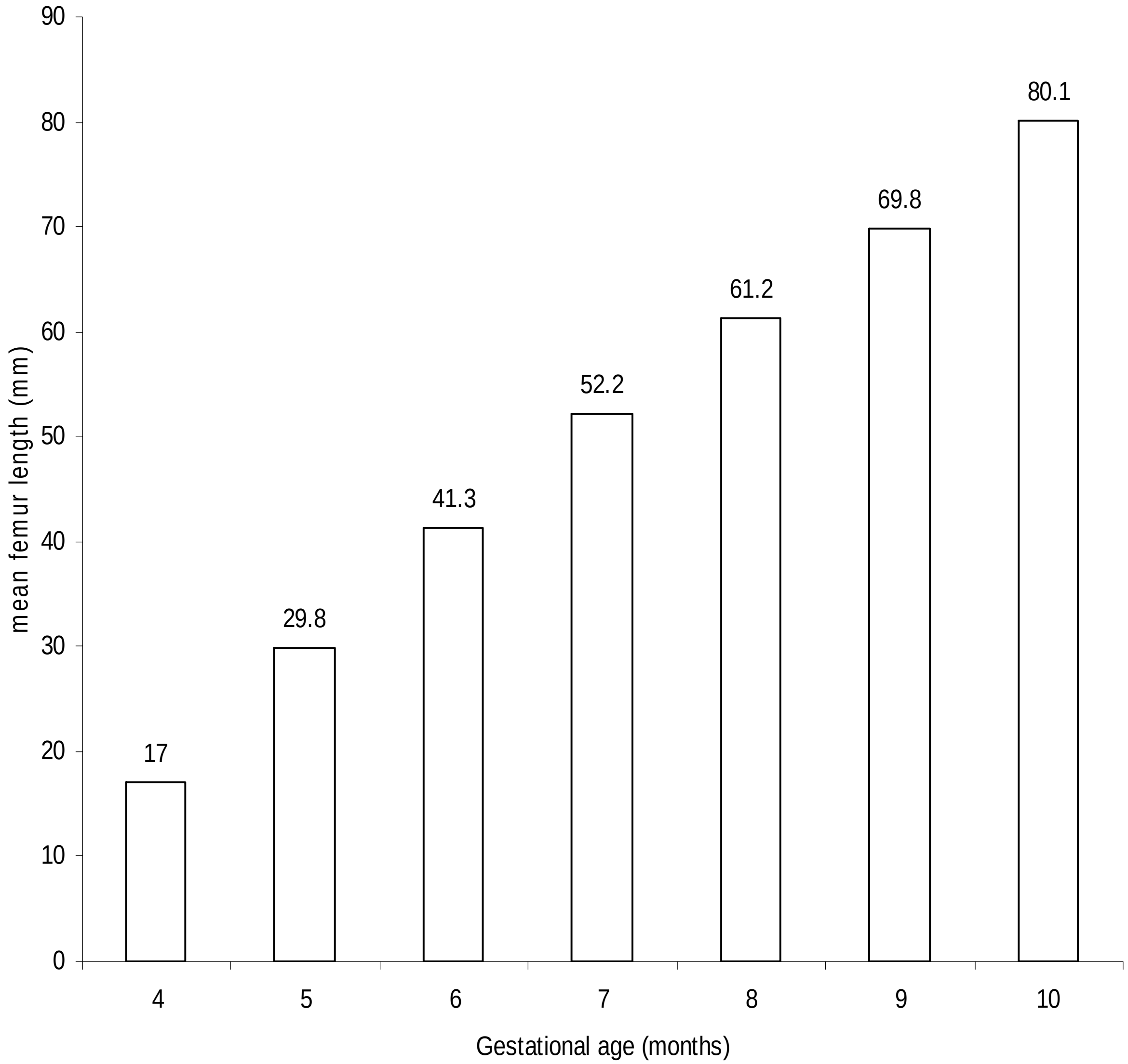

Figure 87: Histogram showing mean femur length values in 13,740 femur length data of fetuses in women of gestational ages from 4 to 10 months.

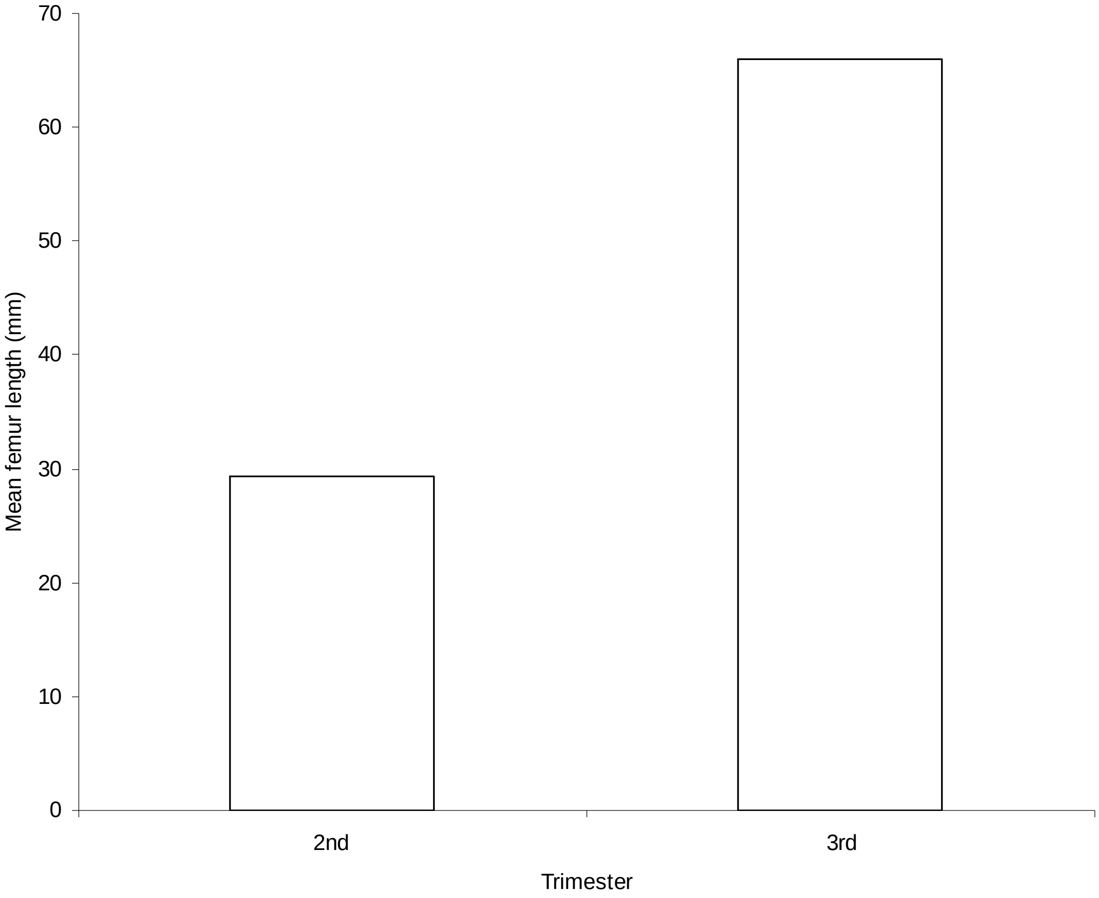

Figure 88: Histogram showing mean femur length values in 13,740 femur length data of fetuses in women of gestational ages from 4 to 10 months divided into two trimesters

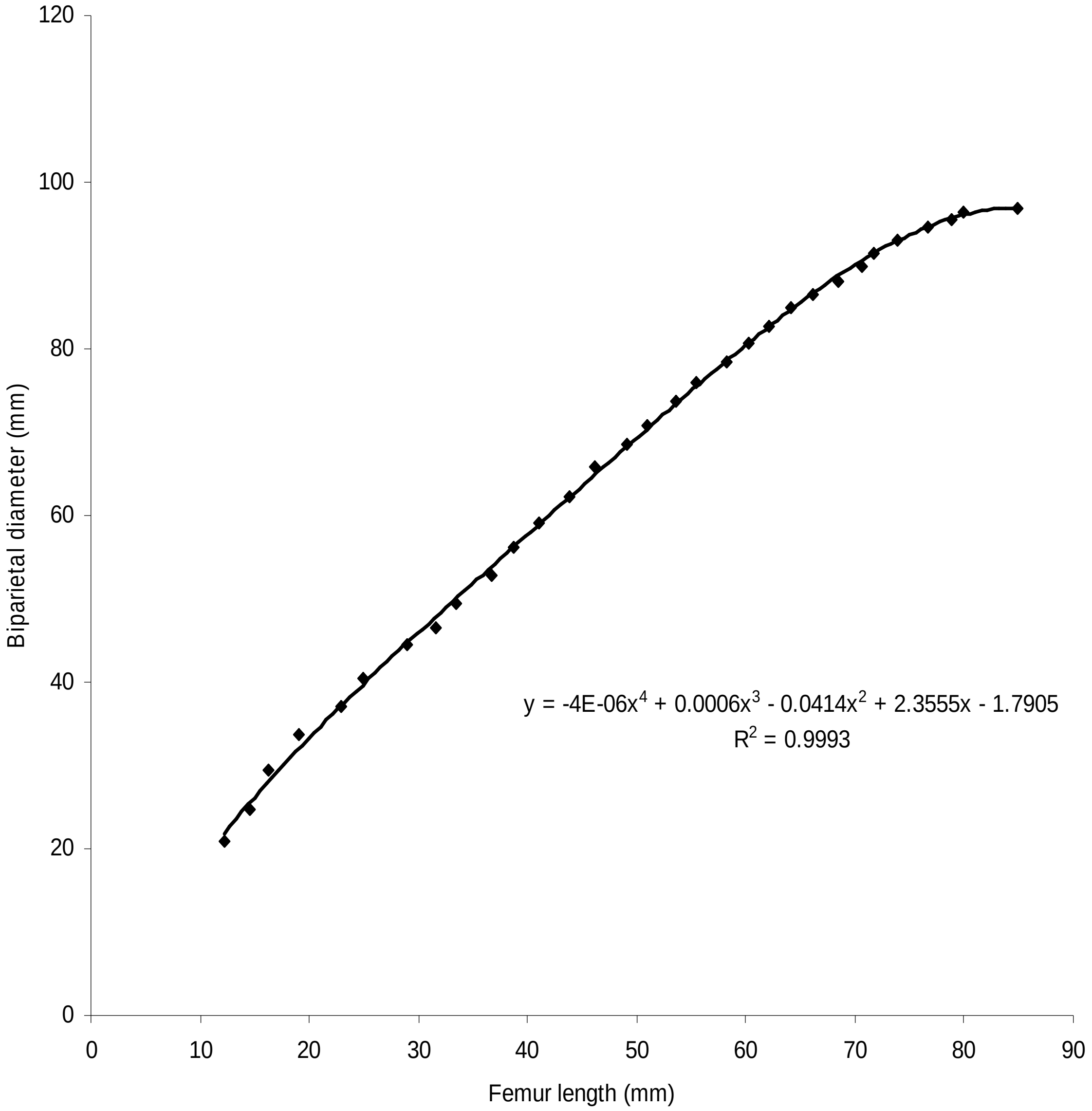

Figure 89: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter

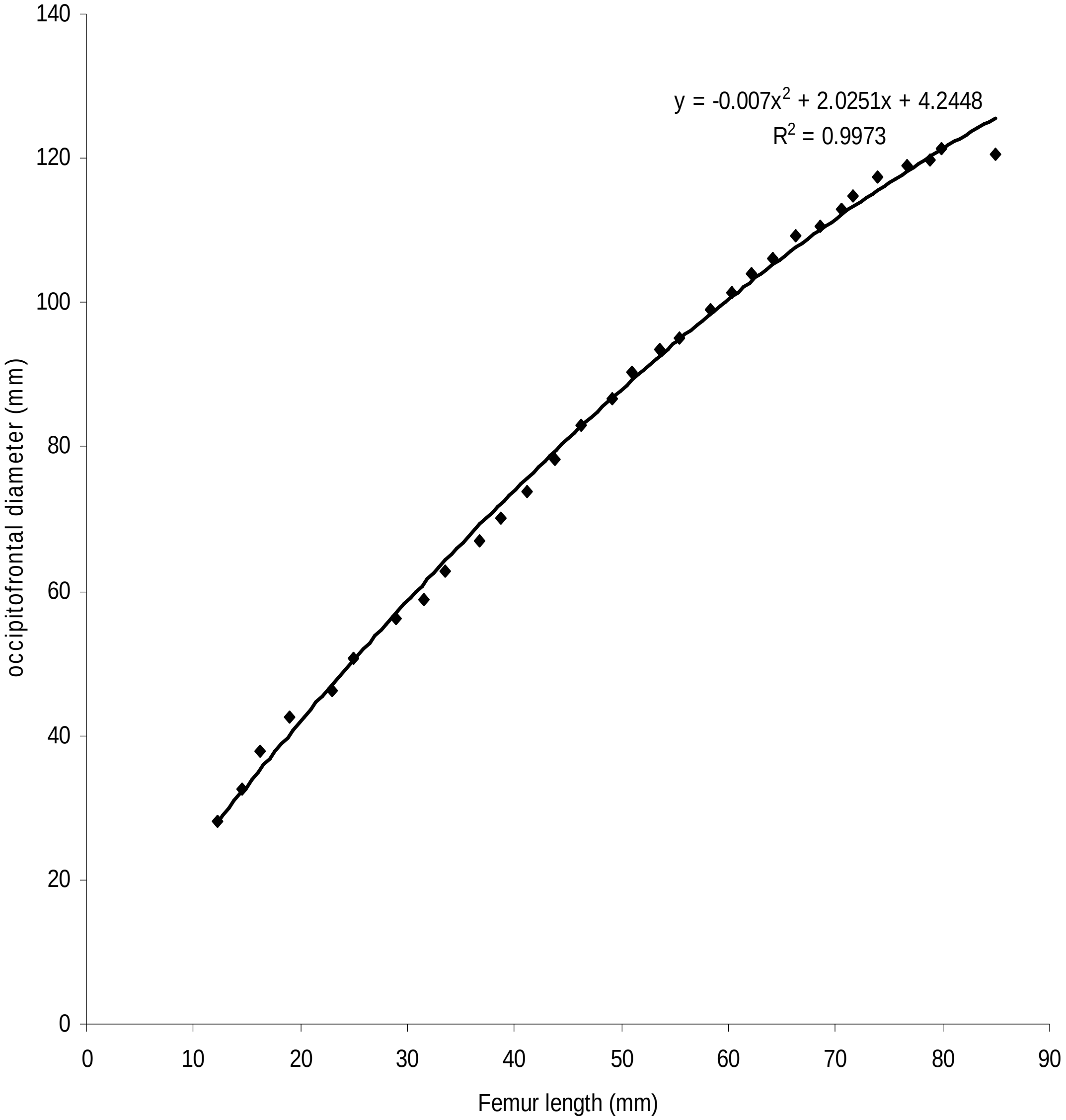

Figure 90: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter

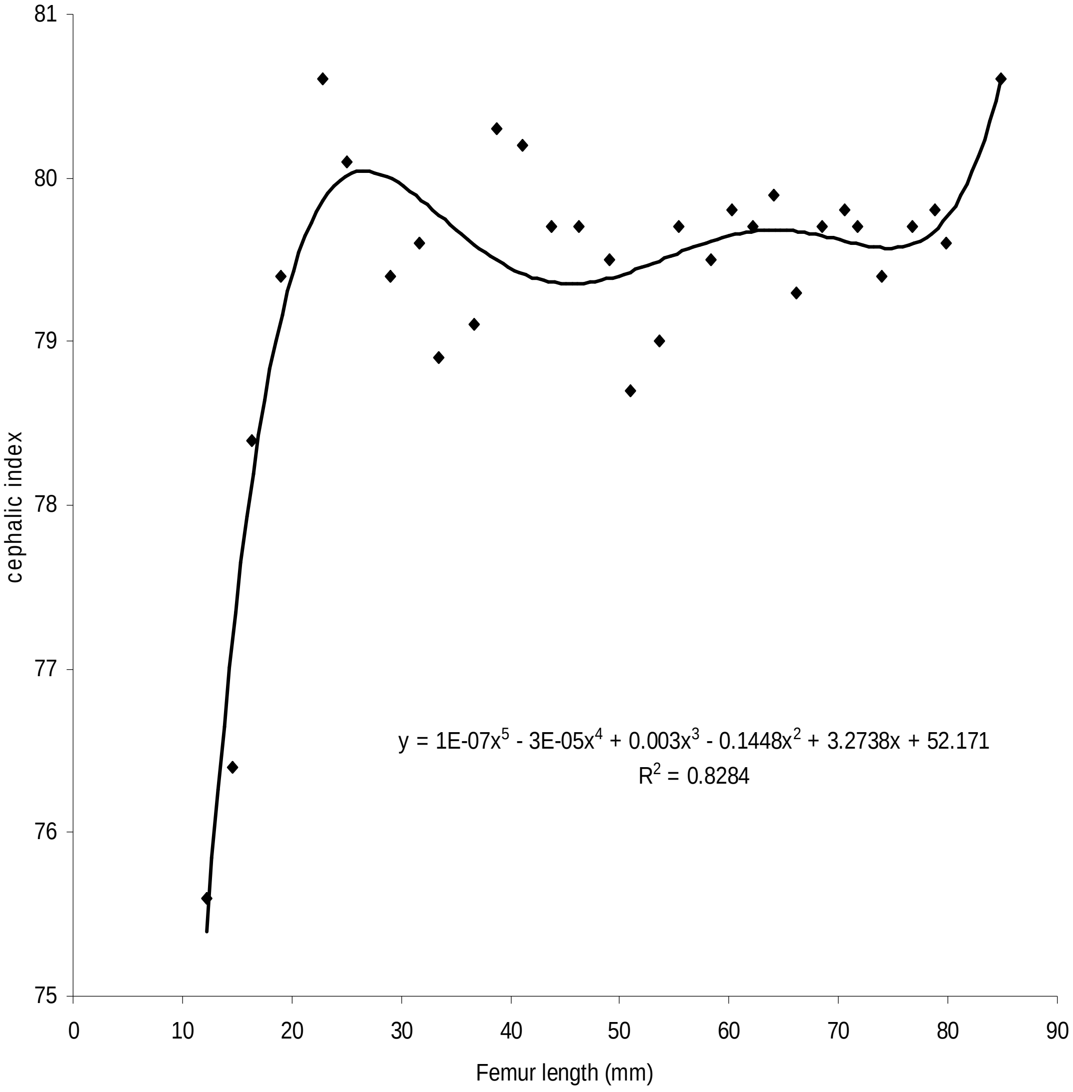

Figure 91: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against cephalic index.

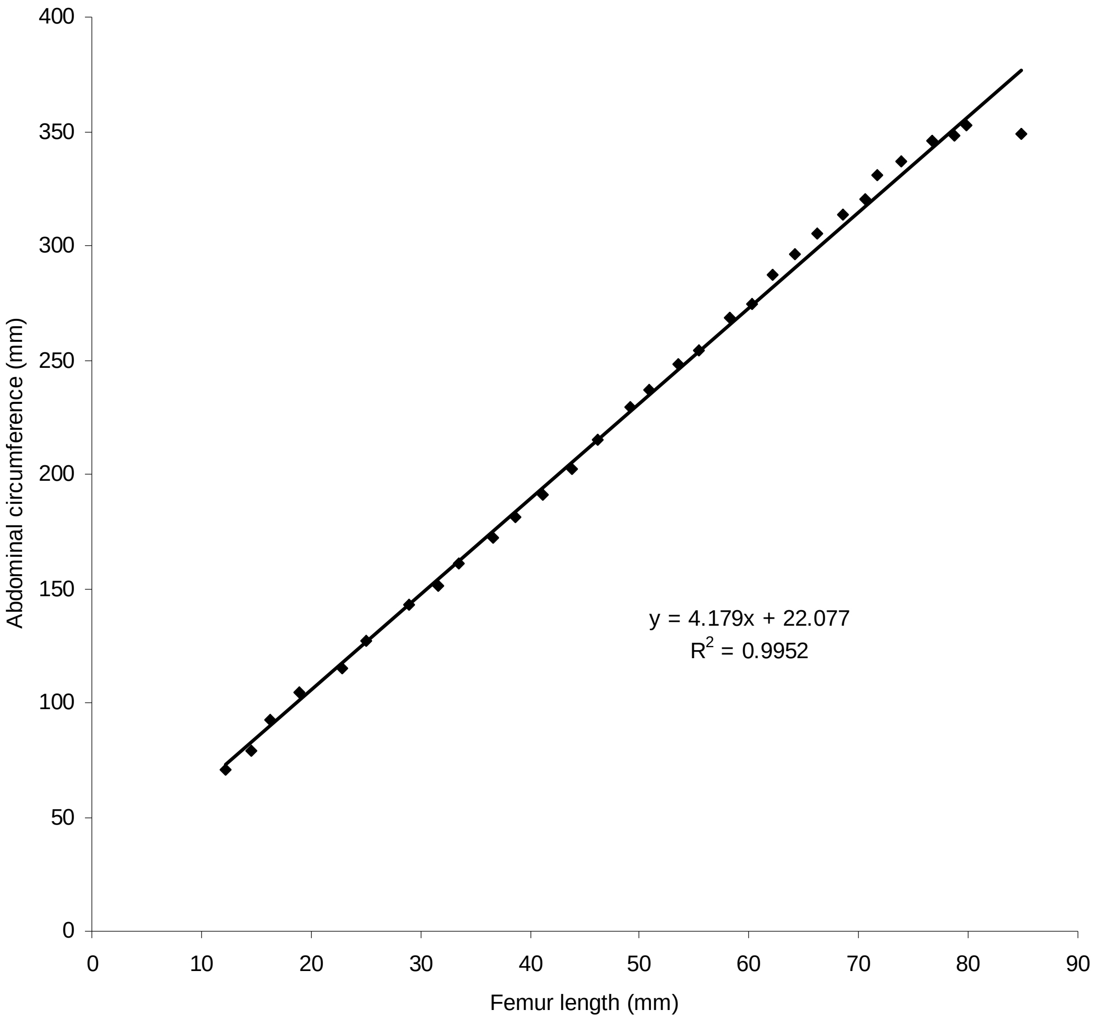

Figure 92: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against femur length

Figure 93 shows relationship between femur length and head circumference. There is a positive polynomial correlation between femur length and head circumference with a correlation of determination of $r^2 = 0.9989$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order regression equation $y = -0.0004x^3 + 0.0429x^2 + 3.1567x + 43.238$ where y is the head circumference in millimeters and x is the femur length in millimeters. Figure 94 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and femur length. From the graph, it can be seen that there is a positive power correlation between fetal weight and femur length with a correlation of determination of $r^2 = 0.9944$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.0575x^{2.534}$ where y is the fetal weight in grams and x is the femur length in millimeters.

When the relationship between femur length and symphysio-fundal height was determined, it was found that there is a positive polynomial correlation between symphysio-fundal height and femur length with a correlation of determination of $r^2 = 0.9941$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order polynomial regression equation $y = 0.0006x^3 - 0.064x^2 + 4.3915x - 32.499$ where y is the femur length in millimeters and x is the symphysio-fundal height in centimeters (figure 95). Femur length centile values for 5th, 50th and 95th centiles are plotted as shown in figure 96. In figure 97, the 5th, 50th and 95th centiles are smoothened into a growth chart which can be utilized to determine growth of fetus using femur length. Figure 98 is a graphical display showing the growth rate of the measured fetal femur length during intrauterine life.

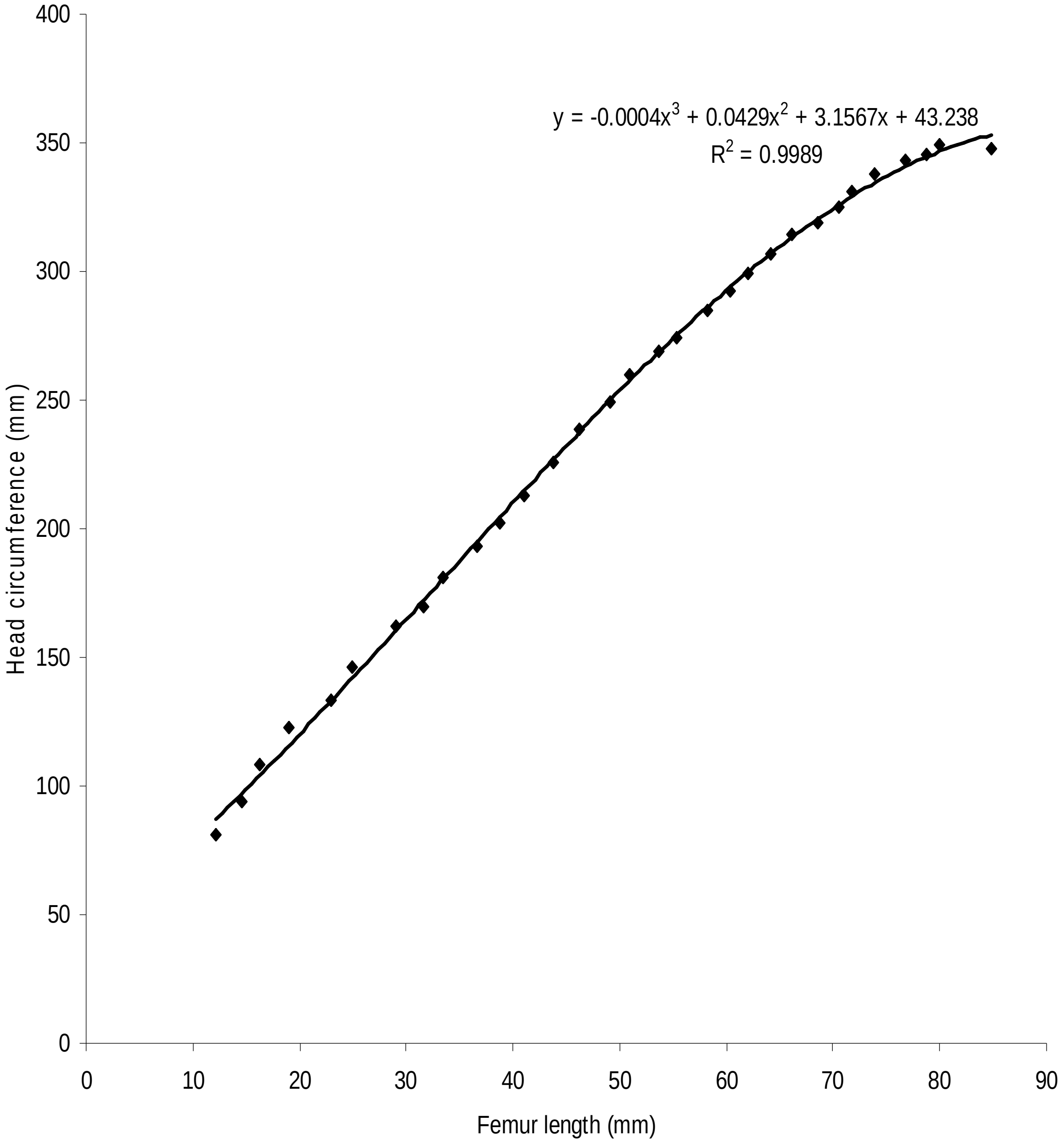

Figure 93: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against femur length.

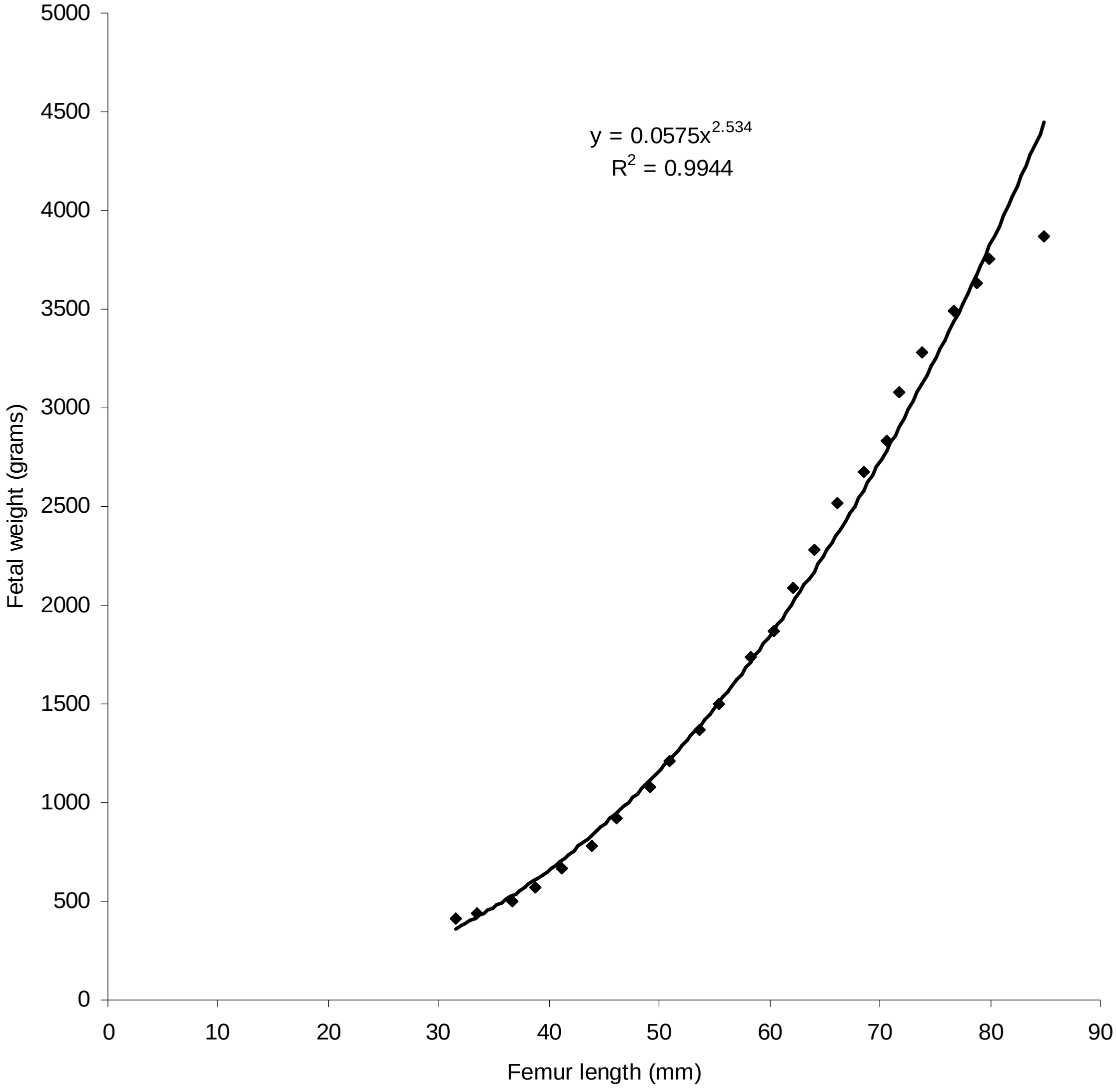

Figure 94: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.

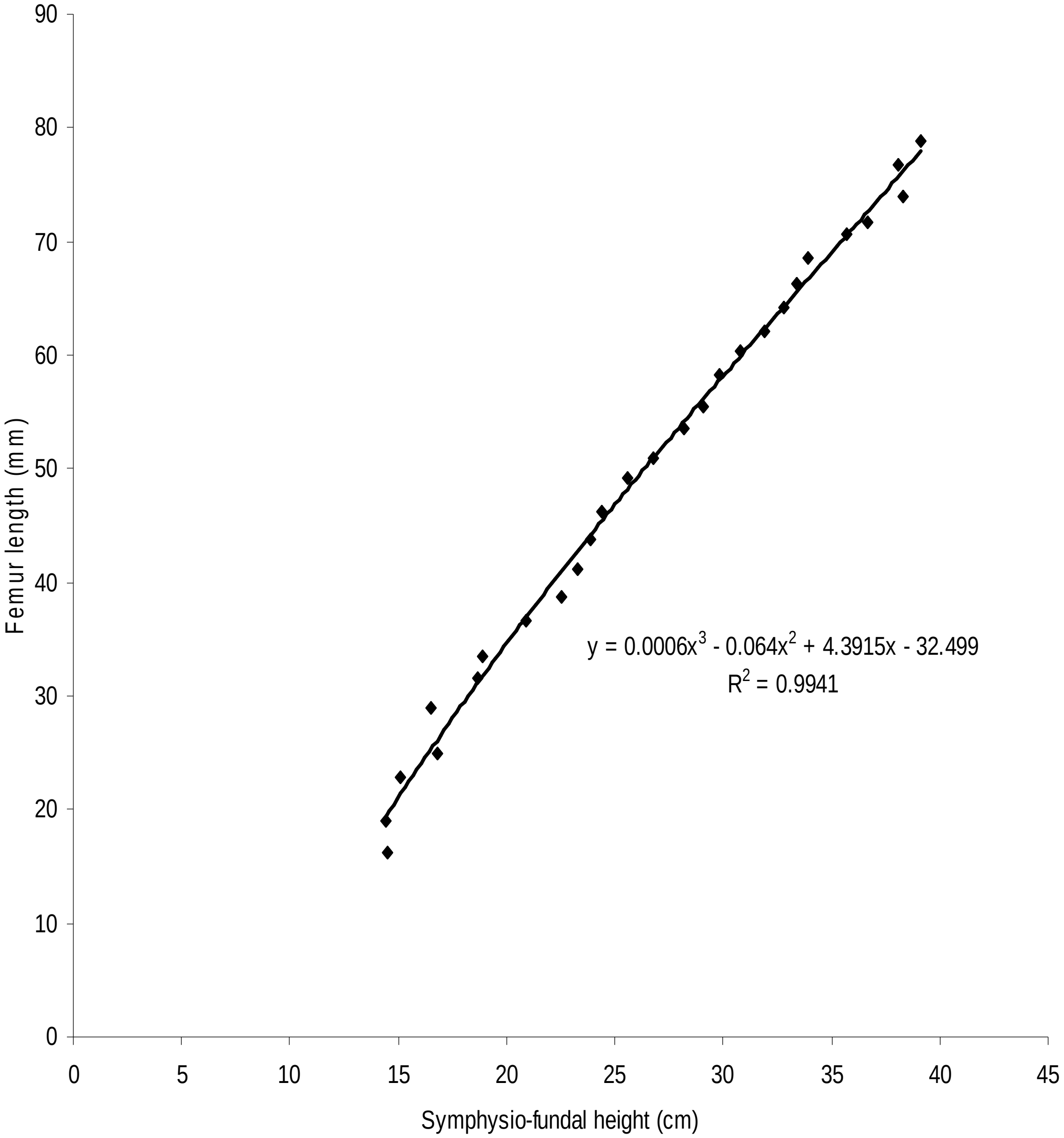

Figure 95: Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against symphysio-fundal height.

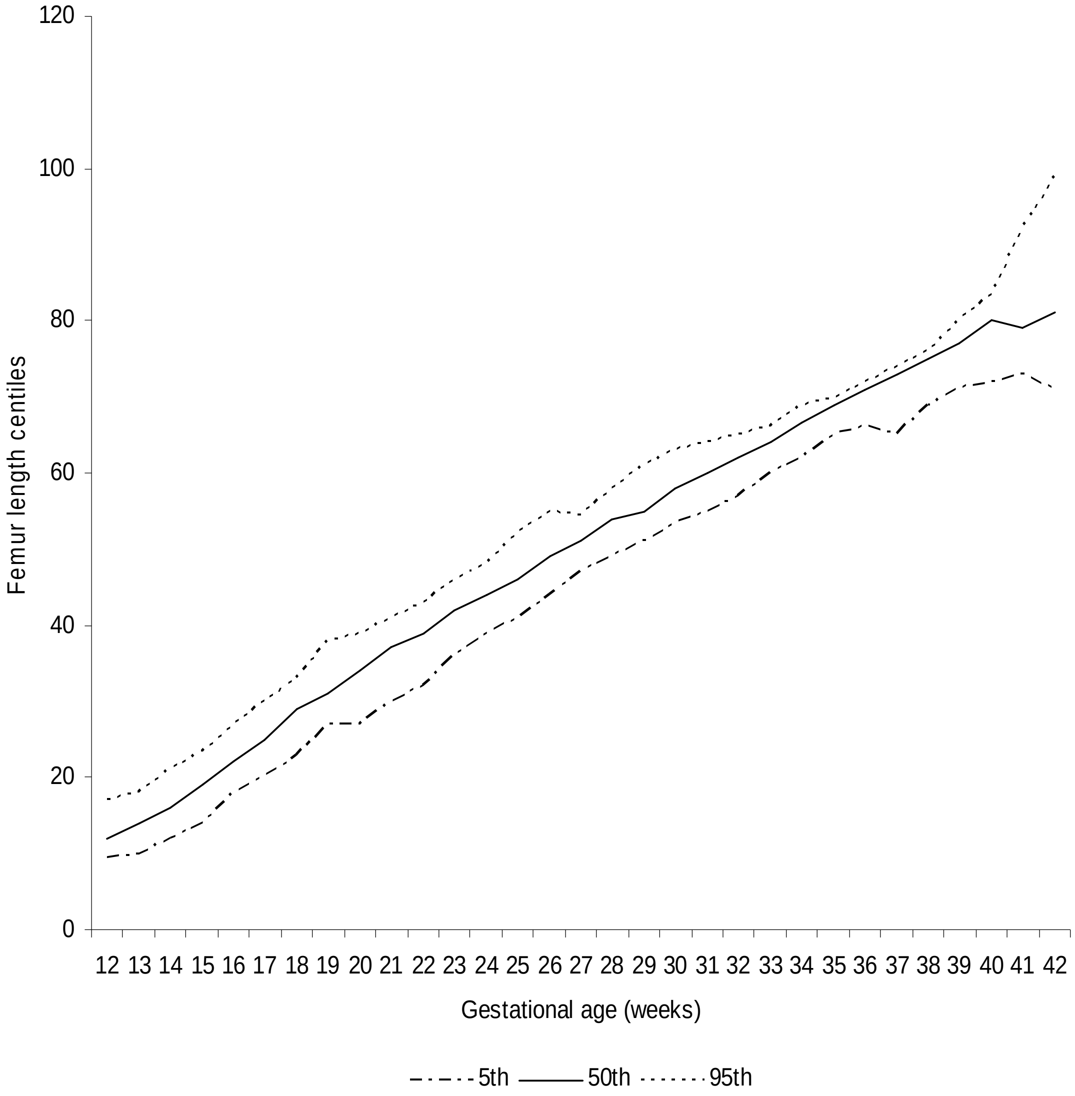

Figure 96: Fifth, 50th and 95th centiles for femur length in 13,740 fetuses at different gestational ages from 12 to 42 weeks.

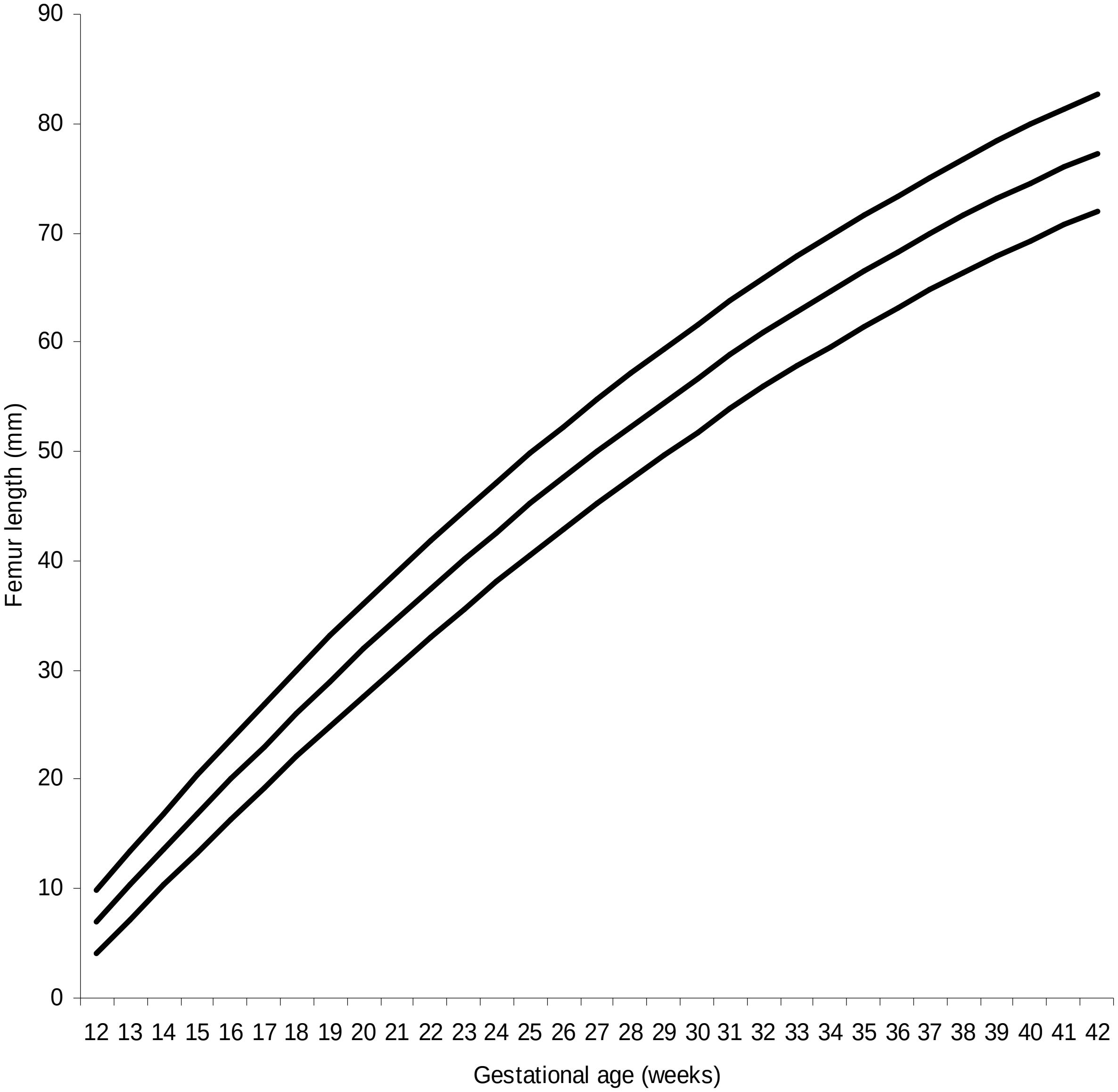

Figure 97: Curves created from 3rd, 50th and 97th fetal femur length centiles.

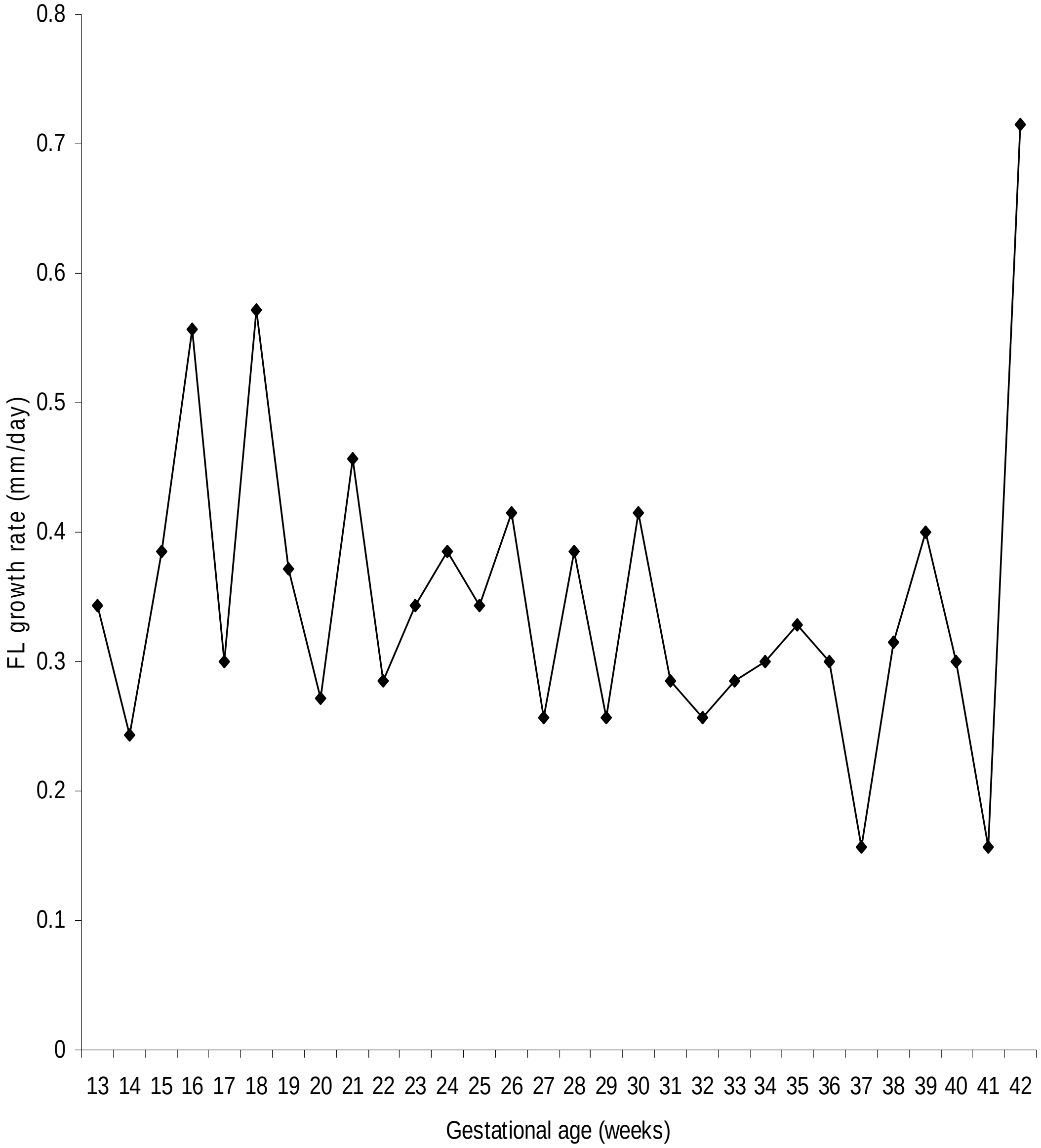

Figure 98: Growth velocity pattern of femur length in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks

4.1.6 Fetal Weight

The fetal weight measurements were classified into twenty six groups. The mean weight values at each week of gestation from 17 – 42 are as shown in table 34. This table gives the mean values of fetal weight measurements for each gestational age in weeks from 17 – 42 weeks together with their corresponding standard deviations and standard errors of mean. The standard deviation is necessary to clear up the mystery of the hidden numbers that made up a mean. For example, the mean weight at 39 weeks is 3490.8g plus 360.3g or 3490.8g minus 360.3g. This means 2 out of 3 measurements of weight at 39 weeks, approximately 350 weight measurements in a class of 525, should be between 3130.5g and 3851.1g. Since the standard error of mean at 39 weeks is 15.8g, it is telling us that the real mean weight of fetuses in Jos at 39 weeks is probably between 3475.0g and 3506.6g (3490.8g plus or minus 15.8g). The variability of the fetal weight measurements increases as gestational age increases. However, at week 18, there is marked variation up to 650 grams.

The geometric means (table 35) of all sets of measurements from 17 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal weight measurements were not identical. Table 36 shows the monthly fetal weight values from 4th month to the 10th month with their corresponding standard deviations and standard error of mean. Table 37 gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal weight measured at different gestational age ranging from 17 – 42 weeks. For example, it can be seen from the table that the 10th percentile of fetal weight at 20 to 20 + 6 weeks gestation is 300 grams. This means that 10% of the fetuses at 20 to 20 + 6 had a mean fetal weight less than 300 grams, while 90% had a mean fetal weight greater than 300 grams. Similarly, the 97th percentile of fetal weight at 36 to 36 + 6 is 3200 grams. Hence 97% of fetuses at 36 to 36 + 6 had a mean fetal weight less than 3200 grams while 3% had a mean fetal weight greater than 3200 grams.

Table 34: Frequency distribution table of fetal weight measurements showing the arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.

GA (week, days)	Fetuses (n)	weight (g)	SD	SEM
17 to 17+6	427	319.0	40.2	8.8
18 to 18+6	446	731.9	650.8	94.9
19 to 19+6	282	413.3	101.8	11.8
20 to 20+6	553	437.6	81.0	4.4
21 to 21+6	400	496.3	73.2	3.9
22 to 22+6	398	567.4	124.5	6.5
23 to 23+6	478	668.4	180.9	8.5
24 to 24+6	520	781.9	161.7	7.2
25 to 25+6	388	925.0	177.6	9.1
26 to 26+6	511	1077.6	217.9	9.7
27 to 27+6	432	1206.8	226.8	11.0
28 to 28+6	548	1370.2	227.7	9.8
29 to 29+6	484	1498.1	204.2	9.4
30 to 30+6	625	1733.8	297.7	12.0
31 to 31+6	523	1865.1	295.3	13.0
32 to 32+6	583	2086.1	276.3	11.5
33 to 33+6	516	2279.6	298.8	13.2
34 to 34+6	744	2516.0	333.0	12.4
35 to 35+6	739	2675.0	352.8	13.0
36 to 36+6	599	2837.0	341.3	14.1
37 to 37+6	532	3079.8	392.0	17.2
38 to 38+6	481	3276.7	351.3	16.2
39 to 39+6	525	3490.8	360.3	15.8
40 to 40+6	252	3634.9	419.8	26.4
41 to 41+6	72	3752.9	350.9	41.9
42 to 42+6	22	3868.2	599.5	127.8
Total	**12,080**			

Table 35: Frequency distribution table of fetal weight measurements showing arithmetic mean, geometric mean and harmonic mean from 17 – 42 weeks gestation.

GA (week, days)	Number of fetuses (n)	Arithmetic mean	Geometric mean	Harmonic mean
17 to 17+6	427	319.0476	316.8977	315
18 to 18+6	446	731.9149	544.7203	447.3412
19 to 19+6	282	413.3333	406.0622	401.4273
20 to 20+6	553	437.574	431.6011	426.7036
21 to 21+6	400	496.3173	491.1159	485.939
22 to 22+6	398	567.3854	559.6849	554.3026
23 to 23+6	478	668.3516	654.8652	645.9038
24 to 24+6	520	781.8898	769.4403	759.0261
25 to 25+6	388	925.0000	911.0558	897.5364
26 to 26+6	511	1077.624	1061.000	1046.67
27 to 27+6	432	1206.792	1187.759	1169.68
28 to 28+6	548	1370.24	1353.363	1336.422
29 to 29+6	484	1498.105	1484.898	1472.064
30 to 30+6	625	1733.764	1710.785	1688.828
31 to 31+6	523	1865.125	1841.298	1815.473
32 to 32+6	583	2086.066	2065.578	2039.616
33 to 33+6	516	2279.648	2256.348	2225.095
34 to 34+6	744	2515.978	2490.586	2457.018
35 to 35+6	739	2674.966	2651.654	2627.941
36 to 36+6	599	2836.974	2813.571	2785.043
37 to 37+6	532	3079.808	3039.085	2949.43
38 to 38+6	481	3276.744	3255.992	3231.927
39 to 39+6	525	3490.822	3472.1	3453.111
40 to 40+6	252	3634.921	3611.771	3589.447
41 to 41+6	72	3752.857	3736.914	3721.155
42 to 42+6	22	3868.182	3822.286	3775.203
Total	**12080**			

Table 36: Monthly mean fetal weight values (in grams) in a Nigerian population

GA (months)	Fetuses (n)	Mean (mm)	SD	SEM
4	1660			
5	1708	473.5	178.5	89.2
6	2184	687.8	170.8	76.4
7	1975	1288.2	184.2	92.1
8	2247	1991.2	241.1	120.5
9	3095	2876.9	305.6	136.7
10	871	3686.7	161.6	80.8
Total	13,740			

Table 37: Frequency distribution table of fetal weight measurements showing the 3rd, 5th, 10th, 50th, 90th, 95th and 97th centile values from 17 – 42 weeks.

	Weight centiles (grams)						
Gestational age	3rd	5th	10th	50th	90th	95th	97th
17 to 17+6	300	300	300	300	400	400	400
18 to 18+6	300	300	300	400	1900	2400	2400
19 to 19+6	300	300	400	400	400	500	860
20 to 20+6	400	400	400	400	500	600	700
21 to 21+6	400	400	400	500	600	600	700
22 to 22+6	500	500	500	600	600	700	700
23 to 23+6	500	500	600	600	800	800	800
24 to 24+6	600	600	700	800	900	900	1073
25 to 25+6	643	700	800	900	1100	1100	1157
26 to 26+6	800	900	900	1100	1300	1400	1500
27 to 27+6	800	900	1000	1200	1400	1600	1700
28 to 28+6	1000	1100	1200	1400	1500	1690	1874
29 to 29+6	1100	1200	1300	1500	1800	1800	1900
30 to 30+6	1300	1300	1500	1700	2000	2100	2440
31 to 31+6	1260	1300	1600	1900	2100	2200	2400
32 to 32+6	1600	1700	1800	2100	2400	2500	2600
33 to 33+6	1700	1800	1900	2300	2600	2700	2900
34 to 34+6	2000	2100	2200	2500	2900	3065	3200
35 to 35+6	2000	2180	2300	2700	3100	3300	3400
36 to 36+6	2200	2300	2500	2900	3200	3400	3400
37 to 37+6	2500	2600	2700	3100	3400	3600	3600
38 to 38+6	2600	2700	2900	3300	3700	3800	3900
39 to 39+6	2800	3000	3000	3500	4000	4100	4200
40 to 40+6	2900	3100	3200	3600	4200	4435	4600
41 to 41+6	3100	3155	3210	3800	4190	4545	4600
42 to 42+6	2900	2900	2960	3900	4600	4600	4600

When weight data of 12,080 fetuses was subjected to skewness analysis at different gestational age ranging from 17 – 42 weeks (figure 99), it can be seen that the distribution of weight measurements has a longer “tail” to the right of the central maximum than to the left or is skewed to the right from 17 – 31 weeks; and then later at 35, 39, 40 and 41 weeks. From 32, 33, 34, 36, 37, 38 and 42 weeks, the distribution has a longer “tail” to the left of the central maximum than to the right or is skewed to the left. When the weight data was subjected to kurtosis analysis (figure 100), the analysis was found to be leptokurtic at 19, 22, 23, 24, 25, 26, 28 and 37 weeks of gestation while at the other gestational ages, the distribution was found to be was mesokurtic. The coefficient of dispersion of weight data of 12,080 fetuses at different gestational age shows a decrease in value as gestational age advances except at 18 weeks where it peaks (figure 101). In figure 102, mean weight is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of data demonstrated that the best-fitted regression model (figure 103) to describe the relationship between weight and gestational age was the power regression equation $y = 0.038x^{3.1347}$ where y is the fetal weight in grams and x is the fetal age in weeks with a correlation of determination of $r^2 = 0.9951$ ($P < 0.0001$) in Nigerian fetuses in Jos. When fetal weight was plotted against symphysio-fundal height, it was found out that there is a positive correlation between fetal weight and symphysio-fundal height with a correlation of determination of $r^2 = 0.9951$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.0409x^{3.1217}$ where y is the fetal weight in grams and x is the symphysio-fundal height in centimeters (figure 104).

Figure 105 is a graph showing fetal weight gain from 17 – 42 weeks. From this graph, it can be seen that the human fetus gains the highest weight at 18 weeks but loses it by 19 weeks before it starts gaining weight again as from 20 weeks; and the weight gain keeps rising and becomes relatively constant towards the end of the third trimester.

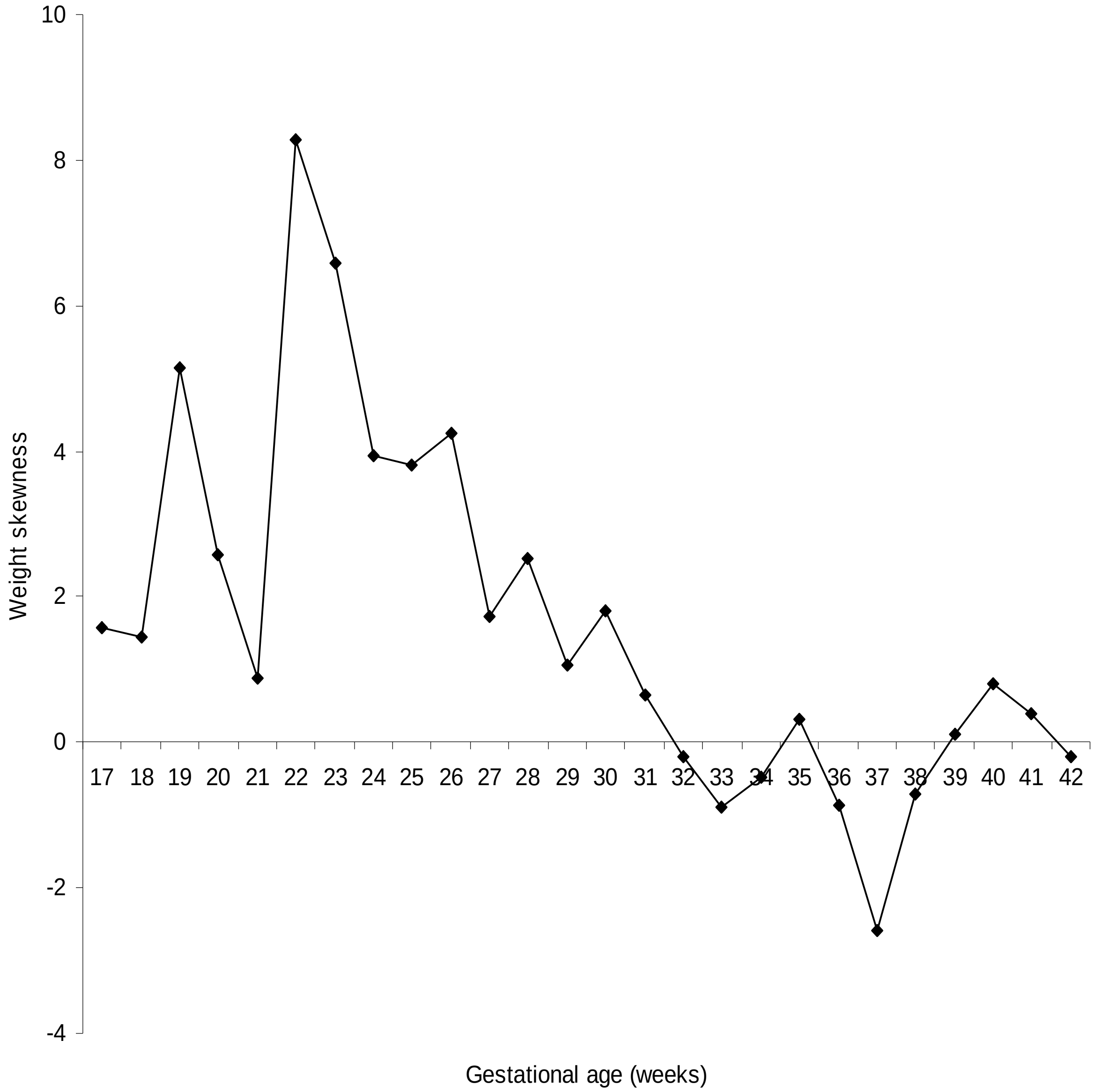

Figure 99: Weight data of 12,080 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.

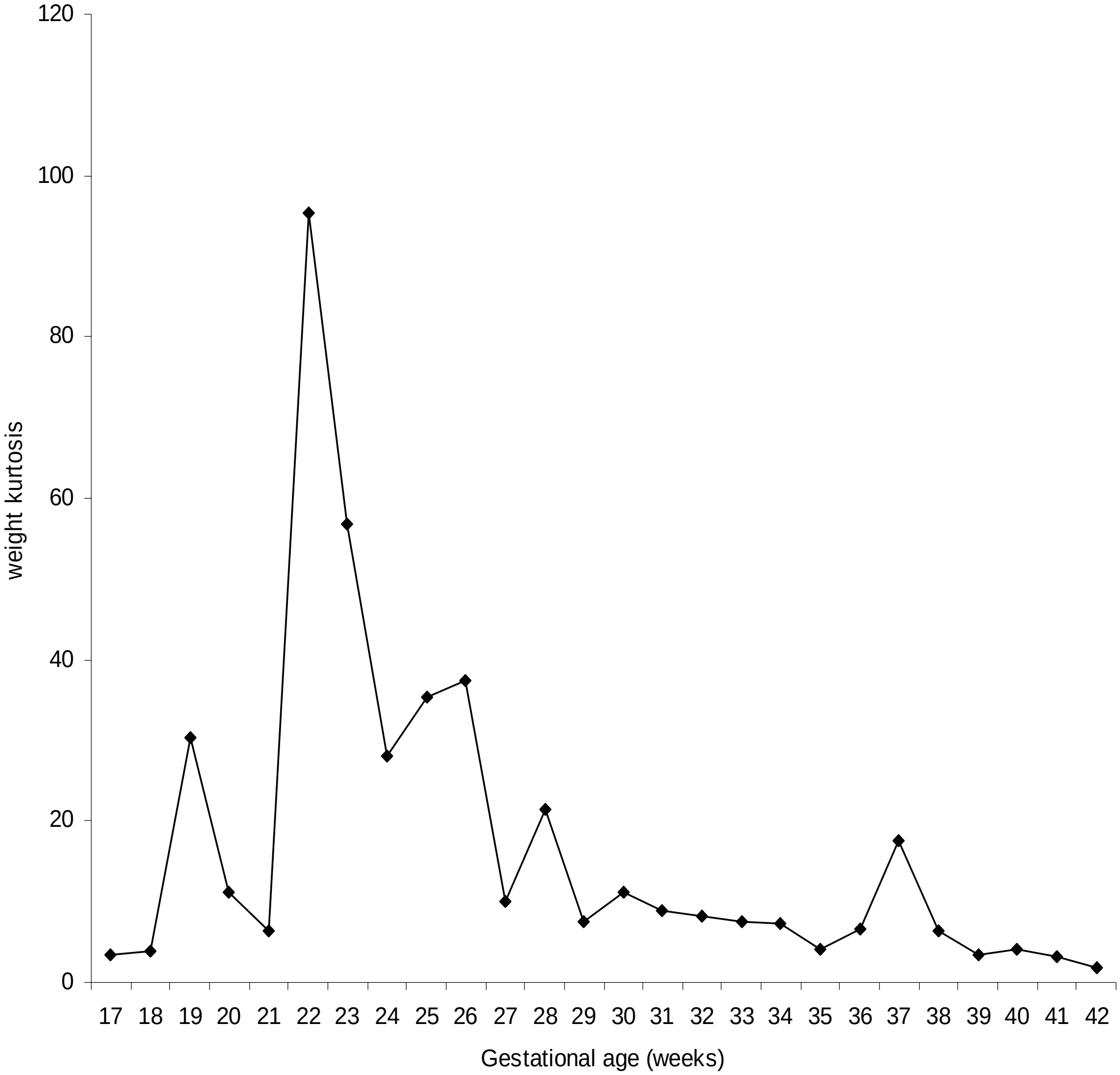

Figure 100: Weight data of 12,080 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.

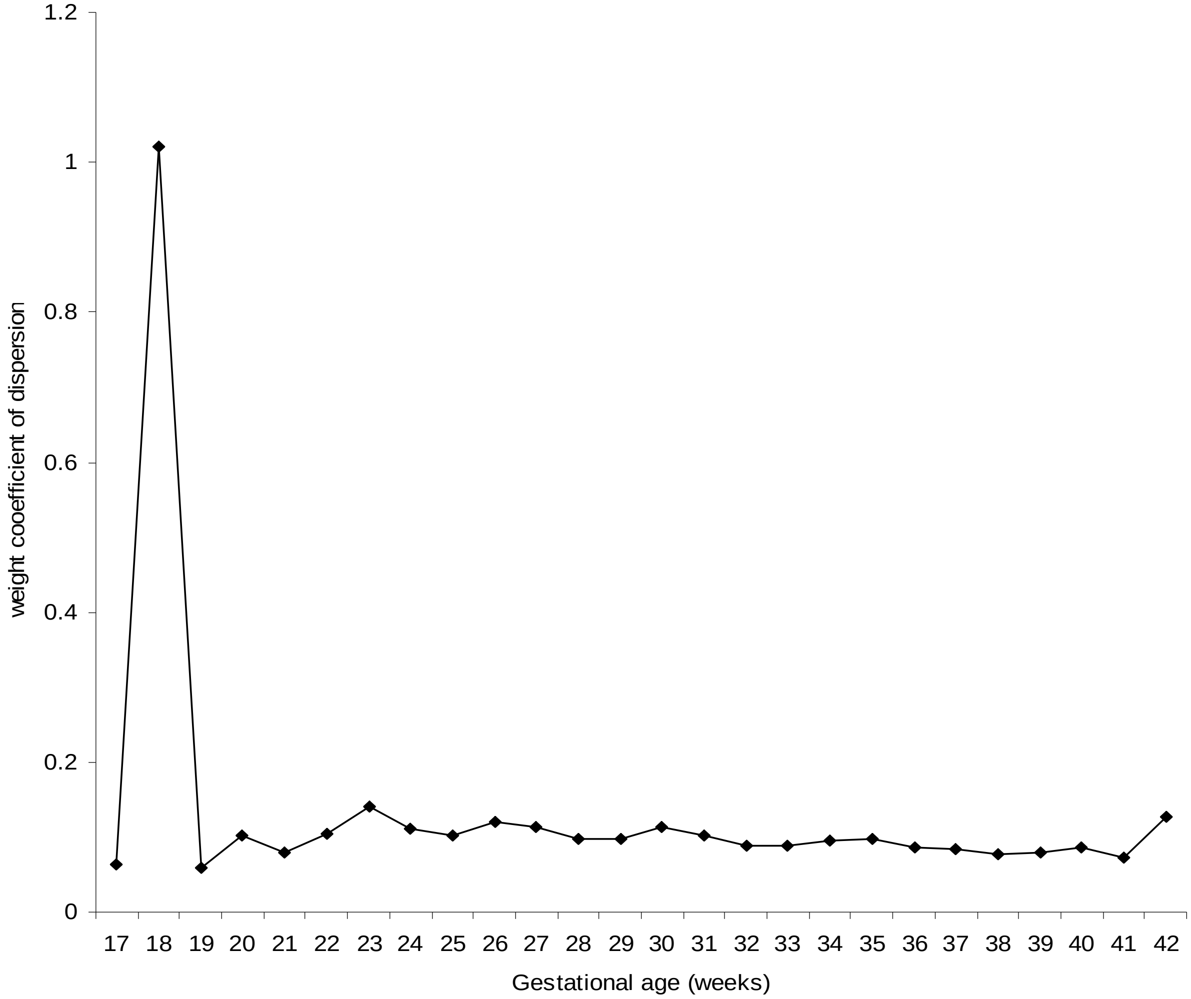

Figure 101: Weight coefficient of dispersion in 12,080 fetuses of gestational ages between 12 to 42 weeks.

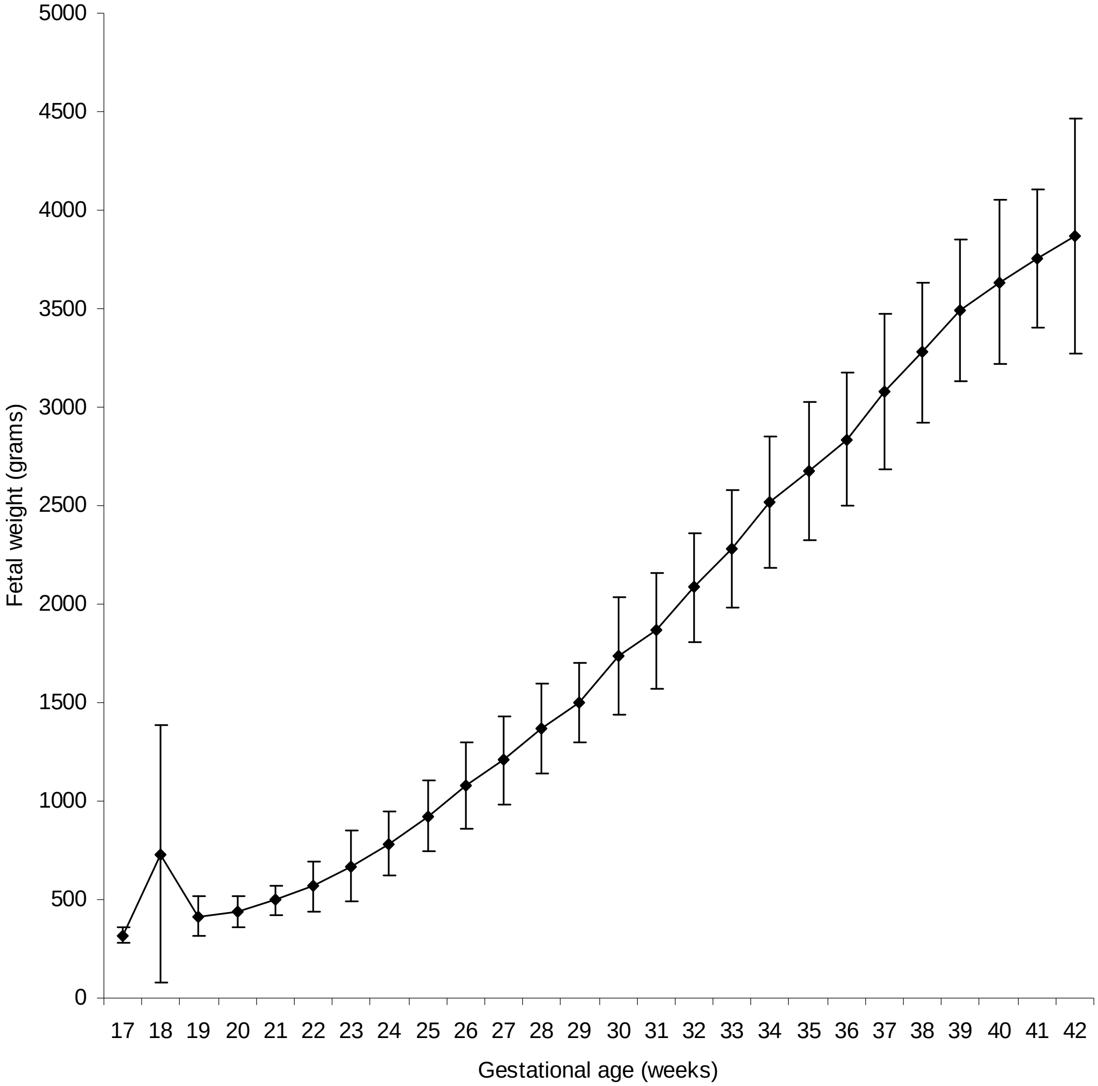

Figure 102: Mean fetal weight values in 12,080 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.

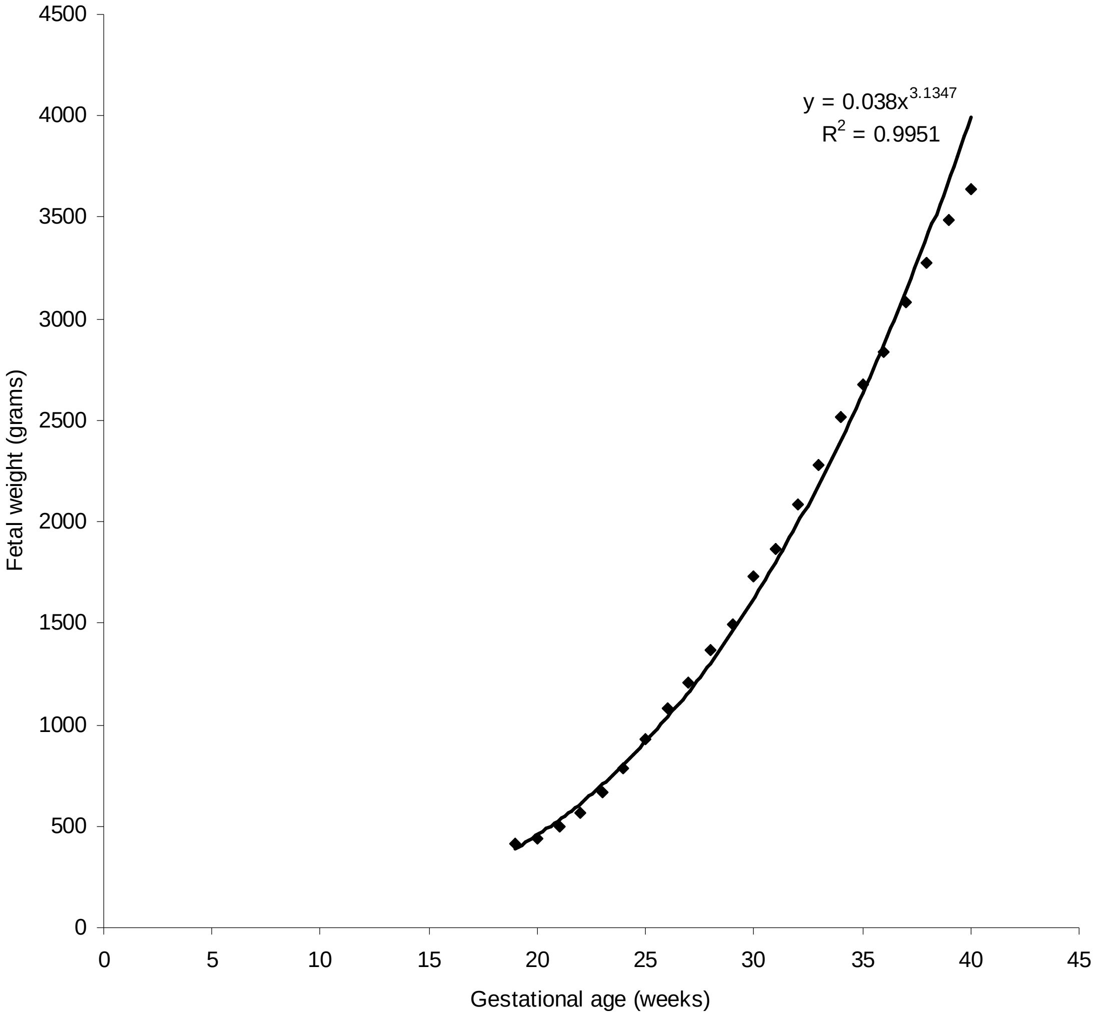

Figure 103: Correlation and regression equation of mean fetal weight values in 12,080 Nigerian fetuses in Jos plotted against gestational age

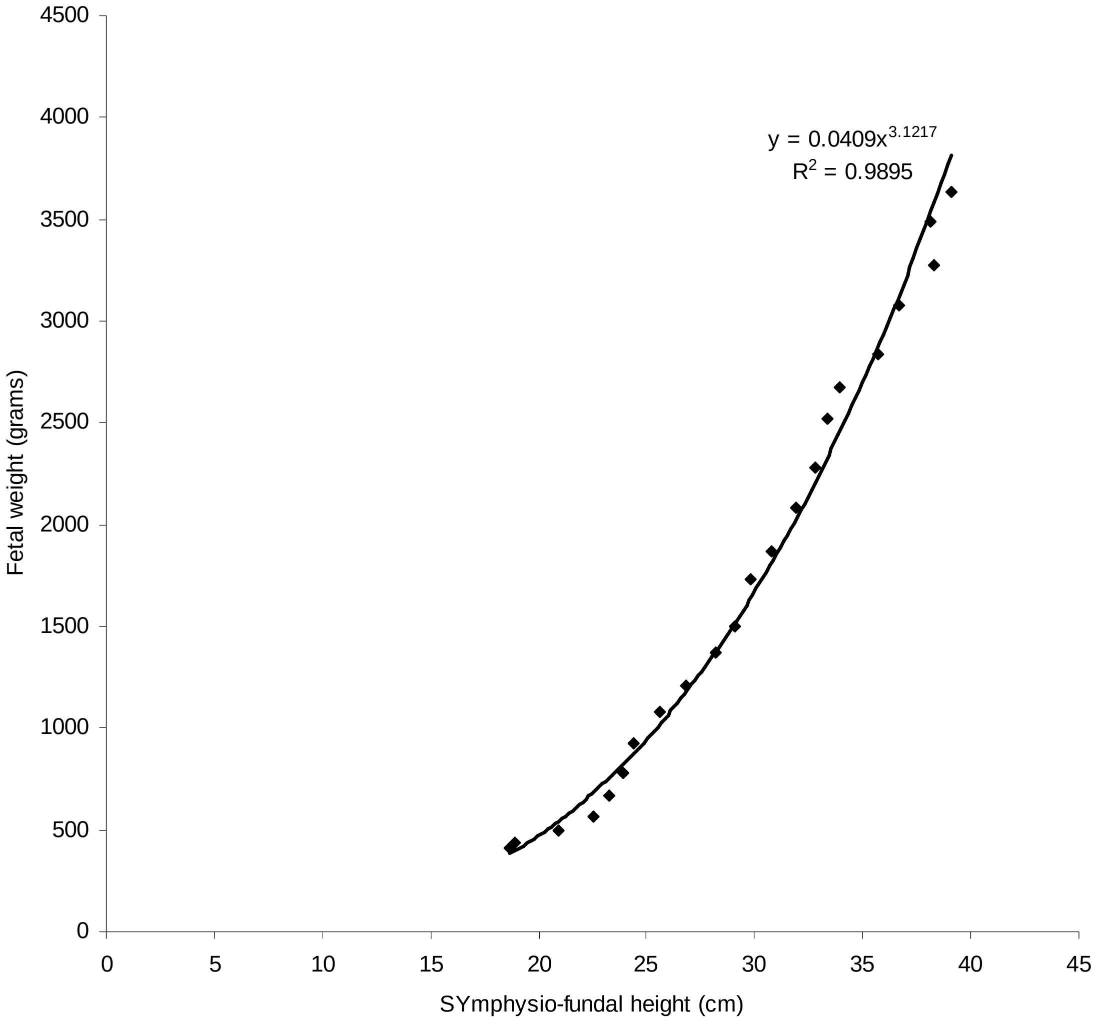

Figure 104: Correlation and regression equation of mean fetal weight values in 12,080 Nigerian fetuses in Jos plotted against symphysio-fundal height

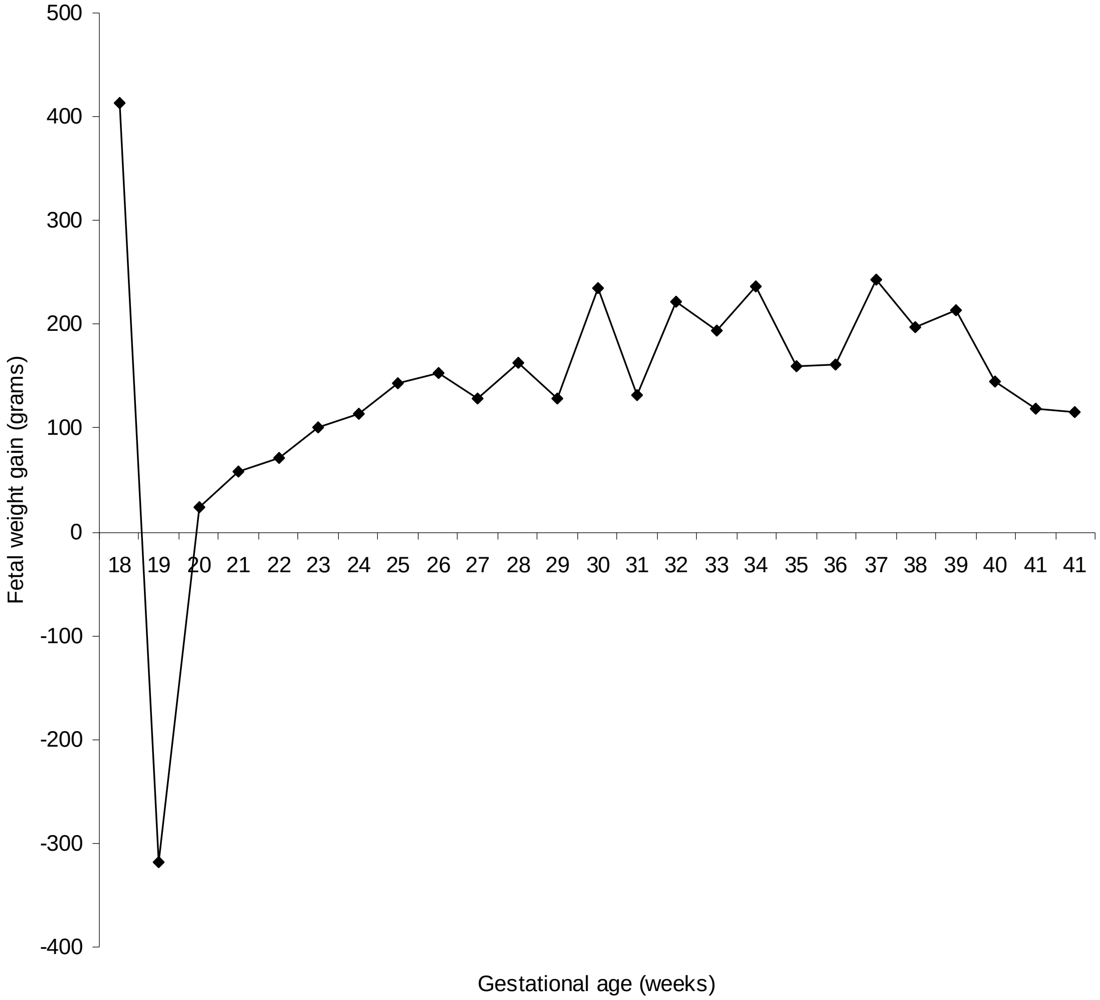

Figure 105: Mean fetal weight gain during normal pregnancy

Figure 106 shows histogram of fetal weight during the 5th month of intrauterine life while figure 107 shows histogram of fetal weight gain during 5th month of life. From this histogram it can be seen that the human fetus looses weight considerably at 19 weeks. Taking a look at the growth velocity of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference and fetal femur length from 13 – 42 weeks, it can be seen that there is a drop in the growth velocity of these parameters at 19 weeks (figures 170 – 174).

When other fetal anthropometric parameters like head circumference, biparietal diameter, occipitofrontal diameter, abdominal circumference and femur length are plotted against weight, certain hidden relationships can be forced out. For example, figure 113 shows the relationship of weight with head circumference. From the graph, it can be seen that there is a positive polynomial correlation between head circumference and weight with a correlation of determination of $r^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = 3E\text{-}12x^4 + 3E\text{-}08x^3 - 0.0001x^2 + 0.2173x + 106.44$ where y is the head circumference and x is the fetal weight in grams. Figure 114 shows the relationship of fetal weight with occipitofrontal diameter which has regression equation of $y = - 9E\text{-}13x^4 + 1E\text{-}08x^3 - 4E\text{-}05x^2 + 0.0779x + 36.004$ where y is occipitofrontal diameter and x is the fetal weight in grams with a correlation of determination of $r^2 = 0.9992$ ($P < 0.0001$) in Nigerian fetuses in Jos. Figure 115 shows the relationship between biparietal diameter and weight. The relationship is best described by the fourth order polynomial regression equation $y = - 3E\text{-}13x^4 + 4E\text{-}09x^3 - 2E\text{-}05x^2 + 0.0472x + 34.356$ where y is the biparietal diameter and x is the weight in grams with a correlation of determination of $r^2 = 0.9994$ ($P < 0.0001$) in Nigerian fetuses in Jos

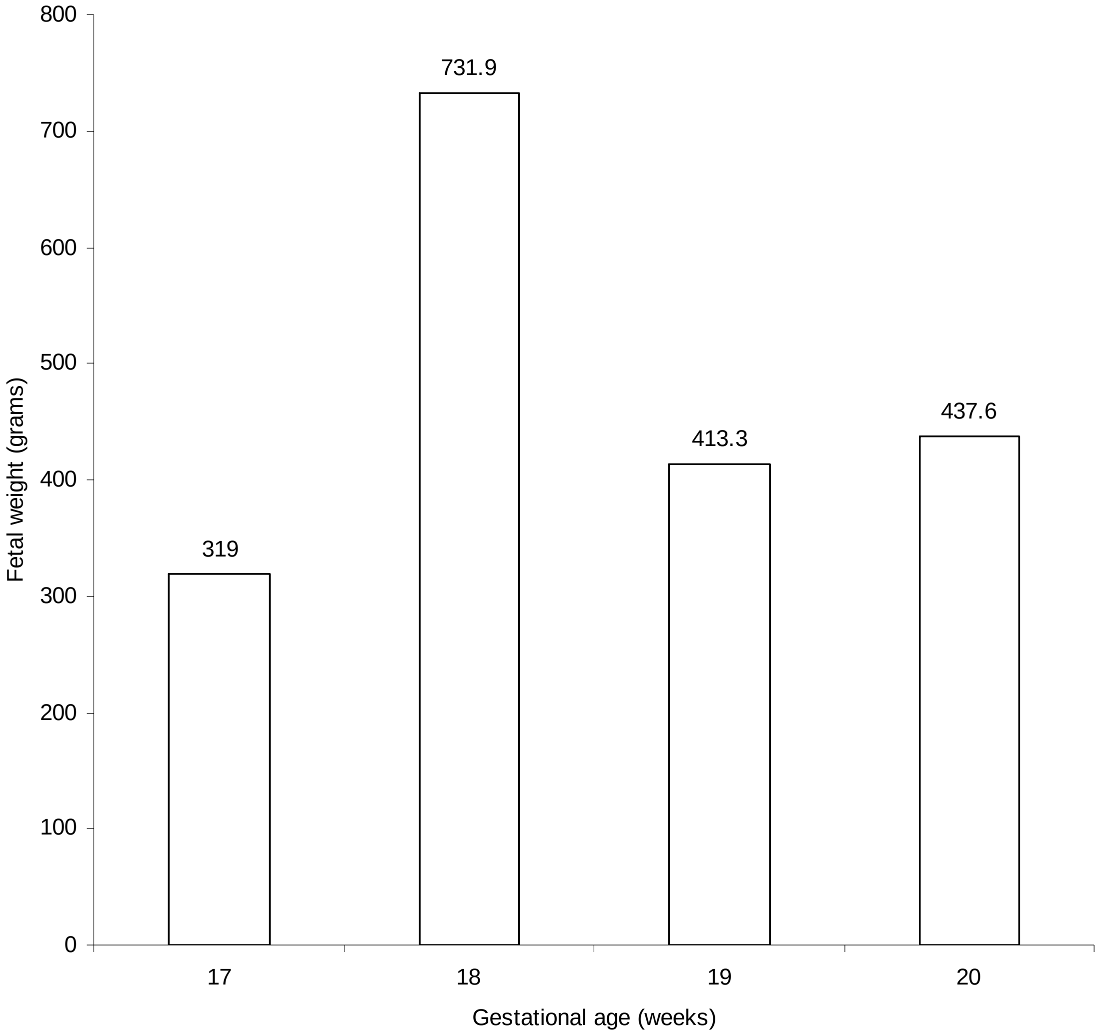

Figure 106: Mean fetal weight at 5 months

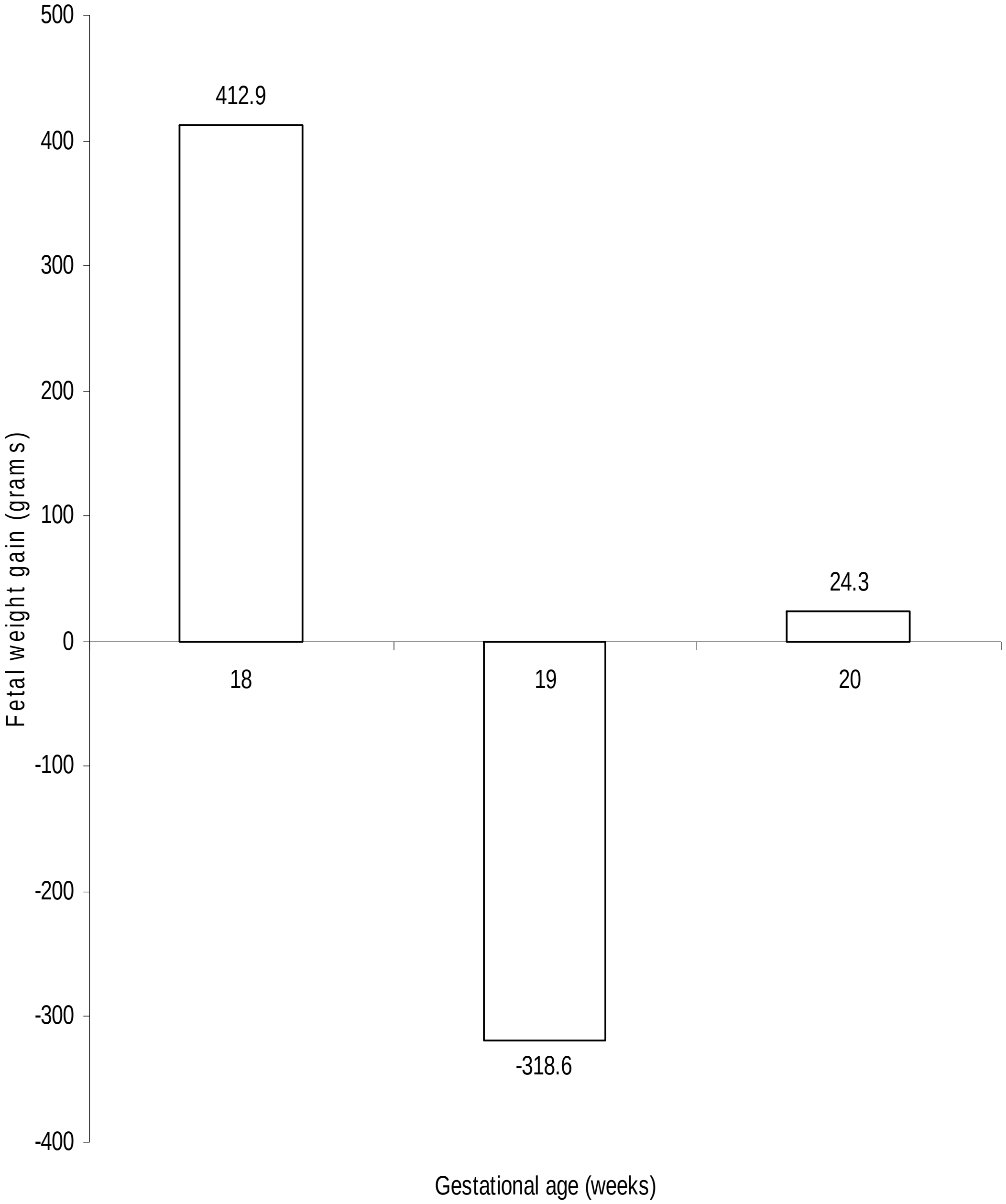

Figure 107: Mean fetal weight gain at 5 months

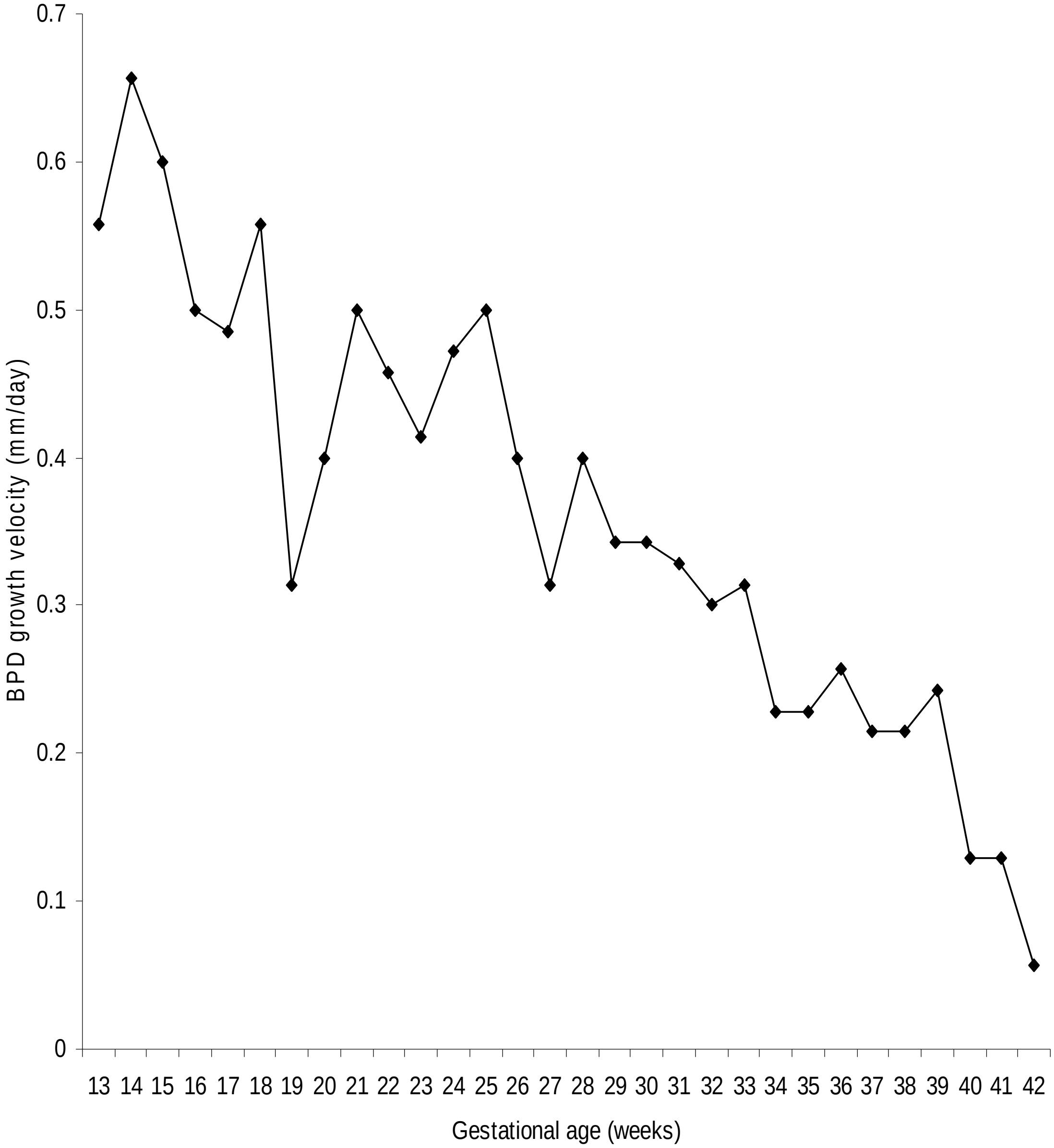

Figure 108: Biparietal diameter growth velocity during normal pregnancy

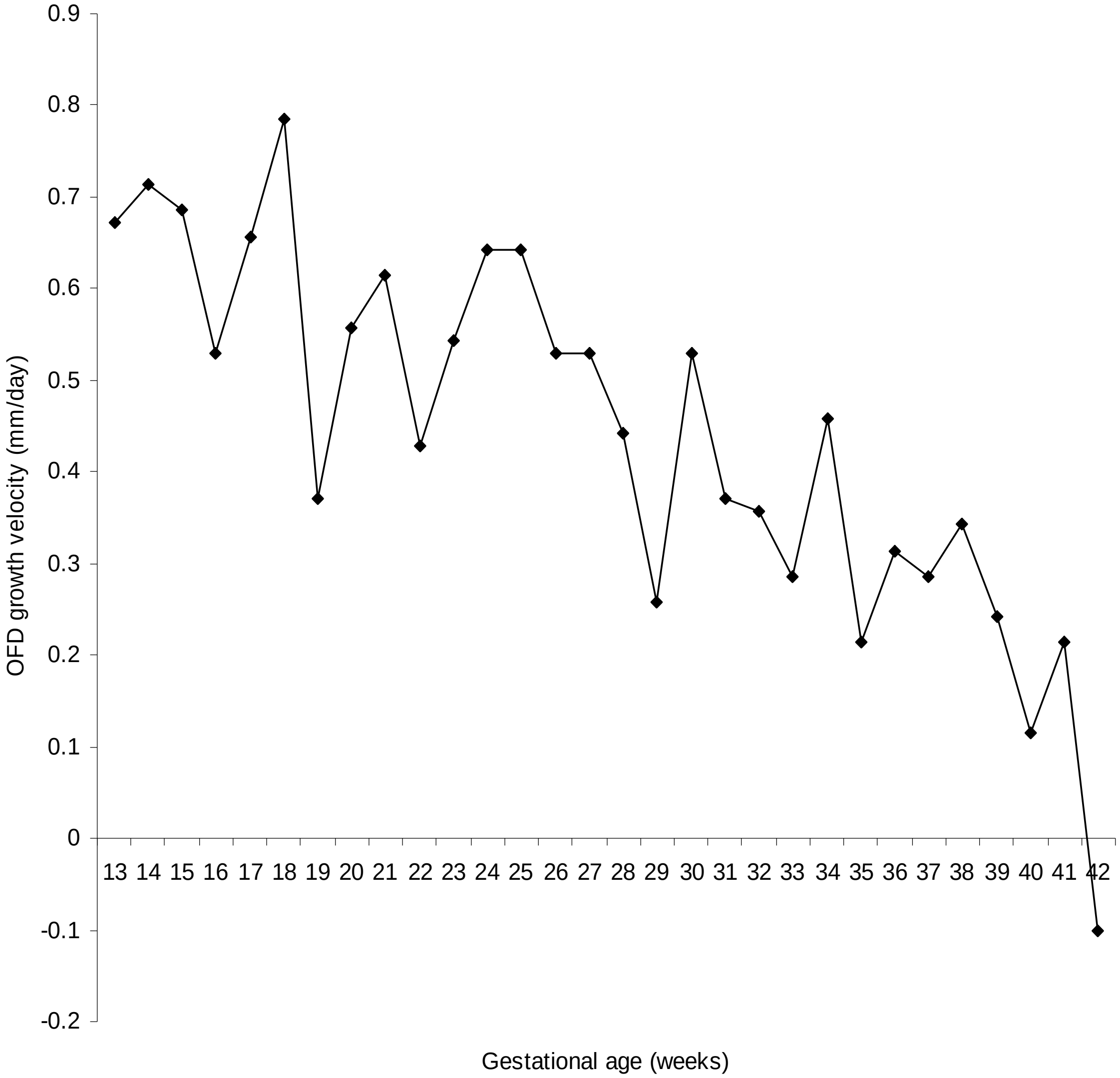

Figure 109: Occipitofrontal diameter growth velocity during normal pregnancy

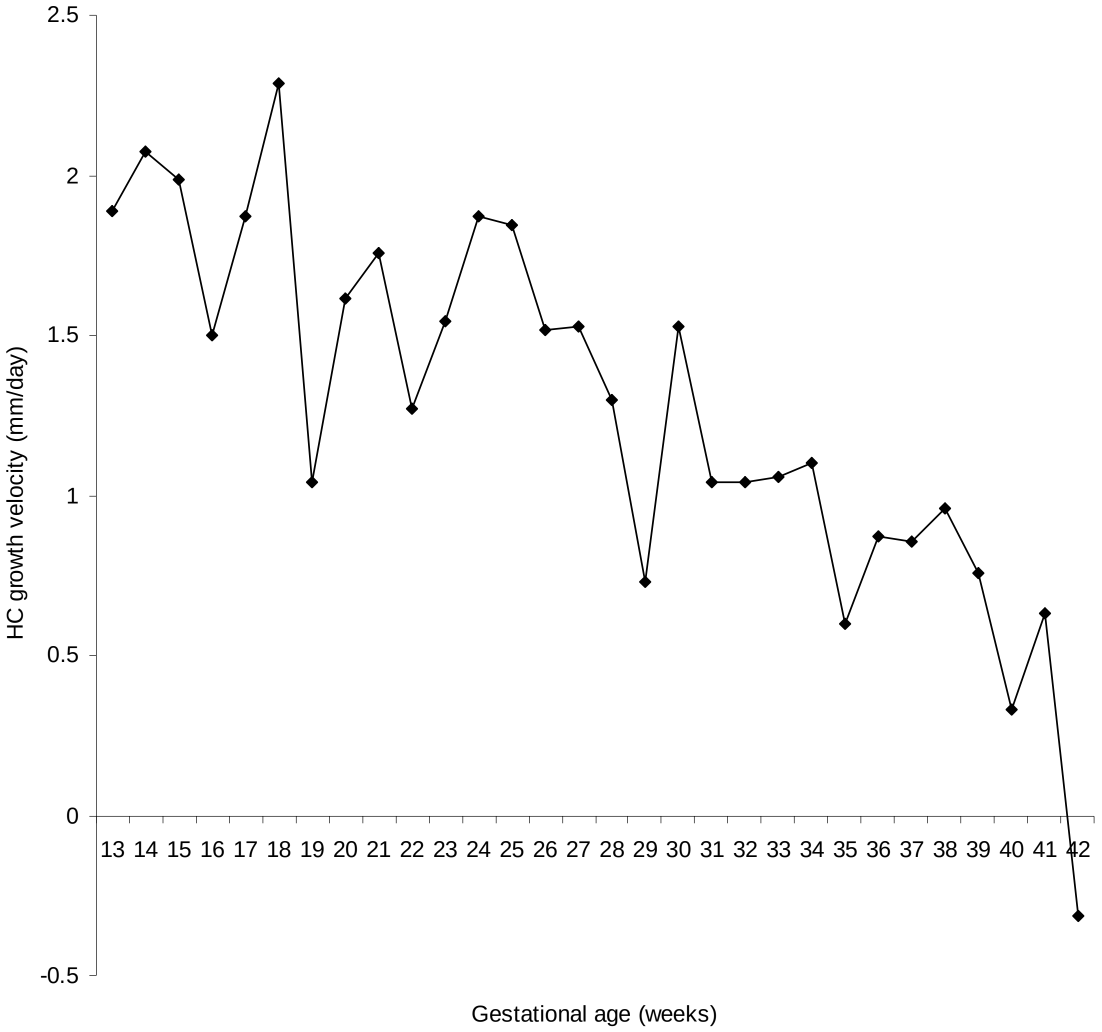

Figure 110: Head circumference growth velocity during normal pregnancy

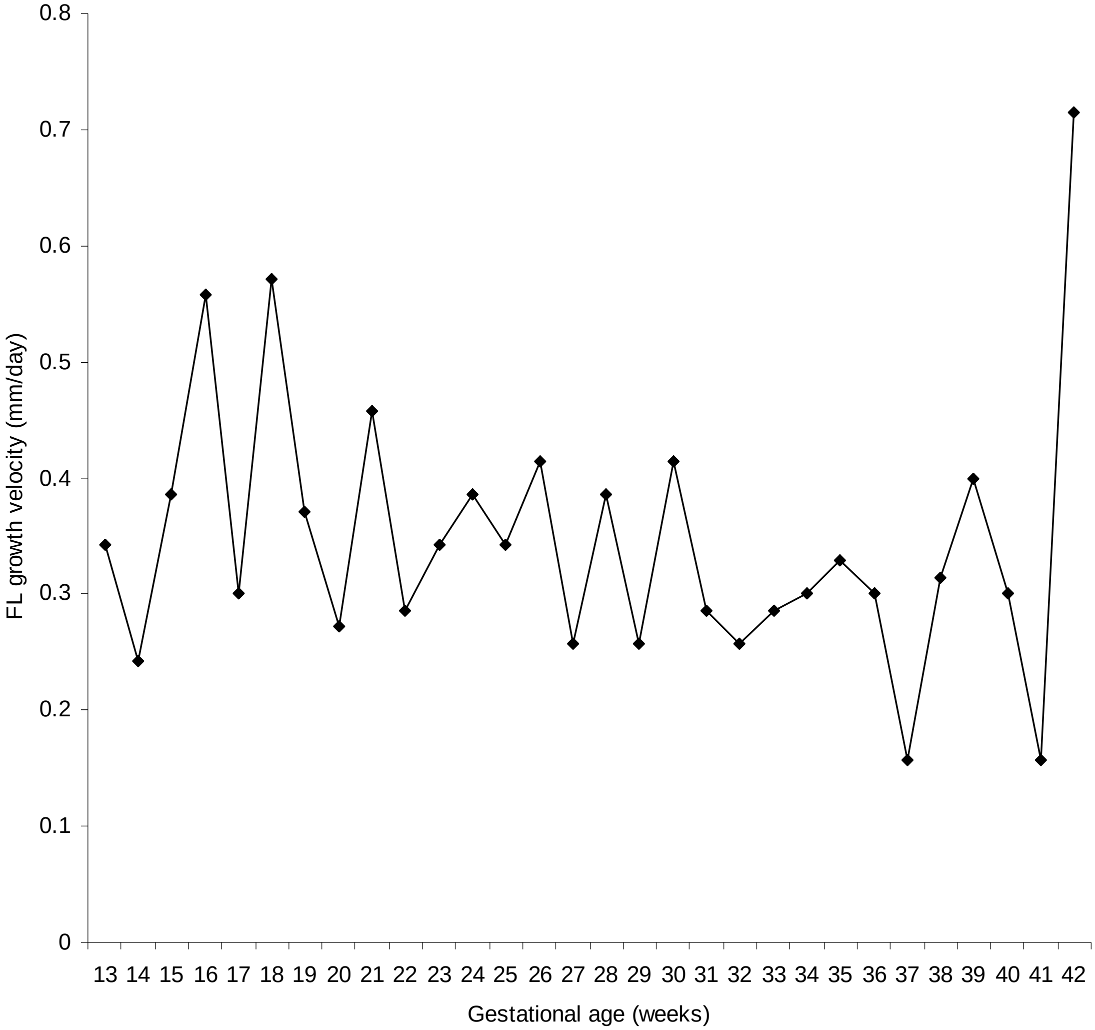

Figure 111: Femur length growth velocity during normal pregnancy

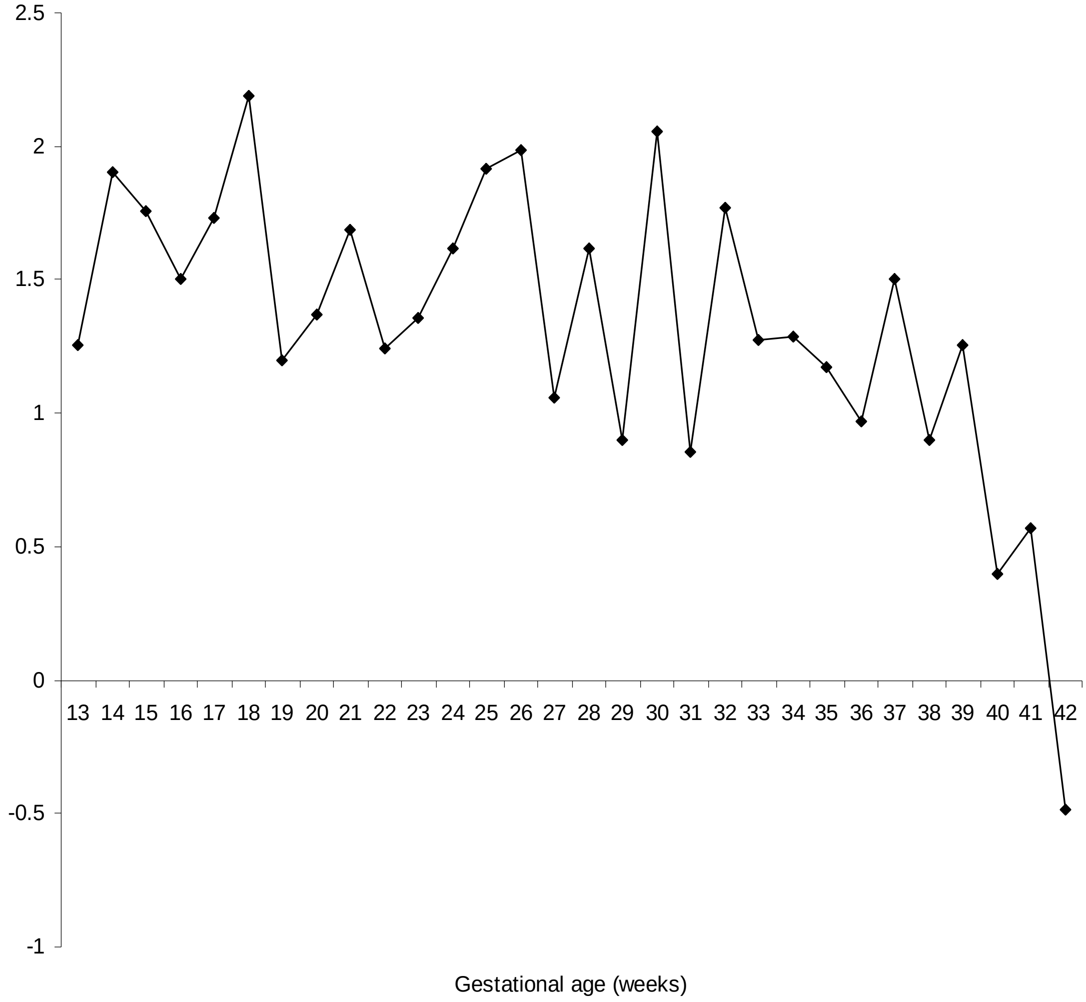

Figure 112: Abdominal circumference growth velocity during normal pregnancy

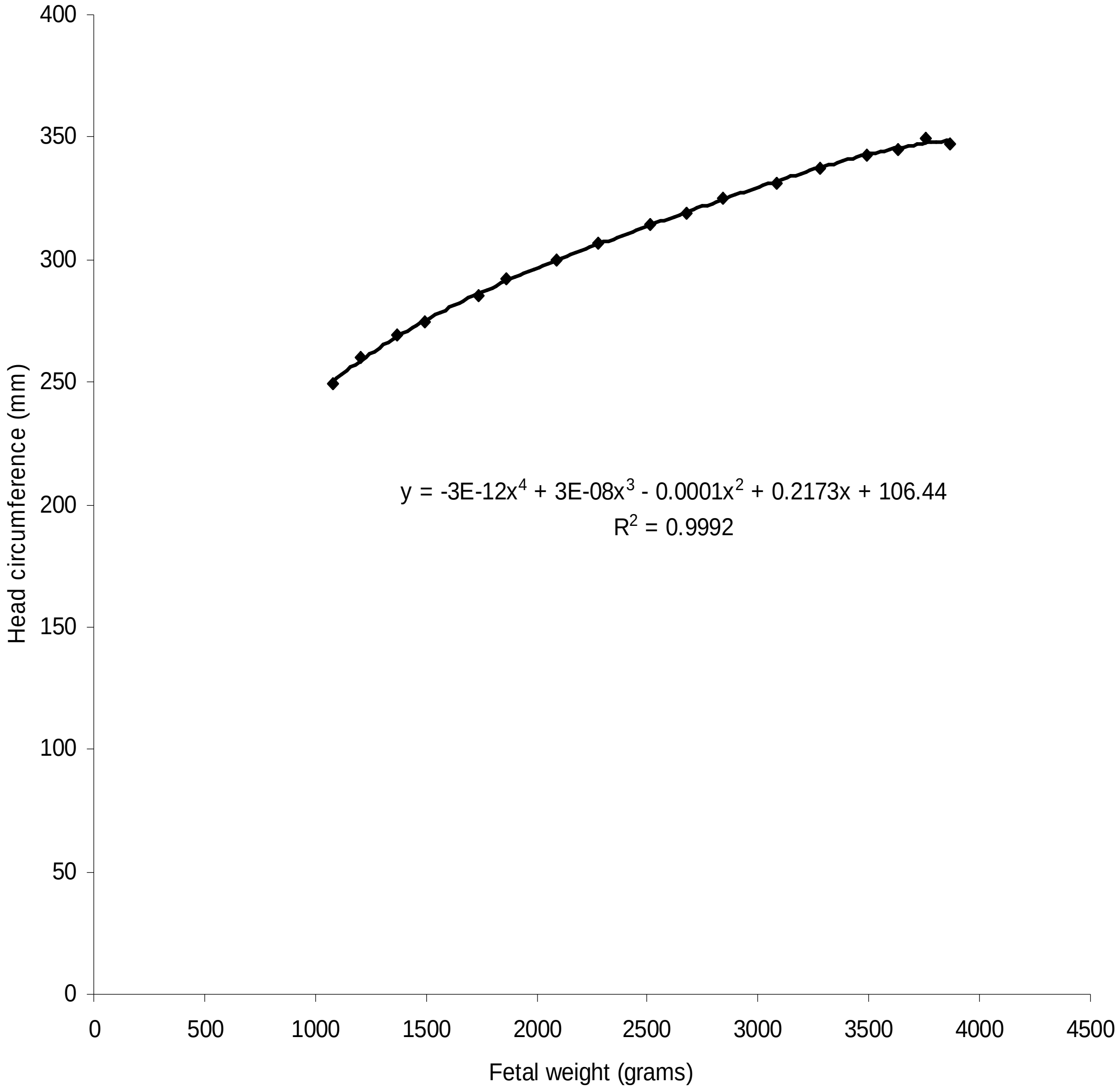

Figure 113: Correlation and regression equation of mean head circumference values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams

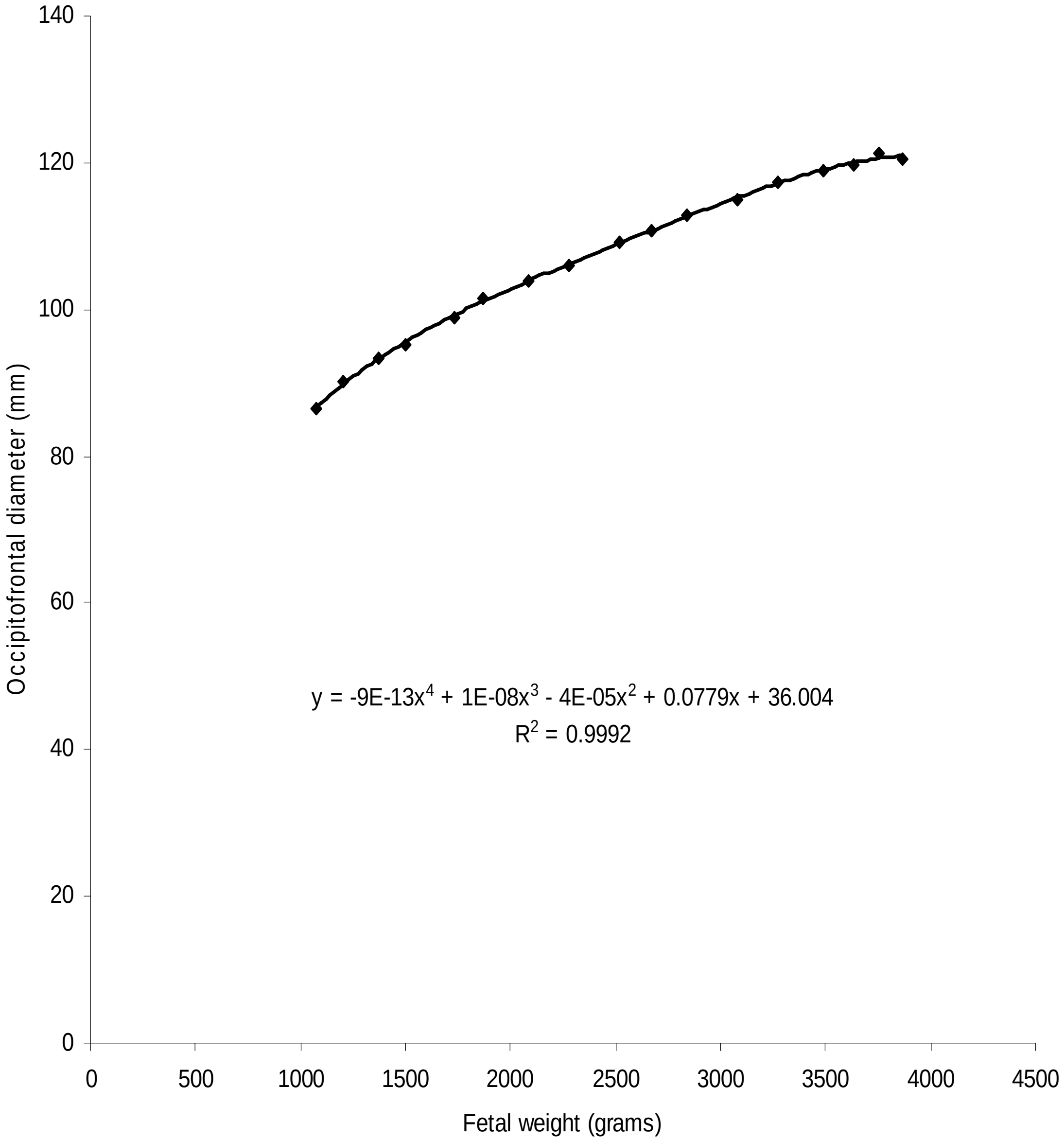

Figure 114: Correlation and regression equation of mean occipitofrontal diameter values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams

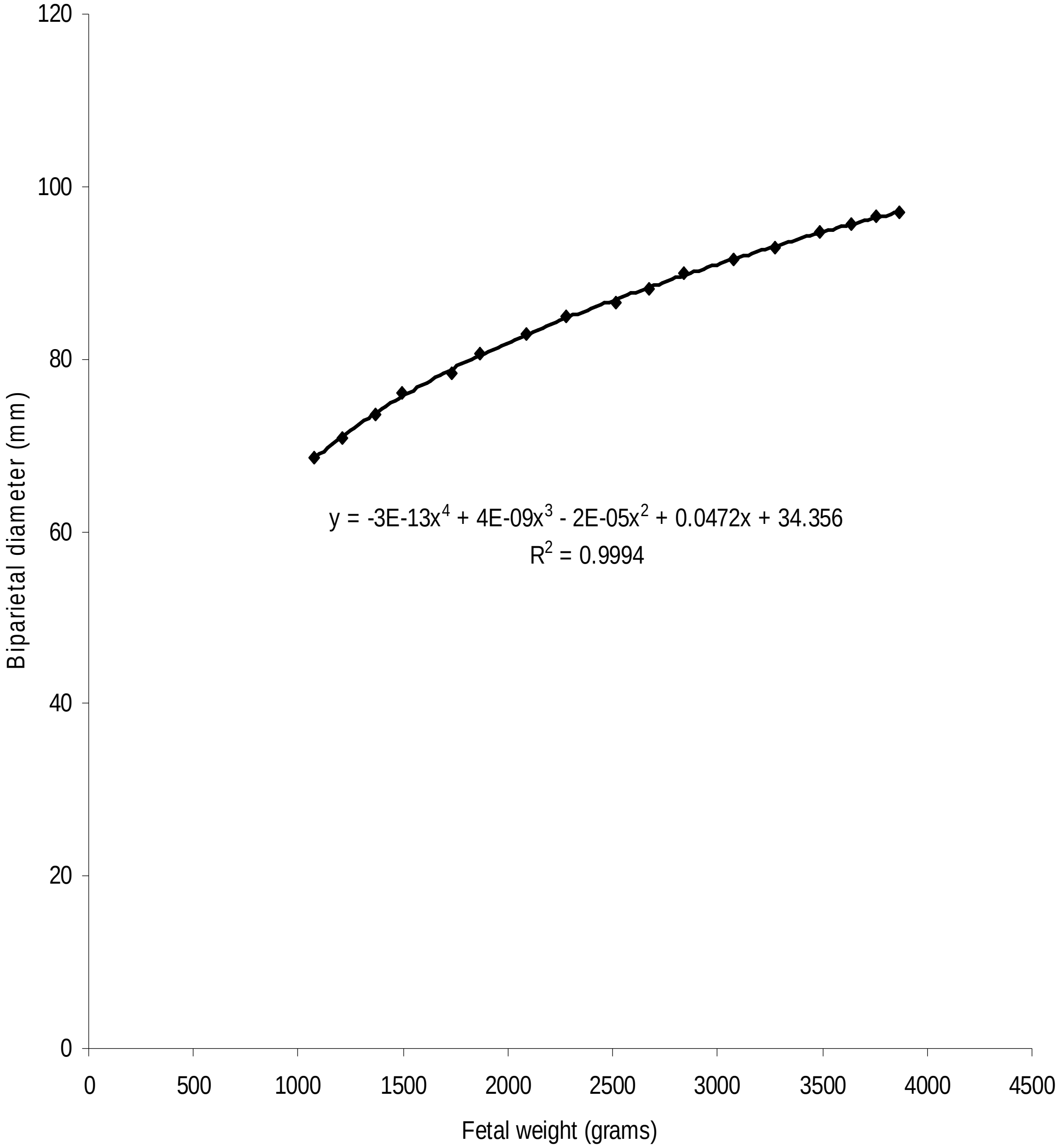

Figure 115: Correlation and regression equation of mean biparietal diameter values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams

Other relationships can be calculated outside the skull. Figure 116 shows relationship of weight with abdominal circumference. From the graph, it can be seen that there is a positive polynomial correlation between abdominal circumference and weight with a correlation of determination of $r^2 = 0.9993$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the forth order polynomial regression equation

$y = – 3E\text{-}12x^4 + 2E\text{-}08x^3 – 9E\text{-}05x^2 + 0.1947x + 95.592$ where y is biparietal diameter and x is the fetal weight in grams with a correlation of determination of $r^2 = 0.9992$ ($P < 0.0001$).

Figure 117 shows relationship between weight and femur length. There is a positive polynomial correlation between weight and femur length with a correlation of determination of $r^2 = 0.9972$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the forth order polynomial regression equation $y = 1E\text{-}12x^4 – 8E\text{-}09x^3 + 2E\text{-}05x^2 – 0.009x + 43.172$ where y is femur length and x is the fetal weight in grams.

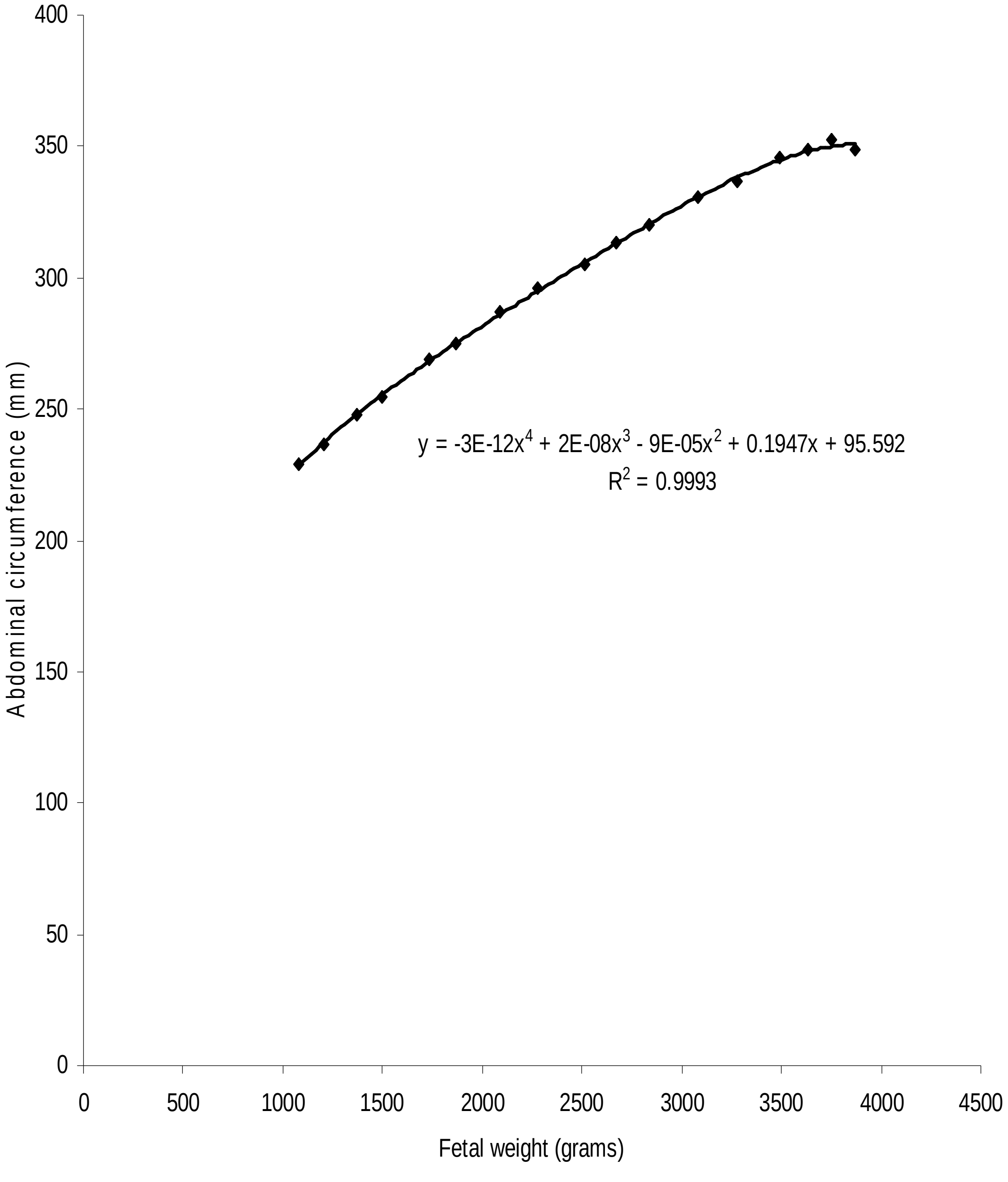

Figure 116: Correlation and regression equation of mean abdominal circumference values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams

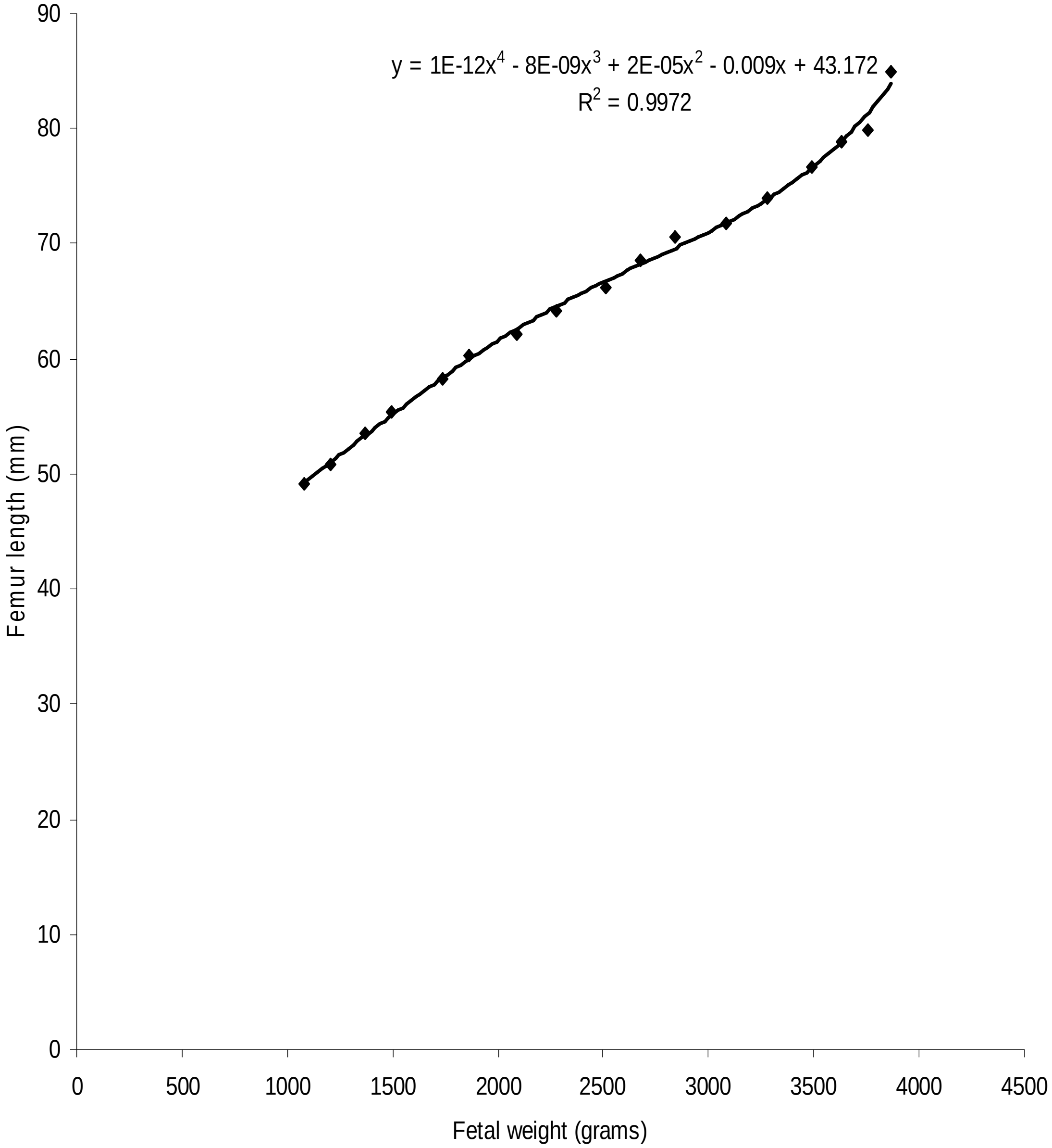

Figure 117: Correlation and regression equation of mean femur length values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams

4.1.7 Biparietal diameter to Occipitofrontal diameter ratio (Cephalic Index)

The weekly mean of biparietal diameter to occipitofrontal ratio is as shown in table 38. The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. Variability of the cephalic index is more in the early phase of pregnancy. As the age of the fetus increases, variation in cephalic index decreases. When mean values of cephalic index were plotted against gestational age (figure 118), the relationship was found to be linear from 12 to 16 weeks but thereafter, there was a week relationship. The relationship between cephalic index and gestational age from 12 – 16 weeks was best described by the linear regression equation $y = 1.3x + 59.88$ with a coefficient of determination of $r^2 = 0.9844$ (figure 119).

Table 38. Frequency Distribution Table of Mean Cephalic Index of Fetuses from 12 - 42 Together with SD, SE, 3rd, 5th, 10th, 50th, 90th, 95th, 97th, Centiles.

					centiles						
GA(wks)	Fetus	C. I	SD	SE	3rd	5th	10th	50th	90th	95th	97th
12	49	75.6	10.3	1.5	57.6	57.6	59.4	77.8	86.7	95.7	100
13	384	76.4	7.9	0.4	62.3	63.9	66.7	77.1	85.2	87.5	90.8
14	371	78.4	7.5	0.4	63.6	68.3	71.8	78.4	85.7	87.9	93.0
15	351	79.4	6.5	0.3	65.4	69.4	72.3	79.5	85.4	88.9	94.3
16	505	80.6	6.1	0.3	68.6	70.2	74.5	80.4	86.7	89.8	92.1
17	427	80.1	5.3	0.3	67.2	71.2	73.2	80.4	85.7	89.3	92.7
18	446	79.4	6.5	0.3	64.8	67.2	72.9	79.6	86.2	91.8	93.5
19	282	79.6	6.1	0.4	67.2	70.1	72.1	79.7	85.5	90.0	97.9
20	553	78.9	5.0	0.2	68.3	71.9	73.8	79.4	83.8	86.2	87.8
21	400	79.1	4.3	0.2	69.6	70.7	74.0	79.1	83.1	85.2	89.8
22	398	80.3	5.0	0.2	72.4	74.0	75.3	80.3	84.3	86.2	87.7
23	478	80.2	5.4	0.2	72.5	73.3	75.0	79.7	84.9	87.9	92.1
24	520	79.7	4.5	0.2	70.0	72.7	75.0	79.9	84.0	86.1	91.2
25	388	79.7	5.1	0.3	70.7	72.8	75.0	79.3	83.3	88.6	92.0
26	511	79.5	4.6	0.2	71.2	72.7	74.7	79.3	85.0	87.5	89.5
27	432	78.7	4.4	0.2	71.7	72.0	74.1	78.3	82.6	86.7	89.2
28	548	79.0	5.0	0.2	71.7	73.4	74.7	78.9	83.0	85.2	88.1
29	484	79.7	4.5	0.2	72.3	73.3	75.2	79.2	84.6	88.1	92.8
30	625	79.5	4.7	0.2	72.4	73.0	75.2	79.2	83.7	85.4	87.1
31	523	79.8	4.6	0.2	74.0	74.3	75.7	79.4	83.5	86.2	92.0
32	583	79.7	3.6	0.1	73.9	74.5	75.9	79.8	83.3	84.6	86.6
33	516	79.9	3.7	0.2	73.9	74.8	76.1	79.6	83.3	85.3	85.6
34	744	79.3	3.1	0.1	72.7	74.4	75.9	79.3	83.0	84.2	85.3
35	739	79.7	3.2	0.1	74.3	75.0	76.3	79.6	83.2	84.5	85.6
36	599	79.8	3.0	0.1	74.3	75.0	76.9	79.6	83.5	84.3	85.7
37	532	79.7	3.5	0.2	73.8	74.5	76.1	79.3	83.8	86.6	88.7
38	481	79.4	3.6	0.2	72.0	74.8	76.5	79.5	83.5	83.8	85.8
39	525	79.7	3.5	0.2	71.4	74.6	76.3	79.7	83.3	85.3	86.6
40	252	79.8	3.0	0.2	72.2	74.6	76.6	79.8	83.3	83.9	84.7
41	72	79.6	2.8	0.3	72.4	74.1	75.6	80.0	82.8	84.2	85.0
42	22	80.6	3.7	0.8	73.9	73.9	73.9	79.8	85.8	85.8	85.8
Total	**13740**										

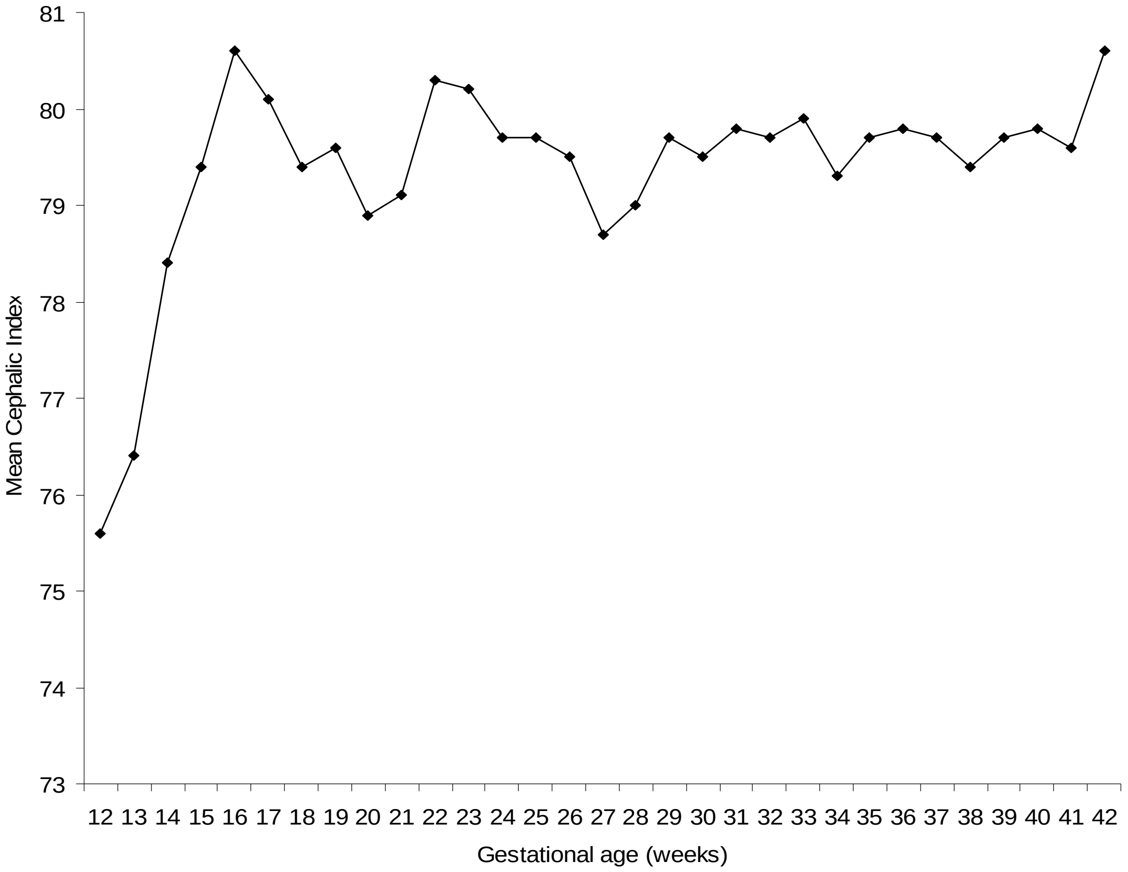

Figure 118. Mean cephalic index values in 13,740 fetuses of Nigerian women from 12 to 42 weeks of gestation

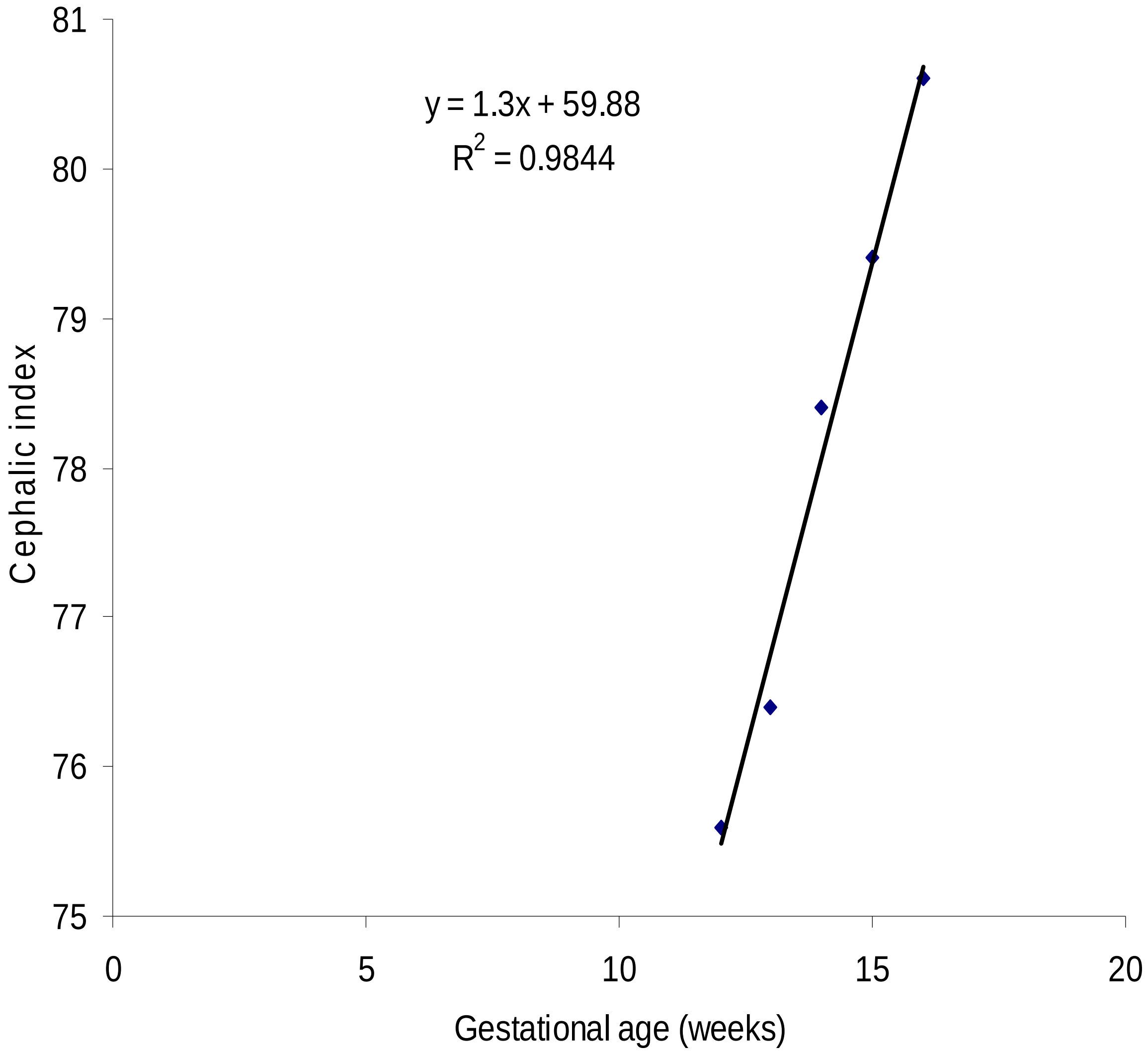

Figure 119. Mean cephalic index of fetuses from 12 to 16 weeks of gestation with regression equation.

4.1.8 Biparietal diameter to Femur length ratio (BPD/FL).

The weekly mean of biparietal diameter to femur length ratio is as shown in table 39. The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. Variability of the biparietal diameter to femur length ratio is more in the early phase of pregnancy. As the age of the fetus increases, variation in biparietal diameter to femur length ratio decreases. When the mean values of biparietal diameter to femur length ratio are plotted against gestational age, the correlation graph was found as shown in figure 120. When mean values of biparietal diameter to femur length ratio before 32 weeks gestation were plotted against gestational age, a positive polynomial correlation between gestational age and biparietal diameter to femur length ratio with a coefficient of determination of $r^2 = 0.9945$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 121). The relationship is best described by the sixth order polynomial regression equation

$y = -6E\text{-}07x^6 + 5E\text{-}05x^5 - 0.0014x^4 + 0.0201x^3 - 0.1461x^2 + 0.422x + 1.4531$ where y is the biparietal diameter to femur length ratio and x is the gestational age weeks.

Table 39. Frequency Distribution of Fetal Mean Biparietal Diameter to Femur Length Ratio Together With Standard Deviation (SD) and Standard Error of Mean of from 12 – 42 Weeks.

Gestational Age (wks)	Number of fetuses	BPD/FL	SD	SE
12	49	1.753645	0.299061	0.042723
13	384	1.835002	0.373818	0.019076
14	371	1.856655	0.287827	0.014943
15	351	1.803558	0.277156	0.014793
16	505	1.671191	0.245	0.010902
17	427	1.642656	0.192299	0.009306
18	446	1.550236	0.166775	0.007897
19	282	1.49587	0.17883	0.010649
20	553	1.489886	0.158105	0.006723
21	400	1.458348	0.168216	0.008411
22	398	1.461995	0.170543	0.008549
23	478	1.441225	0.105595	0.00483
24	520	1.430122	0.118144	0.005181
25	388	1.437108	0.159406	0.008093
26	511	1.40403	0.097001	0.004291
27	432	1.394295	0.071814	0.003455
28	548	1.379489	0.096341	0.004115
29	484	1.376124	0.09054	0.004115
30	625	1.34999	0.086905	0.003476
31	523	1.343527	0.078737	0.003443
32	583	0.337037	0.069011	0.002858
33	516	1.327187	0.067198	0.002958
34	744	1.309745	0.078617	0.002882
35	739	1.288194	0.056903	0.002093
36	599	1.277402	0.057548	0.002351
37	532	1.309174	0.529752	0.022968
38	481	1.270184	0.202183	0.009219
39	525	1.236812	0.05193	0.002266
40	252	1.215692	0.064275	0.004049
41	72	1.2117	0.079385	0.009356
42	22	1.16019	0.141613	0.030192
Total	13740			

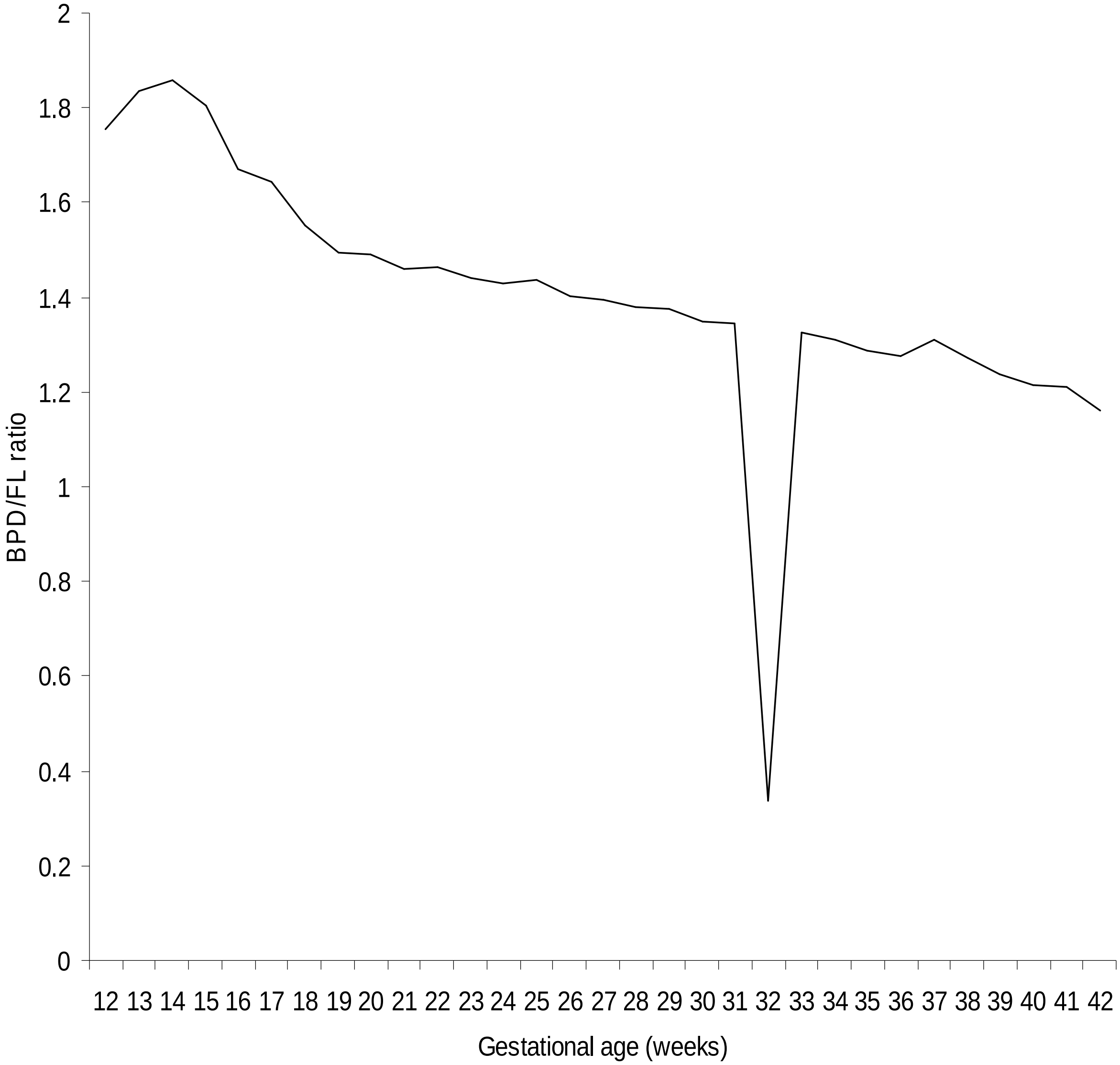

Figure 120. Graph Showing Mean Biparietal Diameter to Femur Length Ratio Plotted Against Gestational Age in Weeks

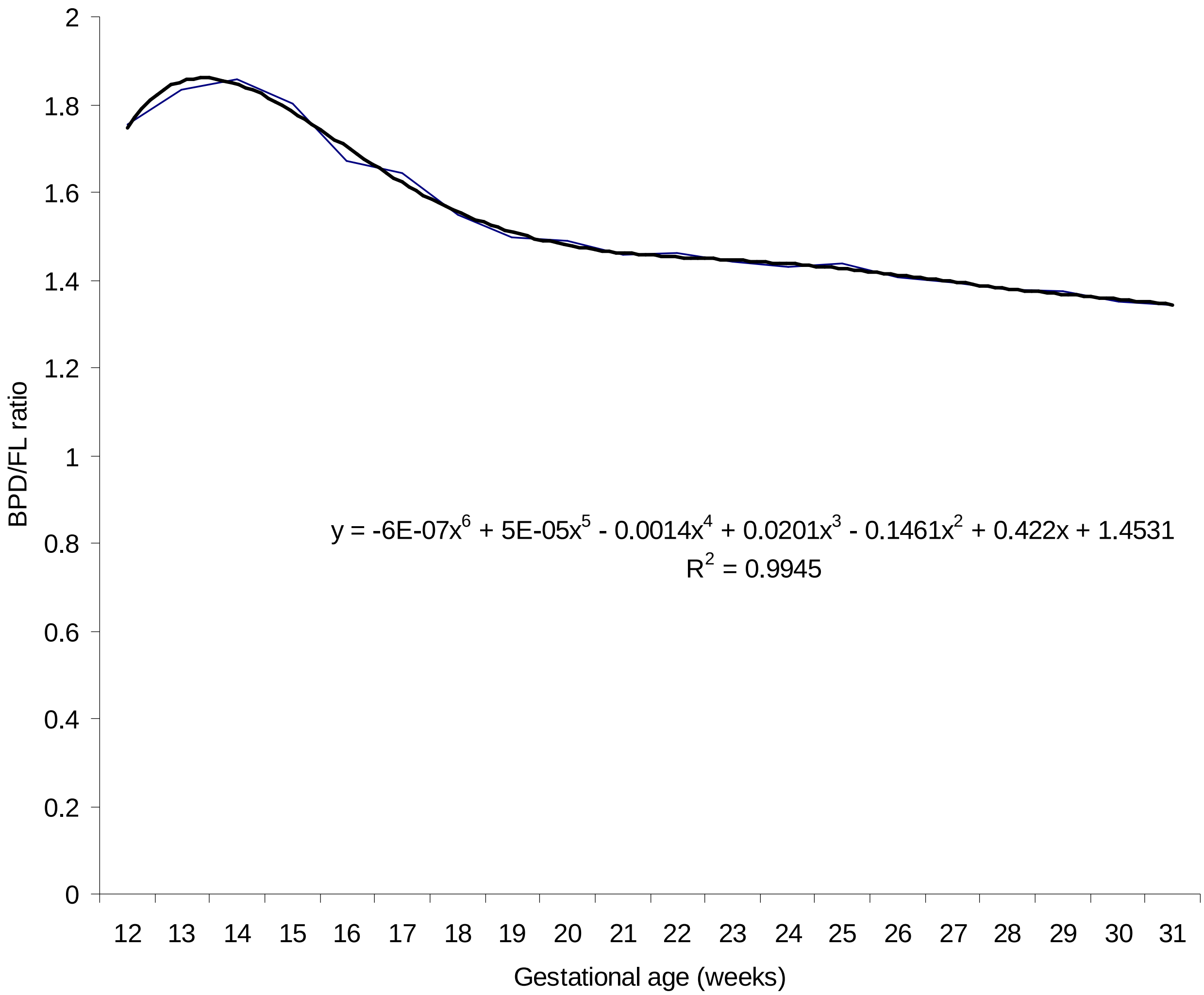

Figure 121. Graph Showing Correlation and Regression Equation of Mean Biparietal Diameter to Femur Length Ratio before 32 weeks Plotted against Gestational Age in Weeks

4.1.9 Femur length to Head circumference ratio (FL/HC).

The weekly mean of femur length to head circumference ratio is as shown in table 40. The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. When the mean values of femur length to head circumference ratio were plotted against gestational age, a positive polynomial correlation between gestational age and femur length to head circumference ratio with a coefficient of determination of $r^2 = 0.976$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 122). The relationship is best described by the third order polynomial regression equation $y = 7E\text{-}06x^3 - 0.0003x^2 + 0.0075x + 0.1407$ where y is the femur length to head circumference ratio and x is the gestational age weeks.

Table 40. Frequency Distribution of Fetal Mean Femur Length to Head Circumference Ratio Together With Standard Deviation (SD) and Standard Error of Mean of from 12 – 42 Weeks.

Gestational Age (wks)	Number of fetuses	FL/HC	SD	SE
12	49	0.154851	0.0411	0.005871
13	384	0.157828	0.094823	0.004839
14	371	0.151485	0.045633	0.002369
15	351	0.156104	0.023968	0.001279
16	505	0.173078	0.047379	0.002108
17	427	0.171775	0.022736	0.0011
18	446	0.179564	0.021279	0.001008
19	282	0.187513	0.0261	0.001554
20	553	0.18601	0.02191	0.000932
21	400	0.19088	0.023181	0.001159
22	398	0.192317	0.019561	0.000981
23	478	0.194207	0.017854	0.000817
24	520	0.194396	0.015795	0.000693
25	388	0.194023	0.017997	0.000914
26	511	0.197497	0.017211	0.000761
27	432	0.19638	0.01341	0.000645
28	548	0.199305	0.014117	0.000603
29	484	0.204955	0.044033	0.002001
30	625	0.205162	0.016343	0.000654
31	523	0.206708	0.014895	0.000651
32	583	0.207528	0.012778	0.000529
33	516	0.209367	0.01188	0.000523
34	744	0.210937	0.013213	0.000484
35	739	0.215293	0.011563	0.000425
36	599	0.217528	0.012009	0.000491
37	532	0.21719	0.019346	0.000839
38	481	0.219302	0.016703	0.000762
39	525	0.224066	0.011988	0.000523
40	252	0.228576	0.013994	0.000882
41	72	0.228729	0.014226	0.001677
42	22	0.243909	0.025364	0.005408
Total	13740			

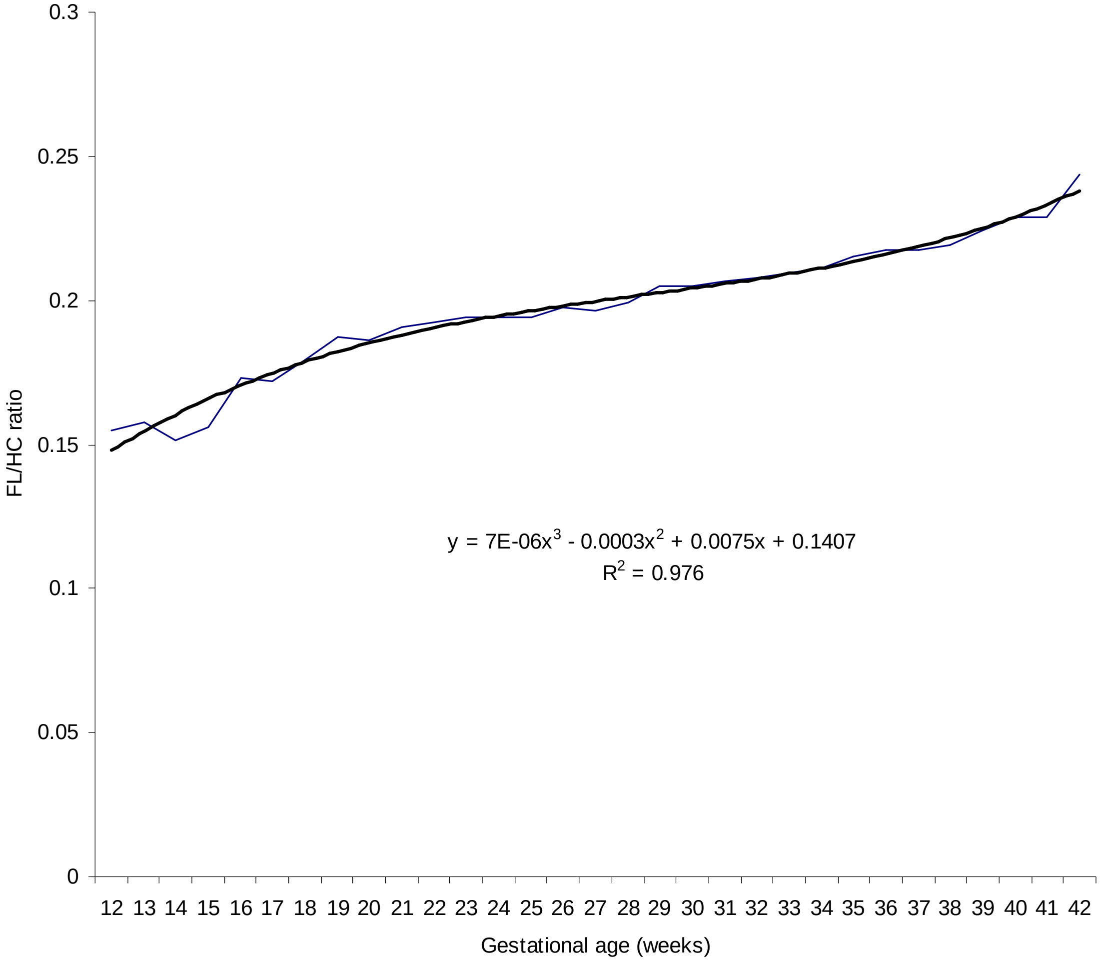

Figure 122. Graph Showing Correlation and Regression Equation of Mean Femur Length to Head Circumference Ratio Plotted against Gestational Age in Weeks

4.1.10 Femur Length to Abdominal Circumference Ratio (FL/AC)

The weekly mean of femur length to abdominal circumference ratio is as shown in table 41. The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. When the mean values of femur length to abdominal circumference ratio were plotted against gestational age, a positive polynomial correlation between gestational age and femur length to abdominal circumference ratio with a coefficient of determination of $r^2 = 0.9545$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 123). The relationship is best described by the sixth order polynomial regression equation $y = 7E\text{-}09x^6 – 7E\text{-}07x^5 + 2E\text{-}5x^4 – 0.005x^3 – 0.0039x^2 – 0.0098x + 0.1892$ where y is the femur length to abdominal circumference ratio and x is the gestational age weeks.

Table 41. Frequency Distribution Table of Fetal Mean Femur Length to abdominal Circumference Ratio Together With Standard Deviation (SD) and Standard Error of Mean of from 12 – 42 Weeks.

Gestational Age (wks)	Number of fetuses	FL/AC	SD	SE
12	49	0.18081	0.050699	0.007243
13	384	0.189417	0.121501	0.0062
14	371	0.179003	0.056181	0.002917
15	351	0.182606	0.026424	0.00141
16	505	0.200872	0.059151	0.002632
17	427	0.198337	0.029701	0.001437
18	446	0.204628	0.024884	0.001178
19	282	0.210685	0.030539	0.001819
20	553	0.210224	0.028659	0.001219
21	400	0.216092	0.036468	0.001823
22	398	0.214909	0.023462	0.001176
23	478	0.217837	0.028364	0.001297
24	520	0.217874	0.020593	0.000903
25	388	0.215509	0.022092	0.001122
26	511	0.215067	0.01982	0.000877
27	432	0.216285	0.017013	0.000819
28	548	0.216702	0.017584	0.000751
29	484	0.218678	0.016362	0.000744
30	625	0.217626	0.017112	0.000684
31	523	0.220434	0.019809	0.000866
32	583	0.216615	0.013369	0.000554
33	516	0.217455	0.015206	0.000669
34	744	0.217803	0.014789	0.000542
35	739	0.219535	0.014305	0.000526
36	599	0.221086	0.013803	0.000564
37	532	0.217674	0.021371	0.000927
38	481	0.219919	0.0177	0.000807
39	525	0.222724	0.01555	0.000679
40	252	0.226619	0.013604	0.000857
41	72	0.242955	0.028509	0.006078
42	22	0.242955	0.028509	0.006078
Total	13740			

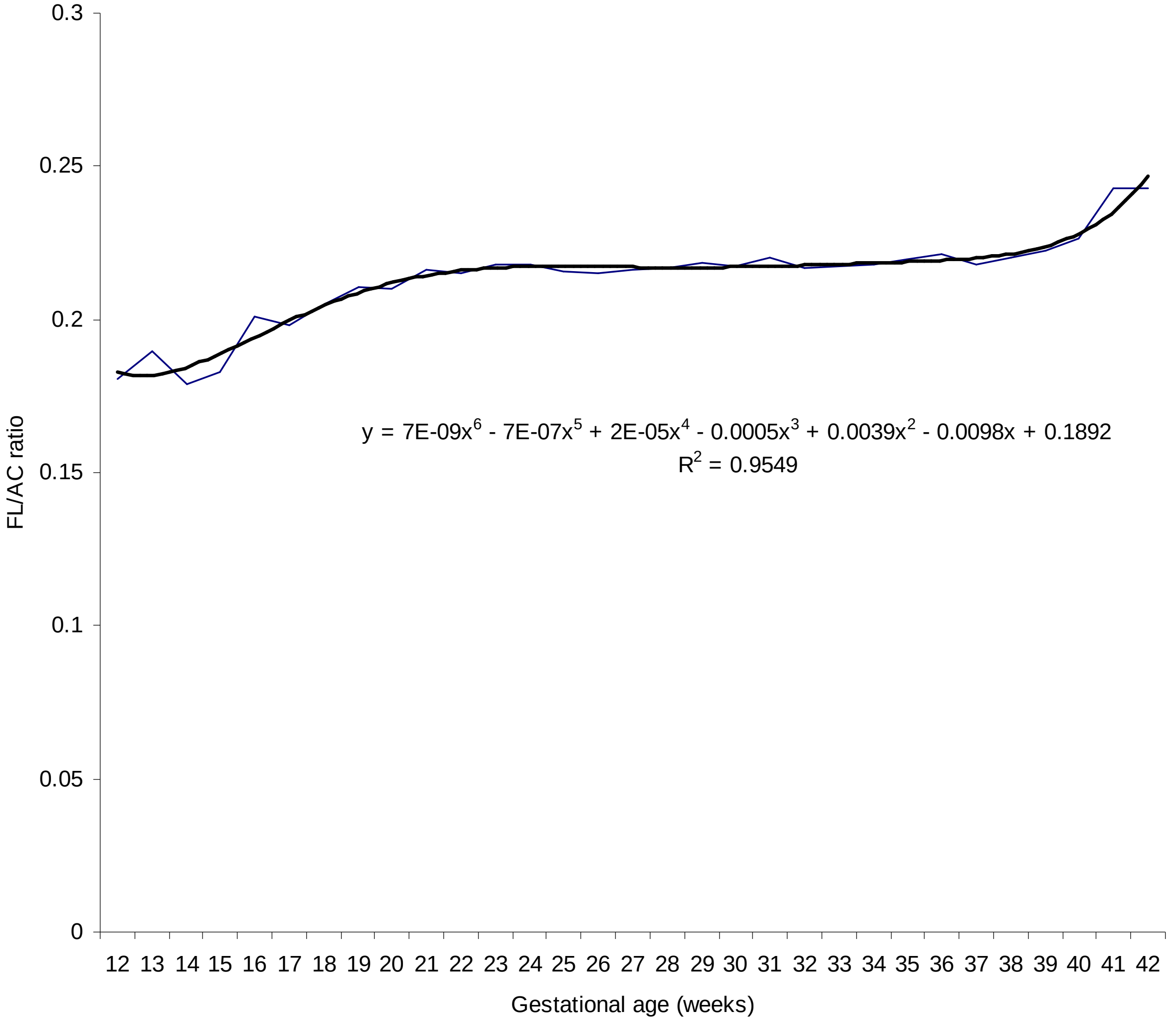

Figure 123. Graph Showing Correlation and Regression Equation of Mean Femur Length to Abdominal Circumference Ratio Plotted against Gestational Age in Weeks

4.1.11 Head Circumference to Abdominal Circumference Ratio (HC/AC)

The weekly mean of head circumference to abdominal circumference ratio is as shown in table 42. The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. When the mean values of head circumference to abdominal circumference ratio were plotted against gestational age, a linear correlation between gestational age and head circumference to abdominal circumference ratio with a coefficient of determination of $r^2 = 0.9807$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (figure 124). The relationship is best described by the linear regression equation $y = 0.0072x + 1.2037$ where y is the head circumference to abdominal circumference ratio and x is the gestational age weeks.

Table 42. Frequency Distribution of Fetal Mean Head Circumference to abdominal Circumference Ratio Together With Standard Deviation (SD) and Standard Error of Mean of from 12 – 42 Weeks

Gestational Age (wks)	Number of fetuses	HC/AC	SD	SE
12	49	1.183216	0.217999	0.031143
13	384	1.204067	0.14757	0.007531
14	371	1.191163	0.193846	0.010064
15	351	1.175971	0.108242	0.005778
16	505	1.162018	0.110583	0.004921
17	427	1.157268	0.113619	0.005498
18	446	1.146764	0.132374	0.006268
19	282	1.128061	0.105658	0.006292
20	553	1.131677	0.097607	0.004151
21	400	1.134282	0.153016	0.007651
22	398	1.119457	0.080648	0.004043
23	478	1.125375	0.136145	0.006227
24	520	1.123904	0.098869	0.004336
25	388	1.113473	0.094731	0.004809
26	511	1.091532	0.081464	0.003604
27	432	1.104059	0.090227	0.004341
28	548	1.088647	0.06907	0.002951
29	484	1.082194	0.098106	0.004459
30	625	1.063426	0.076023	0.003041
31	523	1.068138	0.083179	0.003637
32	583	1.045634	0.06323	0.002619
33	516	1.039827	0.06748	0.002971
34	744	1.033927	0.060538	0.002219
35	739	1.02084	0.060837	0.002238
36	599	1.017397	0.053525	0.002187
37	532	1.003896	0.065258	0.002829
38	481	1.004513	0.063128	0.002878
39	525	0.995545	0.070296	0.003068
40	252	0.993062	0.054936	0.003461
41	72	0.993108	0.045305	0.005339
42	22	0.995974	0.046431	0.009899
Total	13740			

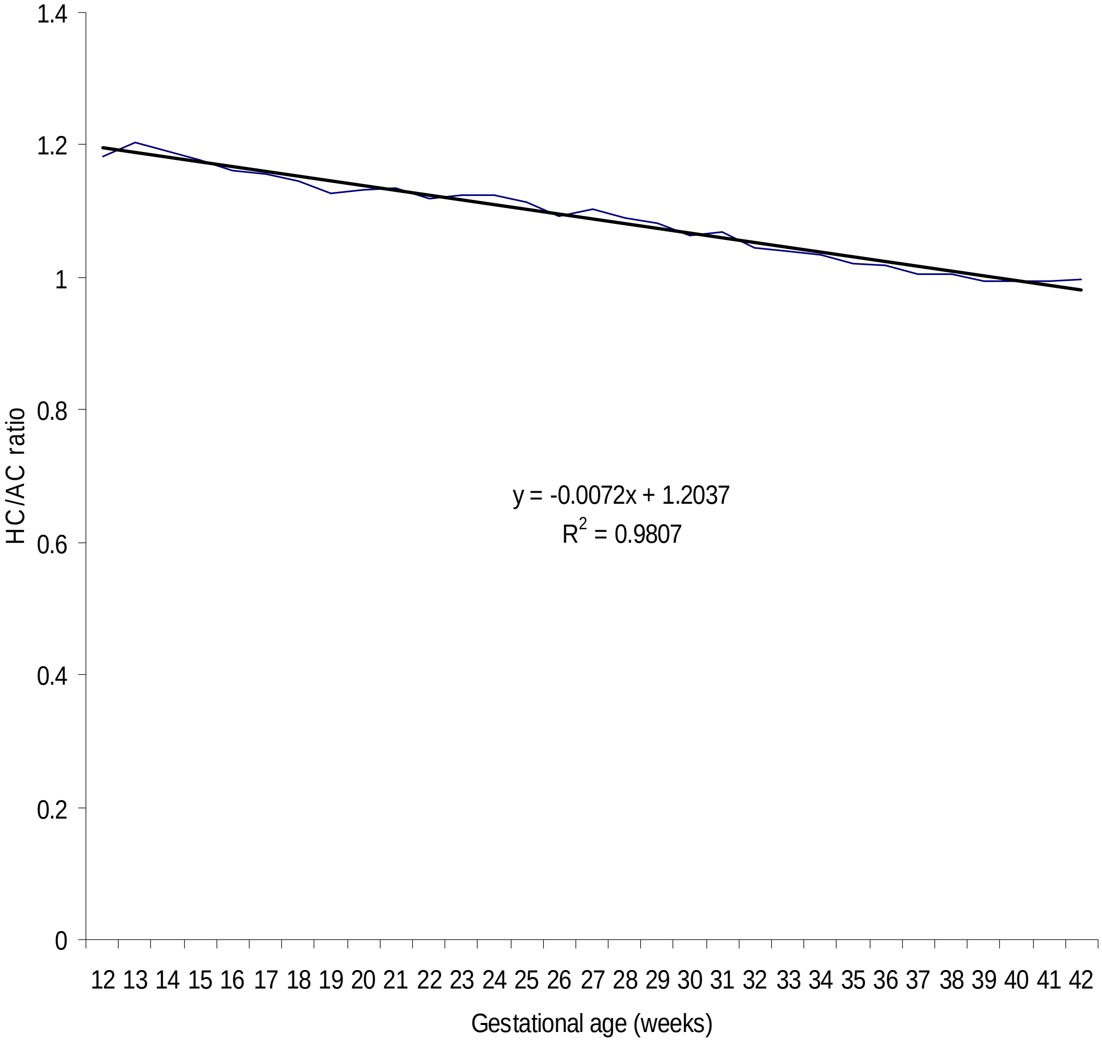

Figure 124. Graph Showing Correlation and Regression Equation of Mean Head Circumference to Abdominal Circumference Ratio Plotted against Gestational Age in Weeks

CHAPTER FIVE
DISCUSSION

5.0 GENERAL DISCUSSION

Mean values of biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight of fetuses of Nigerian women in Jos have been established. These findings agree with those of Chitty, *et al.*, 1994b-d; Kurmanavicius, *et al.*, 1999a-b; *S*nijders and Nicolaides, 1994; Kankeow, 2007. The mean values of these fetal parameters have relatively small standard error of mean signifying that the mean values obtained for the fetal parameters from the sample are a reflection of the fetal population means in Jos, Nigeria. This will enable the benefiting specialist (obstetricians, perinatologist, embryologist and forensic pathologist) to use the mean values with confidence since it was obtained form a very large sample size. When the correlation between the various fetal parameters and gestational age was studied, a positive correlation between biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight of fetuses of Nigerian women in Jos with gestational age found and their corresponding regression equations derived. Again, when mean values of BPD, HC, FL, and AC of fetuses in Jos were compared with those of Kankeow obtained from an Asian population, statistically significant difference was found with mean values from this study being higher than those of the Asian population at p level of 0.001

Growth rate studies of the fetal parameters measured in Jos, Nigerian revealed the biparietal diameter growth rate is highest at 14 weeks (0.68mm/day) while femur length growth rate is highest at 42 weeks (0.7mm/day), occipitofrontal diameter growth rate is highest at 18 weeks (0.8mm/day), head circumference growth rate is highest at 18 weeks (2.4mm/day) and abdominal circumference growth rate is highest at 18 weeks (2.3mm/day). Fetal weight gain on the other hand is highest at 18 weeks (58.8g/day). Based on the findings of this study, a pattern of growth has been found in which there is drop in growth rate at 19 weeks with concomitant weight loss. This has led to the identification of the 19 week gestation problem.

In this study, particular attention was paid to the methodology used to construct these new ranges, doing our best to follow the recommendations made by the authors of previous methodological reviews (Altman and Chitty, 1994; Royston and Wright, 1998). The analytical method followed standard recommendations strictly. Unlike previous investigators (Okupe, et., 1984; Osinusi, 1990; Okonofua and Atoyebi, 1989; Paladini *et al*., 2005; Okonofua, *et al*., 1988, Okonofua and Ayangade, 1986; Marinho *et al*., 1987; Jacquemyn, *et al*., 2000) that used small sample size, this study had to deal with a very large sample (over 13 000 fetuses) in order to illustrate Jos sonography practice as a whole. The standard deviations of the parameters in this study are in keeping with those of other references (Chitty, *et al*., 1994b-d; Kurmanavicius, *et al*., 1999a-b; *S*nijders and Nicolaides, 1994; Kankeow, 2007. This study makes available an original and practical graphical means for comparing a new reference with existing references from other parts of world such Europe and Asia (Appendix 2). It also provides new charts and equations for fetal size in Jos, based on a very large sample of fetuses.

5.1 SPECIFIC DISCUSSION

In determining mean values and the relationship between biparietal diameter, occipitofrontal diameter, head circumference, femur length, abdominal circumference and weight of fetuses in Jos with gestational age and symphysio-fundal height-fundal height, it was established that there is a high positive correlation between the measured fetal parameters and gestational age and symphysio-fundal height-fundal height indicating that gestational age and symphysio-fundal height-fundal height have a statistically significant (p = 0.001) effect on fetal biparietal diameter, occipitofrontal diameter, head circumference, femur length, abdominal circumference and weight. Several authors have emphasized the value of using customised fetal biometry charts that consider variables such as head circumference, biparietal diameter, occipitofrontal diameter, abdominal circumference, femur length and fetal weight. The results of this study have confirmed the findings of Jung *et a.,l* (2007), Nasrat and Bondagji (2002), Salomon *et al.,* (2006), Drooger *et al.,* (2005) and Jacquemyn *et al.,* (2000) that fetal parameters differ form population to population.

When comparing the derived centiles for fetal size parameters from this study with those of Kurmanavicius *et al.,* (1999) from a Western population it was found out that the 50th centiles of head circumference in the study were significantly higher than those of the Western population. The 50th centiles of the western population catch up from 19 weeks and decline from 25 weeks up to term (appendix II figure 1). On the other hand, the 50th centiles of biparietal diameter of study and western populations are the same up to 18 weeks (appendix II figure 2). Thereafter, the 50th centiles of the study population decline (though not significantly) up to term. The 50th centile of occipitofrontal diameter in the study population leads throughout pregnancy. Western population catches up at 19 weeks and declines from 26 weeks (appendix II figure 3). The 50th centile of abdominal circumference in the study population leads throughout pregnancy so also does the 50th centile of femur length (appendix II figure 4; appendix II figure 5).

When comparing the derived centiles for fetal size parameters from this study with those of kankeow (2007) from an Asian population it was found out that the 50th centiles of head circumference in the study were significantly higher (p = 0.001) than those of the Asian population. The Asian population catches up at 18 weeks then declines from 23 weeks up to term (appendix II figure 6). The 50th centiles of biparietal diameter, abdominal circumference and femur length in the study population (appendix II figure 7, appendix II figure 8, appendix II figure 9) show higher values throughout pregnancy which are statistically significant (p = 0.001). These findings are similar to studies that were conducted in Thailand (Siwadune *et al*., 2000; Titapant *et al*., 2000; Sunsaneevithayakul *et al*., 2000).

When comparing biparietal diameter mean values of the present study with those of Okupe *et al.*, (1984) from Nigeria, it was found out that Okupe's mean values were higher (though not statistically significant at p = 0.001) than those of the present study. The study mean caught up at 16 weeks but declined at 19 weeks (appendix II figure 10). This discrepancy might be as a result of small sample size (552) used by Okupe *et al.*, (1984) as against 13,740 sample size used in the present study.

5.1.0 Biparietal Diameter

Fetal biparietal diameter has been studied previously in Nigerian fetuses but populations have been very small (Okupe *et al*., 1984; Ayangade and Okonofua, 1986; Marinho and Bamgboye, 1987; Okonufua *et al*., 1988; Okonofua and Atoyebi, 1989; Osinusi, 1990) to provide statistically significant data for the relationship between gestational age and biparietal diameter. The standard error of mean of biparietal diameter measurements in this study were found to be very small suggesting that the mean values of biparietal diameter in this sample is not quite different from the population mean. By implication, the sonographers, obstetricians, embryologist, perinatologist, forensic pathologist, clinical anthropologist and scientific investigators in Jos can use the mean values obtained in this study confidently because they are a reflection of the population mean in this environment. Using the correlation and regression equations obtained in this study, one can easily predict the biparietal diameter of any fetus in this environment once one knows the gestational age. On the other hand, if one is not sure of the gestational age but can measure the symphysio-fundal height, he or she can use the symphysio-fundal value to predict the biparietal diameter of the fetus in the woman's uterus with much confidence since the regression equation was obtained using a very large sample size that has a standard error of mean that is very close to the population mean. In places where ultrasound services are not available, these equations can be used to predict the biparietal diameter of fetuses of women around there. Furthermore, if one knows the mean biparietal diameter at any given age, he can use it to predict the mean value of either occipitofrontal diameter, head circumference, abdominal circumference, femur length or weight of that that particular fetus at the given age. These predictive formulae are as follows:

When the gestational age is known, the equation $y = -0.0511x^2 + 5.3221x - 35.511$ can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the gestational age in weeks. This means that gestational age could predict the biparietal diameter by 99.99 percent in 13, 740 fetuses ($R^2 = 0.9999$). When the symphysio-fundal height is known, the equation $y = -5E\text{-}06x^6 + 0.0009x^5 - 0.0628x^4 + 2.2514x^3 - 44.398x^2 + 458.64x - 1907.6$ can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the symphysio-fundal height in centimeters ($r^2 = 0.9958$). On the other hand, when the fetal biparietal diameter is known, the equation:

$y = 3.5811x + 3.1775$ can be used to predict the head circumference of a fetus where x is the biparietal diameter in millimeters and y is the head circumference in millimeters.

Or

$y = 1.2425x + 1.1552$ can be used to predict the occipitofrontal diameter of a fetus where y is the occipitofrontal diameter in millimeters and x is biparietal diameter in millimeters.

Or

$y = 0.0144x^2 + 2.0241x + 21.816$ can be used to predict the abdominal circumference of a fetus where y is the abdominal circumference in millimeters and x is the biparietal diameter in millimeters.

Or

$y = 5E\text{-}06x^4 - 0.0011x^3 + 0.0855x^2 - 2.0951x + 27.664$ be used to predict the femur length of a fetus where y is the femur length in millimeters and x is the biparietal diameter in millimeters.

Or

$y = 45.141e^{0.0461x}$ be used to predict the weight of a fetus where y is the fetal weight in grams and x is the biparietal diameter in millimeters.

The present cross-sectional study of fetal biparietal diameter confirms the findings of William, Jordaan and Okupe. However, the mean BPD values in this study were lower than those found by Okupe (1984) except from 16 – 19 weeks where the measurements were the same. This difference is probably due to the fact that measurements reported by Okupe were done by one person while in the present study, many people were involved in the measurements and each fetus was included in the study just once which was not the case in Okupe's study. Furthermore, Okupe compared his findings with Caucasian values generated before 1974, which might have accounted for the wide variation noticed between the two populations. The present study compared the values obtained with those of other investigators that generated their charts after 1974.

Comparing mean biparietal diameter values of the studied population with those of Chitty *et al* (1994), it was found out that those of chitty were initially lower than those of study population up to 26 weeks after which the situation reverses itself where Chitty's mean values became higher though not statistically significantly. The reason for this reversal might probably be as a result of the exponential increase in the growth velocity among the Caucasian population noticed at 26 weeks of gestation in Chitty's study where the growth velocity becomes significantly higher than that of study population. Dubowitz and Goldberg (1981) studied biparietal diameter of fetuses of Caucasian, Negro and Indian mixed origin but found no significant differences except after 30 weeks of gestation. Parker *et al.,* (1982) further reported that there was no significant difference in biparietal diameter between Asian and European fetuses.

The growth velocity of biparietal diameter of study population was found to vary with gestational age. From 13 – 16weeks the growth velocity was 3.525mm/week, 17 – 20weeks, 3.515mm/week, 21 – 25weeks, 2.603mm/week, 26 – 29weeks, 2.363mm/week, 30 – 33 weeks, 2.0437mm/week and from 34 – 38 weeks, 1.2mm/week. When the growth velocity of the study population was compared with that of chitty *et al.,* (1994), the pattern was found to be the same except from 26 – 27 weeks where the growth rate was found to be significantly higher in chitty's study than that of the study population. It was also observed that deceleration in the growth rate from 18 – 19 weeks before another rise in the growth rate. During the fourth month of intrauterine life the biparietal diameter growth rate in the study population was found to be higher than that calculated from values of Chitty's study. But by the fifth month of intrauterine life, the reverse was the case. This finding might explain why fetal head in Caucasians engages by 36 weeks of age while that of Africans remains unengaged until labour is well advanced. This is because the Caucasian pelvis might have adapted so well to the rapid increase in the biparietal diameter of their fetuses. If the Caucasian fetal head does not engage before 39 weeks it might be difficult for it to pass through the pelvic brim because its rate of BPD increase is still high even at that age while that of the study population might pass because the rate of increase in BPD was so low that there is negligible increase in the size of the BPD after 39 weeks of gestation. Since the rate of increase in BPD was so low in the study population compared to the Caucasian population at term, this fact might account for the reason why fetal head in the tropics remains high in the majority of cases at this time and may even remain so until near the second stage of labour when there is a rapid descent just before delivery. The reason why there is rapid descent just before delivery might be because the uterus has to push with much force the BPD through the anteroposterior diameter of the pelvic brim and once the head has passed through the pelvic brim, then it rapidly descents. Evidence available in the literature to explain this well-known phenomenon in African parturients (Orhue and Otubu, 2006) implicated the inclination of the pelvic brim without being mindful of the passenger, which in this case is the fetus. It is an established fact that the plane of the pelvic brim makes an angle of 60 degrees with the horizontal when the patient is in the upright position. This angle varies considerably with posture, for if the symphysis is raised by rotation of the pelvis around the heads of the femora and the lumbar curve is straightened out the angle is considerably reduced. Similarly if the lumbar curve is increased the pelvic inclination is increased. According to Malpas and Hamilton, a high inclination is one of the commonest causes of dystocia. Briggs (1984) reported that Africans have a higher pelvic inclination and lumbar curvature than Caucasians that is why fetuses of African parturients remain unengaged until labour is well advanced thereby placing the Caucasians higher in the evolutionary scale than the Africans. However, in the supine position these factors do not come into play leaving only the fetus as the most likely cause since the maternal pelvis (the passage), the fetus (the passenger) and uterine contractions (the power) are the three factors that govern the course of normal labour. Ordinarily if inclination of the pelvic brim and lumbar curvature were the only factors responsible for unengagement of the fetal head at term without any contribution from the fetus then "head fitting test" would have been used to make the fetal head to pass through the pelvic brim with the woman lying in the supine position. But this is not usually the case hence pointing to the fact that the fetal head contributes to this well-known phenomenon in Africans. A decrease in the inclination of the pelvis in Caucasians is likely to be an adaptative feature developed by the Caucasians in response to the increase in BPD growth velocity observed at 26 weeks of gestation.

Campbell (1969), Varma (1973) and Tuli *et al.,* (1995) observed higher growth rates up to 30th and slower growth rates from 30th to 40th week of gestation. In the present study too, uniform growth rate was not observed whereas higher rates were noted.

5.1.1 Head Circumference

Head circumference is a useful parameter in the determination of data to determine gestational age in pregnancy and monitoring of brain growth. This parameter has not been fully studied in Nigerian population. The present study therefore constructed new mean values and reference charts and regression equation for fetal head circumference (HC) from Nigerian fetuses in Jos at 12 – 42 weeks using large enough sample size which was found to be statistically significant. The standard error of mean from 12 – 42 weeks are very small suggesting that the mean value of head circumference obtained in this study were very close to the population mean in this environment.

Just as is the case with biparietal diameter, when gestational age of a fetus is known, the equation $y = -0.0029x^3 + 0.0518x^2 + 13.136x - 78.198$ can be used to predict the head circumference of fetus ($R^2 = 0.9962$) where y is the head circumference in millimeters and x is the gestational age in weeks. When the symphysio-fundal height is known, the equation $y = -2E\text{-}05x^6 + 0.0037x^5 - 0.2533x^4 + 9.0473x^3 - 177.54x^2 + 1823.4x - 7544.3$ can be used to predict the head circumference of a fetus where y is the head circumference in millimeters and x is the symphysio-fundal height in centimeters ($r^2 = 0.9954$). On the other hand, when the fetal head circumference is known, the equation:

$y = 0.2792x - 0.8656$ can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the head circumference in millimeters.

Or

$y = 0.347x + 0.0528$ can be used to predict the occipitofrontal diameter of a fetus where y is the occipitofrontal diameter in millimeters and x is head circumference in millimeters.

Or

$y = 1.0644x - 29.032$ can be used to predict the abdominal circumference of a fetus where y is the abdominal circumference in millimeters and x is the head circumference in millimeters.

Or

$y = 0.046x^{1.2897}$ can be used to predict the femur length of a fetus where y is the femur length in millimeters and x is the head circumference in millimeters.

Or

$y = 57.144e^{0.012x}$ can be used to predict the weight of a fetus where y is the fetal weight in grams and x is the head circumference in millimeters.

Variations in head size and brain volume are genetic and since the times of Galton, it has been customary to associate size of the head (and *ipso facto* size of brain) as measured by head circumference, with intelligence. Even the genes responsible for brain size (which is directly related to head circumference, cranial capacity, occipitofrontal diameter etc) have been identified even though they vary from one continent to another and require to be mapped out. There is a 40% correlation between head size and intelligence quotient (IQ) using MRI (magnetic resonance imaging) studies. Brain size, as determined by small size is said to be positively correlated with memory retention in old age and the onset of dementia. It has also been shown that head circumference is strongly correlated with brain volume which presumably determines intelligence. Racial studies have shown a relationship between brain size and adult intelligence but we do not have enough data to determine what the situation of things is before birth which is different from what obtains after birth. This present study provides data on head circumference in African children with a population size of over 13,000 fetuses.

When centiles from present study were compared with centiles in other studies (Chitty, *et al*., 1994b; Kurmanavicius, *et al*., 1999a; Kankeow, 2007), differences were seen which can be explained on the basis of nature and nurture. But its significance in early maturation of the brain, and its higher values for African babies when compared to other races necessitates the need for further understanding of racial or genetic factors that determine its growth and *ipso facto,* its relationship to intelligence. This study provides extensive data for head circumference of 13,740 African (Nigerian) fetuses and suggests the early maturation of head circumference in African children *vis-à-vis* European, is a genetic rather than nutritional factor. Postnatal development however is probably dependent on nutrition and environment rather than gene.

5.1.2 <u>Symphysio-fundal height</u>

The prediction formulae for the 10th and 90th centiles derived from regression analysis were obtained can be used for the prediction of small-for-dates and large-for-dates babies especially when the values are outside the range of 10 – 90th centiles. Fundal height is an important clinical index for intrauterine growth assessment (Beazley and Underhill, 1970; Loeffler, 1969). Routine assessment of fundal growth with reference to anatomical landmarks such as xiphisternum, umbilicus etc., only allows a semi quantitative assessment not accurate enough for clinical application. However, standardization of fundal height nomogram is subject to errors. It may be difficult to locate the top of uterine fundus accurately. As shown by Calvert *et al.,* (1982), there may be significant concurrent intra and inter observer errors with coefficients of variations up to 4.6% and 6.4% respectively. In our study, inter observer error was eliminated by assigning only one investigator measuring the fundal height. Parametric statistical method using a second degree polynomial mathematical model can provide a more accurate estimation of the mean SFH throughout the period of pregnancy. More importantly is the efficiency of estimation of percentiles for the nomogram by examining the residual sum squares. From the nomogram compiled, intrauterine growth retardation can be picked up by serial measurement of SFH for an individual pregnant woman. Comparisons with other nomograms showed that there are differences between the mean SFH values obtained by other investigators (Tian et al., 1982; Hextan et al., 1988; Quaranta et al., 1981) and those of this study. Not only is there difference in absolute values, the trends also appear to be different, especially after about 32 weeks. This might be as a result of the well known phenomenon in Africans where the fetal head remains unengaged until term. Apart from this, differences with different nomograms can be the result of population differences, such as different size of babies and varying maternal weight and obesity. Methodological difference in measurement may be a more significant factor, although the methods of measurement described in the studies (Belizan *et al.*, 1978; Calvert *et al.*, 1982; Quaranta *et al.*, 1981; Taylor *et al.*, 1984; Zhuo *et al.*, 1980) are similar. The marked difference between the 2 nomograms from the 2 hospitals in Shanghai (Tian, 1982; Zhuo *et al*., 1980) illustrates that even minor discrepancies in the practice of measuring symphysio-fundal height-fundal height affect the measurements. It therefore would appear that a nomogram of SFH should be made, preferable by as few observers as possible, for a local population before the measurement is put to use in detecting growth deviation in the fetus. It would appear to be equally important that the same method that was used in measuring the SFH when the nomogram was prepared most be strictly adhered to in the same institution to minimize any inter observer error.

5.1.3 Abdominal Circumference

A number of previous abdominal circumference studies have used relatively small population (Ayangade and Okonofua, 1986; Marinho and Bamgboye, 1987; Okonufua *et al*., 1988; Okonofua and Atoyebi, 1989; Osinusi, 1990). The results obtained from the cross-sectional study conducted revealed that the mean values of fetal abdominal circumference of the sample size very close to population mean value as indicated by the very small standard error of mean. From the correlation and regression studies conducted with gestational age and symphysio-fundal height, it showed that once one knows the age of a fetus or the symphysio-fundal height, the abdominal circumference of the fetus can be predicted easily from the predictive formulae as shown below. When gestational age of a fetus is known, the equation $y = -0.0004x^4 + 0.0349x^3 - 1.2485x^2 + 30.598x - 172.02$ can be used to predict the abdominal circumference of fetus ($R^2 = 0.9995$) where y is the abdominal circumference in millimeters and x is the gestational age in weeks. When the symphysio-fundal height is known, the equation $y = -0.054x^2 + 12.926x - 71.554$ can be used to predict the abdominal circumference of a fetus where y is the abdominal circumference in millimeters and x is the symphysio-fundal height in centimeters ($r^2 = 0.9942$). On the other hand, when the fetal abdominal circumference is known, the equation:

$y = -0.0003x^2 + 0.3777x - 3.6302$ can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the abdominal circumference in millimeters.

Or

$y = -0.0003x^2 + 0.4671x - 3.1666$ can be used to predict the occipitofrontal diameter of a fetus where y is the occipitofrontal diameter in millimeters and x is abdominal circumference in millimeters.

Or

$y = y = -0.0009x^2 + 1.3431x - 9.0021$ can be used to predict the head circumference of a fetus where y is the head circumference in millimeters and x is the abdominal circumference in millimeters.

Or

$y = 0.2381x - 5.0199$ can be used to predict the femur length of a fetus where y is the femur length in millimeters and x is the abdominal circumference in millimeters.

Or

$y = 0.065x^2 - 16.072x + 1355.5$ can be used to predict the weight of a fetus where y is the fetal weight in grams and x is the abdominal circumference in millimeters.

5.1.4 Femur Length

Femur length studies are few in Nigeria (Osinusi, 1990) and the sample size used for the studies have been too small to provide a meaningful statistically significant data for the relationship between it and gestational age. The femur length mean values obtained in this study can be used confidently because they have a very small standard error of mean giving little or no difference from the population mean in this environment. When the femur length mean values obtained from this study were subjected to the correlation and regression studies with gestational age and symphysio-fundal height, it was found out that once one knows the age of a fetus or the symphysio-fundal height, the femur length of the fetus can be predicted easily from the predictive formulae as shown below. When gestational age of a fetus is known, the equation $y = -0.017x^2 + 3.2794x - 25.282$ can be used to predict the length of femur of fetus ($r^2 = 0.999$) where y is the femur length in millimeters and x is the gestational age in weeks. When the symphysio-fundal height is known, the equation $y = 0.0006x^3 - 0.064x^2 + 4.3915x - 32.499$ can be used to predict the length of femur of a fetus where y is the femur length in millimeters and x is the symphysio-fundal height in centimeters ($r^2 = 0.9941$). On the other hand, when the fetal femur length is known, the equation:

> $y = -4E\text{-}06x^4 + 0.0006x^3 - 0.0414x^2 + 2.3555x - 1.7905$can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the femur length in millimeters.
>
> Or
>
> $y = -0.007x^2 + 2.0251x + 4.2448$ can be used to predict the occipitofrontal diameter of a fetus where y is the occipitofrontal diameter in millimeters and x is femur length in millimeters.
>
> Or
>
> $y = -0.0004x^3 + 0.0429x^2 + 3.1567x + 43.238$ can be used to predict the head circumference of a fetus where y is the head circumference in millimeters and x is the femur length in millimeters.
>
> Or
>
> $y = 4.179x + 22.077$ can be used to predict the abdominal circumference of a fetus where y is the abdominal circumference in millimeters and x is the femur length in millimeters.
>
> Or
>
> $y = 0.0575x^{2.534}$ can be used to predict the weight of a fetus where y is the fetal weight in grams and x is the abdominal femur length in millimeters.

5.1.5 Occipitofrontal Diameter

Occipitofrontal diameter is a useful parameter in the determination of cephalic index during pregnancy. In this study, occipitofrontal diameter measurements were obtained from a large sample size of 13,740 fetuses. The mean fetal occipitofrontal diameter measurements from 12 to 42 weeks gestation are presented in a tabular form together with the regression equation of $y = – 0.001x^3 + 0.01337x^2 + 4.671x – 27.99$ ($R^2 = 0.9996$) of line of best fit between gestational age in weeks and mean occipitofrontal diameter. The mean weekly increase in the occipitofrontal diameter in the 4th month of life was 4.6 mm/week, in the 6th month it was 4.0 mm/week and 2.3 mm/week in the 9th week. This can be easily used in obstetric ultrasound studies for the African (Nigerian) population. When the symphysio-fundal height is known, the equation $y = – 8E\text{-}06x^6 + 0.0013x^5 – 0.0917x^4 + 3.2678x^3 –63.988x^2 + 655.77x – 2708.8$ can be used to predict the occipitofrontal diameter of a fetus where y is the occipitofrontal diameter in millimeters and x is the symphysio-fundal height in centimeters ($r^2 = 0.9954$). On the other hand, when the fetal occipitofrontal diameter is known, the equation:

$y = 0.8046x – 0.9072$ can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the occipitofrontal diameter in millimeters.

Or

$y = 0.0025x^2 + 0.3313x + 1.5192$ can be used to predict the femur length of a fetus where y is the femur length in millimeters and x is occipitofrontal diameter in millimeters.

Or

$y = 2.882x + 0.1487$ can be used to predict the head circumference of a fetus where y is the head circumference in millimeters and x is the occipitofrontal diameter in millimeters.

Or

$y = 0.0092x^2 + 1.6208x + 19.582$ can be used to predict the abdominal circumference of a fetus where y is the abdominal circumference in millimeters and x is the occipitofrontal diameter in millimeters.

Or

$y = 0.0071x^3 – 1.0218x^2 + 57.868x – 925.93$ can be used to predict the weight of a fetus where y is the fetal weight in grams and x is the occipitofrontal diameter in millimeters.

5.1.6 Weight

In the developed countries, fetal weight has been extensively studied and reference values created which reflects the growth pattern in their countries. This study was designed to construct a size chart for fetal weight in Jos using a large sample size which is evenly distributed from 17 – 42 weeks. The mean weights and percentiles of 12,080 fetuses from 17 – 42 weeks have been determined which can be used by the different specialist in this environment. Mathematical modeling of data demonstrated that the best-fitted regression model to describe the relationship between fetal weight and gestational age was the power regression equation $y = 0.038x^{3.1347}$ where y is the fetal weight in grams and x is the fetal age in weeks with a correlation of determination $R^2 = 0.9951$ ($P< 0.0001$) in Nigerian fetuses in Jos. When fetal weight was plotted against symphysio-fundal height, it was found out that there is a positive correlation between fetal weight and symphysio-fundal height with a correlation of determination $R^2 = 0.9951$ ($P< 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.0409x^{3.1217}$ where y is the fetal weight in grams and x is the symphysio-fundal height in centimeters. On the other hand, when the fetal weight is known, the equation:

$y = – 3E\text{-}13x^4 + 4E\text{-}09x^3 – 2E\text{-}05x^2 + 0.0472x + 34.356$ can be used to predict the biparietal diameter of a fetus where y is the biparietal diameter in millimeters and x is the fetal weight in grams.

Or

$y = 1E\text{-}12x^4 – 8E\text{-}09x^3 + 2E\text{-}05x^2 – 0.009x + 43.172$ can be used to predict the femur length of a fetus where y is the femur length in millimeters and x is fetal weight in grams.

Or

$y = 3E\text{-}12x^4 + 3E\text{-}08x^3 – 0.0001x^2 + 0.2173x + 106.44$ can be used to predict the head circumference of a fetus where y is the head circumference in millimeters and x is the fetal weight in grams.

Or

$y = – 3E\text{-}12x^4 + 2E\text{-}08x^3 – 9E\text{-}05x^2 + 0.1947x + 95.592$ can be used to predict the abdominal circumference of a fetus where y is the abdominal circumference in millimeters and x is the fetal weight in grams.

Or

$y = – 9E\text{-}13x^4 + 1E\text{-}08x^3 – 4E\text{-}05x^2 + 0.0779x + 36.004$ can be used to predict the occipitofrontal diameter of a fetus where y is the occipitofrontal diameter in grams and x is the fetal weight in grams.

From the graph of weight plotted against gestational age (figure 452) it was found that variability of weight increases as fetal age increases. However, at 18 weeks there is marked variation. Figure 456 showed fetal weight gain from 17 – 42 weeks. From this graph, it can be seen that the human fetus gains the highest weight at 18 weeks but loses it by 19 weeks before it starts gaining weight again as from 20 weeks; and the weight gain keeps rising and becomes relatively constant towards the end of the third trimester. Figure 457 shows histogram of fetal weight during the 5th month of intrauterine life while figure 458 shows histogram of fetal weight gain during 5th month of life. From this histogram it can be seen that the human fetus looses weight considerably at 19 weeks; the cause of which is not known yet. Taking a look at the growth velocity of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference and fetal femur length from 13 – 42 weeks, it can be seen that there is a drop in the growth velocity of these parameters at 19 weeks (figures 459 – 463) suggesting that there is something happening around the 19^{th} week of gestation in humans. .

5.1.7 Biparietal Diameter to Occipitofrontal diameter Ratio (Cephalic Index)

A constant cephalic index of 78.3 ± 4.4 from 14 – 40 weeks was observed by Hadlock *et al.*, (1981) with no significant change as the fetal age increases. Tuli *et al.*, (1995) too noted a constant value of 76.4 ± 5.1 from 12 – 40 weeks. Jeanty *et al.*, (1984) found that cephalic index was age independent. On the contrary, Gray *et al.*, (1989) observed a change in cephalic index with increasing age of fetus, and reported a wide normal range for cephalic index. The findings of the present study are similar to those of Gray *et al.*, (1989) and with cephalic index of 75.6 ± 10.3 at 12 weeks, 76.4 ± 7.9 at 13 weeks, 78.4 ± 7.5 at 14 weeks, 79.4 ± 6.5 at 15 weeks and cephalic index of 80.6 ± 6.1 at 16 weeks. During this period of intrauterine development, the relationship between gestational age and cephalic index is linear with regression equation of $y = 1.3x + 59.88$; where y is the cephalic index while x is the gestational age in weeks. From 17 weeks to term, the cephalic index becomes relatively constant. When the 50th centile values of our cephalic index were compared with those of Kurmanavicius *et al.*, 1999, it was found out that their values were significantly higher than our own values ($P < 0.001$) throughout pregnancy.

Cephalic index was first developed in the 1840s by Anders Retzius as one of the most influential craniometric techniques. Retzius used precision calipers to measure the heads of people from different backgrounds. He generally classified peoples as having one of two characteristic head shapes—*brachycephalic* (broad-headed) or *dolichocephalic* (long-headed). People with intermediate head shapes were assigned to a third type, *mesocephalic*. Soon after its development, the cephalic index gained popularity in Europe and the United States as a way to classify individuals into races based on similar measurements.

5.1.8 Head Circumference to Abdominal Circumference Ratio (HC/AC)

Head circumference to abdominal circumference ratio is useful in detecting asymmetrical growth retardation. The mean values of this ratio in our environment have been constructed together with their corresponding standard deviations and standard errors of mean. The most widely used definition of intrauterine growth retardation is a fetus whose estimated weight is below the 10th percentile for its gestational age and whose abdominal circumference is below 2.5th percentile. Symmetric growth retardation implies a fetus whose entire body is proportionally small. Asymmetric growth retardation implies a fetus that is undernourished and is directing most of its energy to maintaining growth of vital organs such as the brain and the heart at the expense of the liver, muscle and fat.

5.1.9 Biparietal Diameter to Femur Length Ratio (BPD/FL)

The mean values of biparietal diameter to femur length ratio in this study were found to decrease as gestational age increase. Marked variation is seen in the early phase of pregnancy and the standard error of mean are consistently small indicating that the mean values obtained form the sample are very close to the population mean.

5.1.10 Femur Length to Head Circumference Ratio (FL/HC)

This ratio is used so often by obstetricians in diagnosing dwarfism. The mean values of this ratio in our environment increase with age and there is marked variation in the early phase of pregnancy. A fetus that has normal ratio excludes dwarfism while a low ratio of femur length to head circumference ratio suggest possible dwarfism. A high ratio on the other hand suggests possible microcephaly.

5.1.11 Femur Length to Abdominal Circumference Ratio (FL/AC)

The femur length to abdominal circumference ratio in this study was found to constant throughout pregnancy. This means that an increase in the ratio above normal can be seen in fetuses that are small for gestational age.

5.2 CONCLUSION

From the results obtained from the investigation into the relationship between biometric parameters of Nigerian fetuses in Jos and gestational age/symphysio-fundal, it is concluded that biparietal diameter, head circumference, occipitofrontal diameter, abdominal circumference, femur length fetal weight correlate positively with gestational age and symphysio-fundal height. The study also reveals mean values of fetal biometric parameters in Jos from 12 – 42 weeks together with their corresponding standard deviations and standard error of mean. Again, predictive formulae for the various parameters have been derived.

Once more, the results obtained from this study agreed with the findings of investigators form other parts of the world that fetal biometric parameters vary form population to population. Correlation and regression analysis have shown that gestational age and symphysio-fundal height can be used to predict size of any of the fetal biometric parameter of interest. Again, the correlation and regression analysis has also revealed that once any of the fetal biometric parameters is known, it can used to predict all the other parameters with great precision. Also, a 19 week gestation problem (characterized by decrease in growth rate of fetal parameters measured with concomitant weight loss) has been identified in this study.

5.3 RECOMMENDATIONS

Further studies should examine and assess the significance of 19 weeks problem, and should use a large sample size to enable generalization of the findings. In further studies, the relationship between other fetal parameters and gestational age and symphysio-fundal height-fundal height should be studied. Further studies might conduct the analysis using alternate statistical methods, such as discriminant analysis or log linear analysis, in order to determine other factors related to predicting fetal weight.

But at this level, I am recommending the findings of this study to obstetricians, embryologist, perinatologist, forensic pathologist, clinical anthropologist, scientific investigators and auxiologist in practicing in Jos, Nigeria. To the obstetrician, normal values for the parameters of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight from Nigerian fetuses in Jos between 12 and 42 weeks of gestation will be so useful such that the obstetrician who uses ultrasound routinely in ante natal care can screen for congenital anomalies in the fetus during the period of gestation using ratios of anthropometric measurement as described above in this environment or indeed in Africa/Nigeria. Using ultrasound measurement, the perinatologist can adjudge the weight of the baby being delivered and see from the data provided in this study whether such are normal or not and if not normal, what to provide for underweight fetus at the point of delivery for treatment and monitoring. To the forensic pathologist, the data that has been provided in this study will assist in identifying origin of the fetus. For example a mother may be carrying a surrogate child who is not part of the environment under study or mother may be carrying a baby whose father is from a different extraction. Such may assist the law or the police in obtaining information that may be useful in criminal investigation when such data as described in this study are used- fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight from Nigerian fetuses in Jos between 12 and 42 weeks of gestation.

To the clinical anthropologists, the knowledge of standard values of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight from Nigerian fetuses in Jos between 12 and 42 weeks of gestation in this environment will assist him in providing sound clinical anthropological advice to the would be clinician and will assist himself if he is going to be the clinician. The pure scientist/auxiologist interested in scientific study of human growth will learn about growth pattern for fetuses of humankind from this study. Such may include growth patterns which have been reconstructed because of the large data provided in the present study affecting any of the following - fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference, femur length and weight from Nigerian fetuses in Jos between 12 and 42 weeks of gestation

5.4 APPLICATIONS OF THIS STUDY

1. It can be used as a guideline for predicting fetal weight from maternal anthropometric measurement, in order to ascertain the degree of risk, to encourage mothers to improve their fetus's weight and to come for follow-up
2. It can be used as guide for health education about the risk factors involved in congenital anomalies, intrauterine growth retardation and overweight fetuses
3. It can be used to create awareness among health personnel of the factors that affect fetal weight, especially maternal factors during the 2^{nd} and 3^{rd} trimesters.
4. It can be used for further study in related fields

5.5 LIMITATIONS OF THIS STUDY

Before utilizing the results of this study with any pregnant woman, the following limitations must be noted:

1. The study population was selected from the pregnant women who attended and had ultrasound scan at Centre for Reproductive Health Research only. These women may not be representative of the general population
2. Only one researcher made the anthropometric measurements within a limited time, so only the simplest and quickest measurements were selected

5.6 SUMMARY OF FINDINGS

1. Routine obstetric scan is done at GA 27 ± 7 weeks
2. Reliable reference ranges for fetal biometric parameters have been created using a large sample size which is normally distributed from 12 to 42 weeks of pregnancy

3. Regression equations for fetal biometry have been created for BPD, OFD, HC, AC, FL & fetal weight.
4. The study brought out 19 week gestation problem (characterized by decrease in growth rate of fetal parameters measured with concomitant weight loss) which requires to be pursued by future investigators
5. An equation for calculating fetal weight from SFH has been derived
6. There is a positive relationship between gestational age and BPD, OFD, HC, AC, FL weight ($p<0.0001$) in Nigerian fetuses in Jos.
7. Using z-score, it has been proven scientifically that FL is the best parameter to determine fetal age in the 4th, 7th, 8th and 9th of life while BPD is best for age determination in the 5th and 6th month of life.
8. Ratios were obtained for HC/AC, FL/AC, FL/HC, BPD/FL and may be useful in diagnosis of congenital anomalies
9. An equation for predicting fetal weight from SFH has been derived
10. There is a positive relationship between gestational age and BPD, OFD, HC, AC, FL weight ($p<0.0001$) in Nigerian fetuses in Jos.
11. Using z-score, it has been proven scientifically that FL is the best parameter to determine fetal age in the 4th, 7th, 8th and 9th of life while BPD is best for age determination in the 5th and 6th month of life.

5.7 CONTIBUTIONS TO KNOWLEDGE

1. The study has shown a detailed report of ultrasonic fetal biometry studies in Nigerian fetuses in Jos using a very large sample size
2. This study has identified a 19 week gestation problem (characterized by decrease in growth rate of fetal parameters measured with concomitant weight loss) which requires to be pursued by future investigators.

3. This study has provided a standard against which to compare size in individual fetuses in our environment.
4. This has defined ratios of fetal biometric parameters that can be used in the diagnosis of congenital abnormalities in our environment
5. The study has established the relationship between symphysio-fundal height-fundal height and fetal biometric parameters
6. The study has derived a formula that can be used to estimate fetal weight from symphysio-fundal height measurement.
7. Z-score has been used to prove that FL is the best parameter to determine gestational age in the 4th, 7th, 8th and 9th of life while BPD is best for age determination in the 5th and 6th month of life.
8. The study has shown the correlation of fetal biometric with gestational age together with their corresponding predictive formulae which can be used in the new and emerging field of sonographic embryology

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GLOSSARY

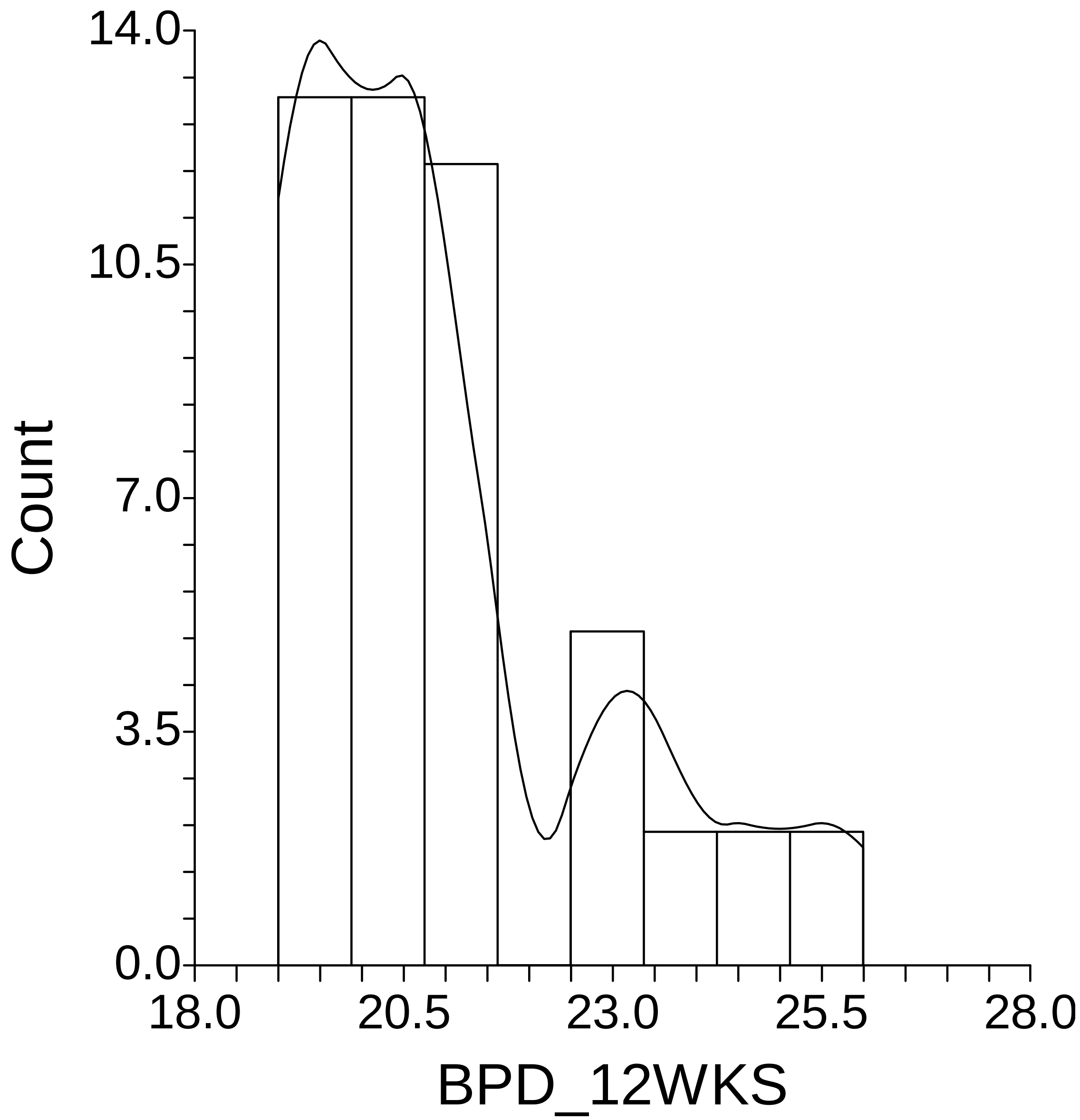
1. **Arithmetic mean:** The arithmetic mean of a set of N numbers is the sum of the numbers divided by N
2. **Coefficient of determination:** Coefficient of determination is the ratio of explained variation to the total variation. If there is zero explained variation, i.e. the total variation is all explained, this ratio is zero. If there is zero unexplained, i.e. the total variation all explained, the ratio is one. In other cases the ratio lies between zero and one. Since the ratio is always non-negative, it is denoted by r^2. The quantity r is called the coefficient of correlation.
3. **Geometric mean:** The geometric mean of a set of N numbers is the Nth root of the product of the numbers
4. **Harmonic mean:** The harmonic mean of a set of N numbers is the reciprocal of the arithmetic mean of the reciprocals of the numbers
5. **Kurtosis:** Kurtosis is the degree of peakedness of a distribution, usually taken relative to a normal distribution. A distribution having a relatively high peak is called leptokurtic, while the curve which is flat-topped is called platykurtic and a curve which is not peaked or very flat-topped is called mesokurtic.
6. **Objective of statistics:** The objective of statistics is to interpret mathematically a set of measurements or numerical observations i.e. to express the data in terms of one or two parameters such as mean and standard deviation. The function of a statistician, of statistics, is to make complicated information simple and understandable. Statisticians spent the great deal of their time, thought, and energy in developing ways to show the results of their work in the form of simple pictures. Why? There are several reasons. 1.

Some people are afraid of numbers. 2. Some people do not understand them. 3. Some people do not have time to read them. 4. Statisticians want their work to be used and understood by as many people as possible. You may have heard the expression, ‘One picture is worth a thousand words.’ The great advantage of a graph (changing numbers into pictures) is that it can tell a long story in a short time. And most people can learn to read a graph with only a little effort.

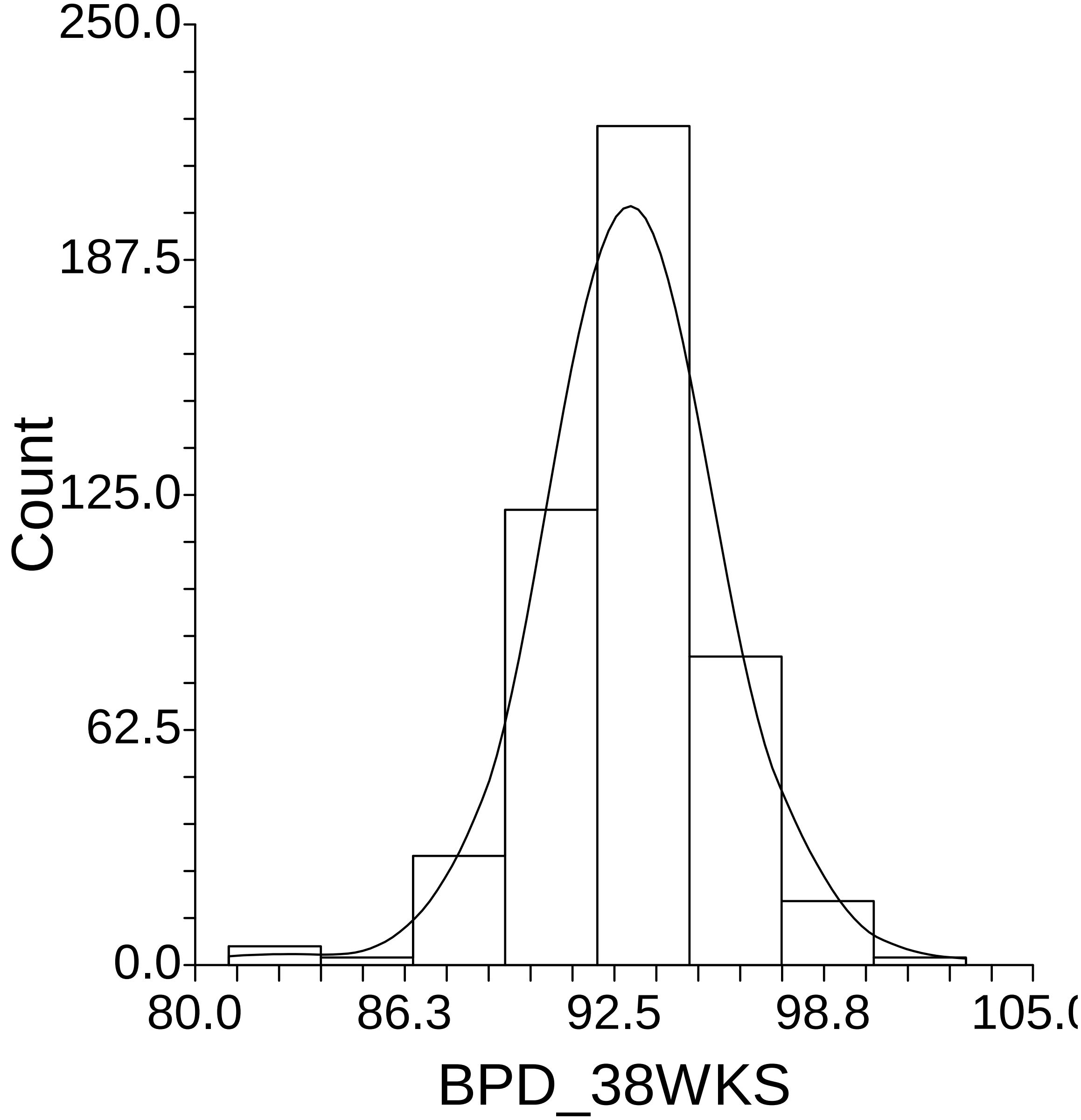
7. **Percentiles:** If a set of data is arranged in order of magnitude, the middle value (or the arithmetic mean of the two middle values) which divides the set into two equal parts is the median. By extending this idea we can think of those values which divide the set into one hundred equal parts. The values dividing the data into one hundred equal parts are called percentiles.
8. **Relationship between arithmetic, geometric and harmonic mean:** The geometric mean of a set of positive numbers $X_1, X_2, \ldots, X_N$ is less than or equal to their arithmetic mean but greater than or equal to their harmonic mean. The equality signs hold only if all the numbers $X_1, X_2, \ldots, X_N$ are identical
9. **Skewness:** Skewness is the degree of asymmetry, or departure from symmetry, of a distribution. If the frequency curve of a distribution has a longer “tail” to the right of the central maximum than to the left, the distribution is said to be skewed to the right or to have positive skewness. If the reverse is true, it is said to be skewed to the left or to have negative skewness.

APPENDIX I

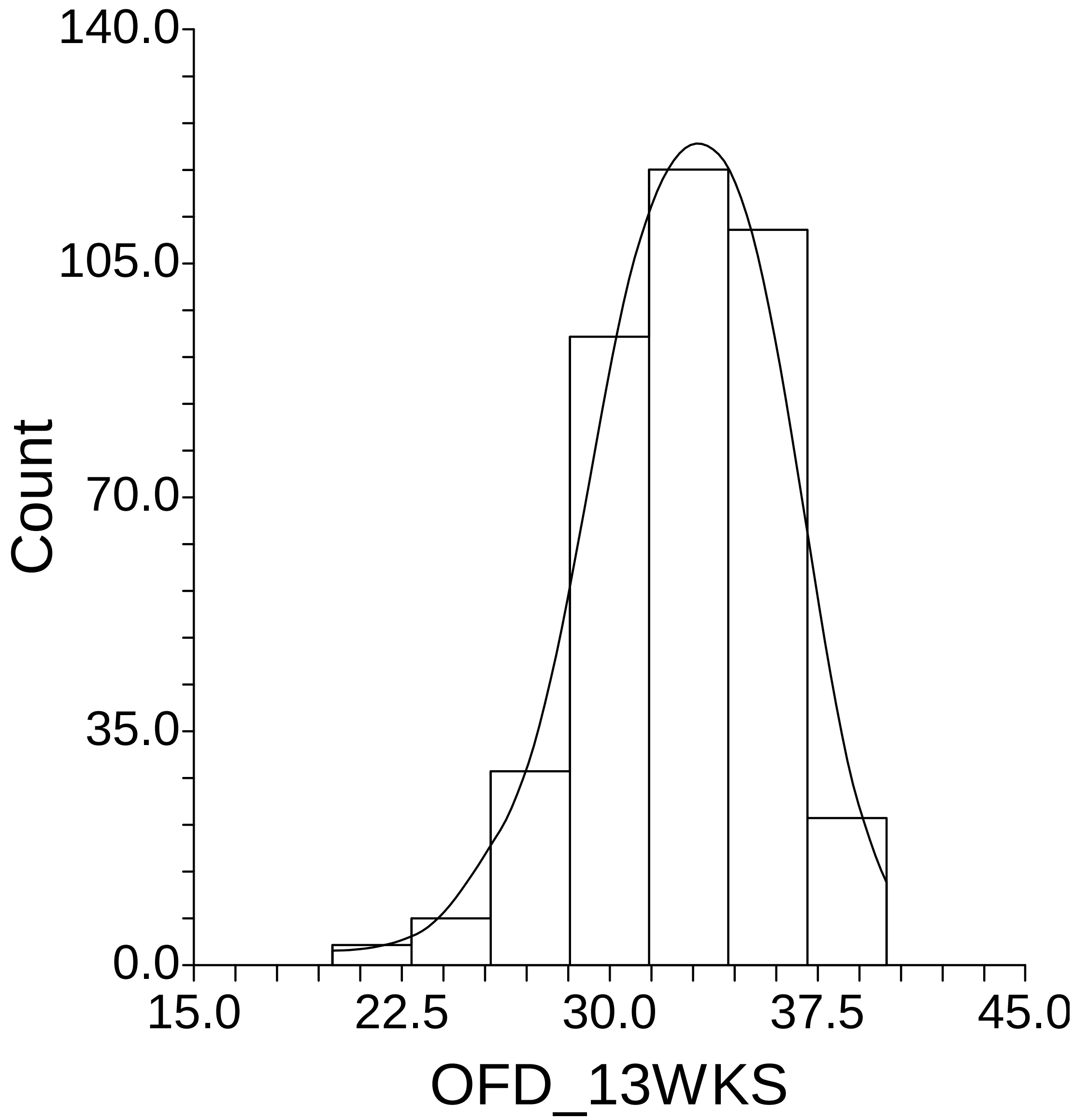
VISUAL NORMALITY TEST HISTOGRAMS



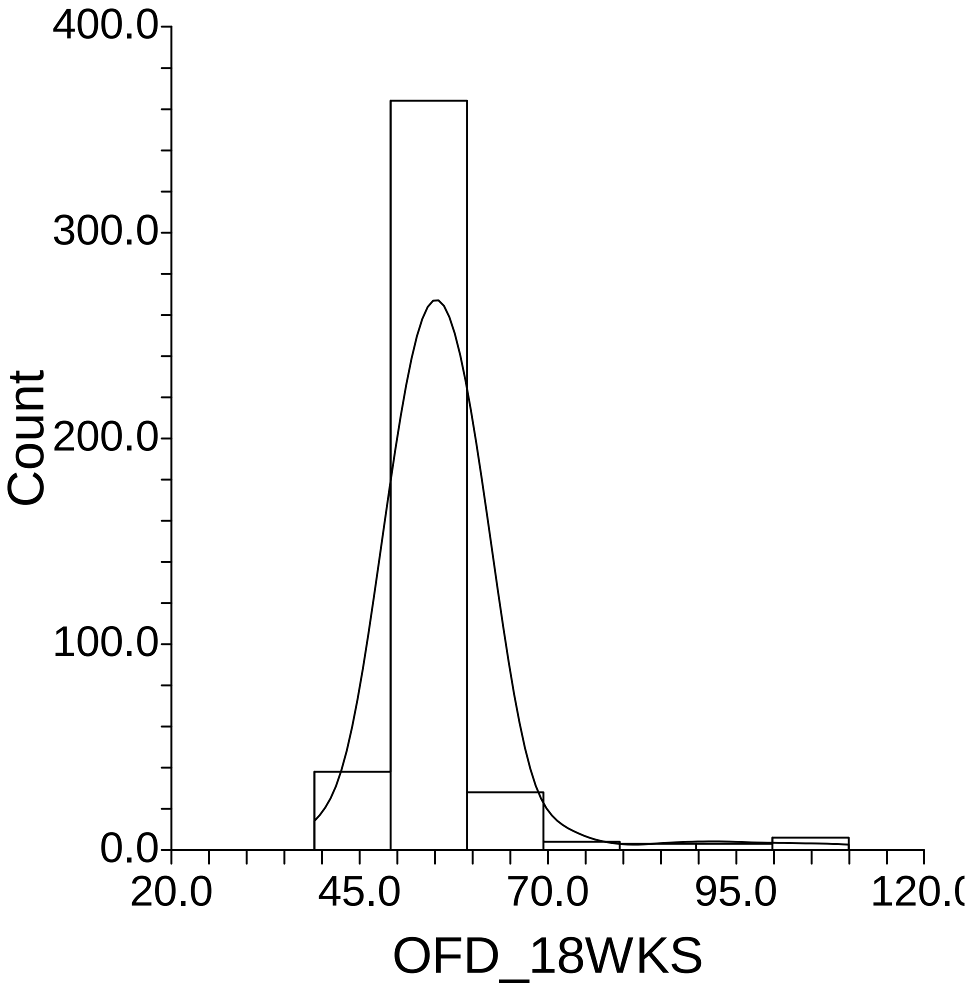
Appendix I Figure 1. Biparietal Diameter visual test for normality histogram superimposed on a normal distribution curve at 12 weeks



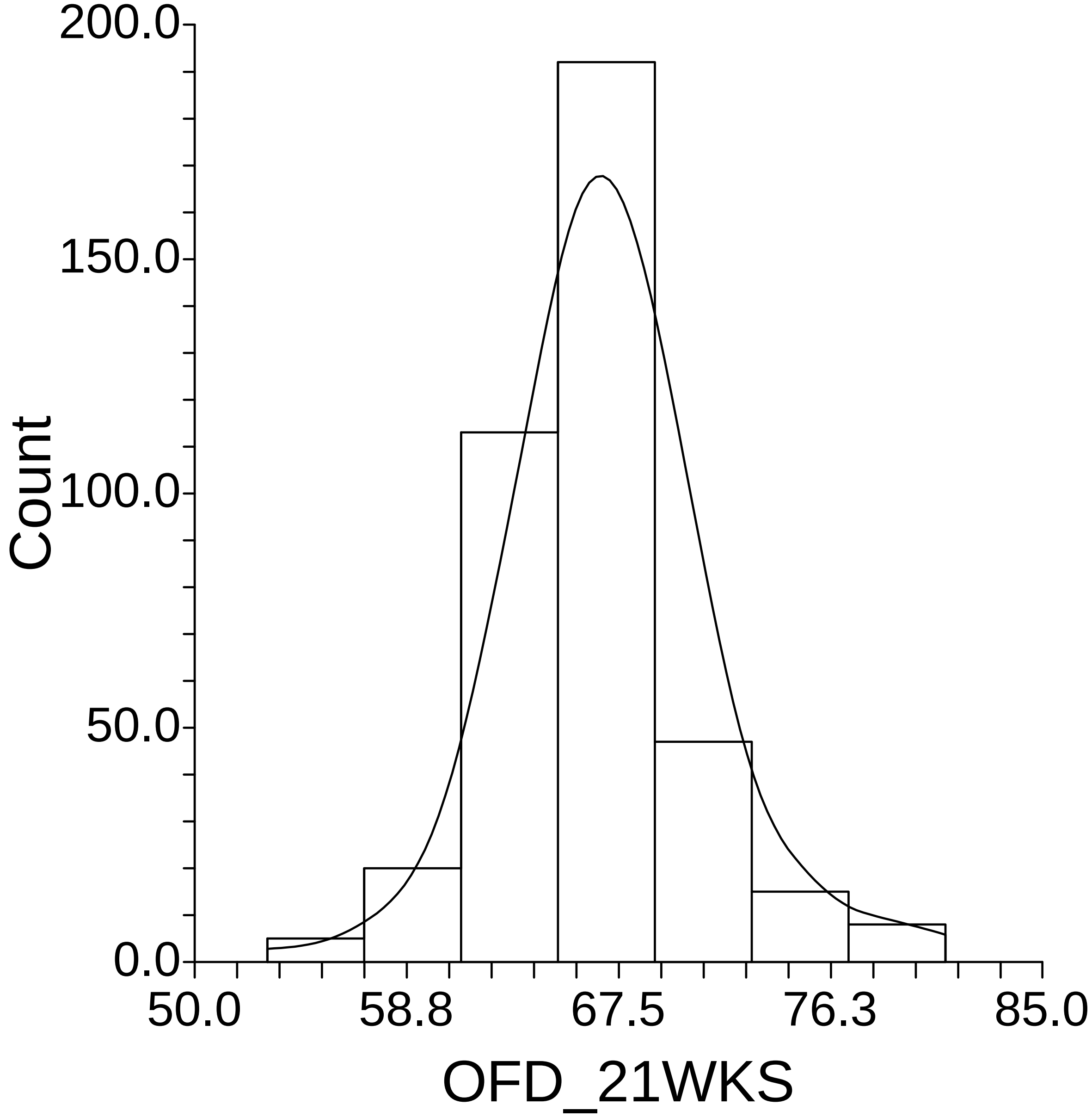
Appendix I Figure 2. Biparietal Diameter visual test for normality histogram superimposed on a normal distribution curve at 38weeks



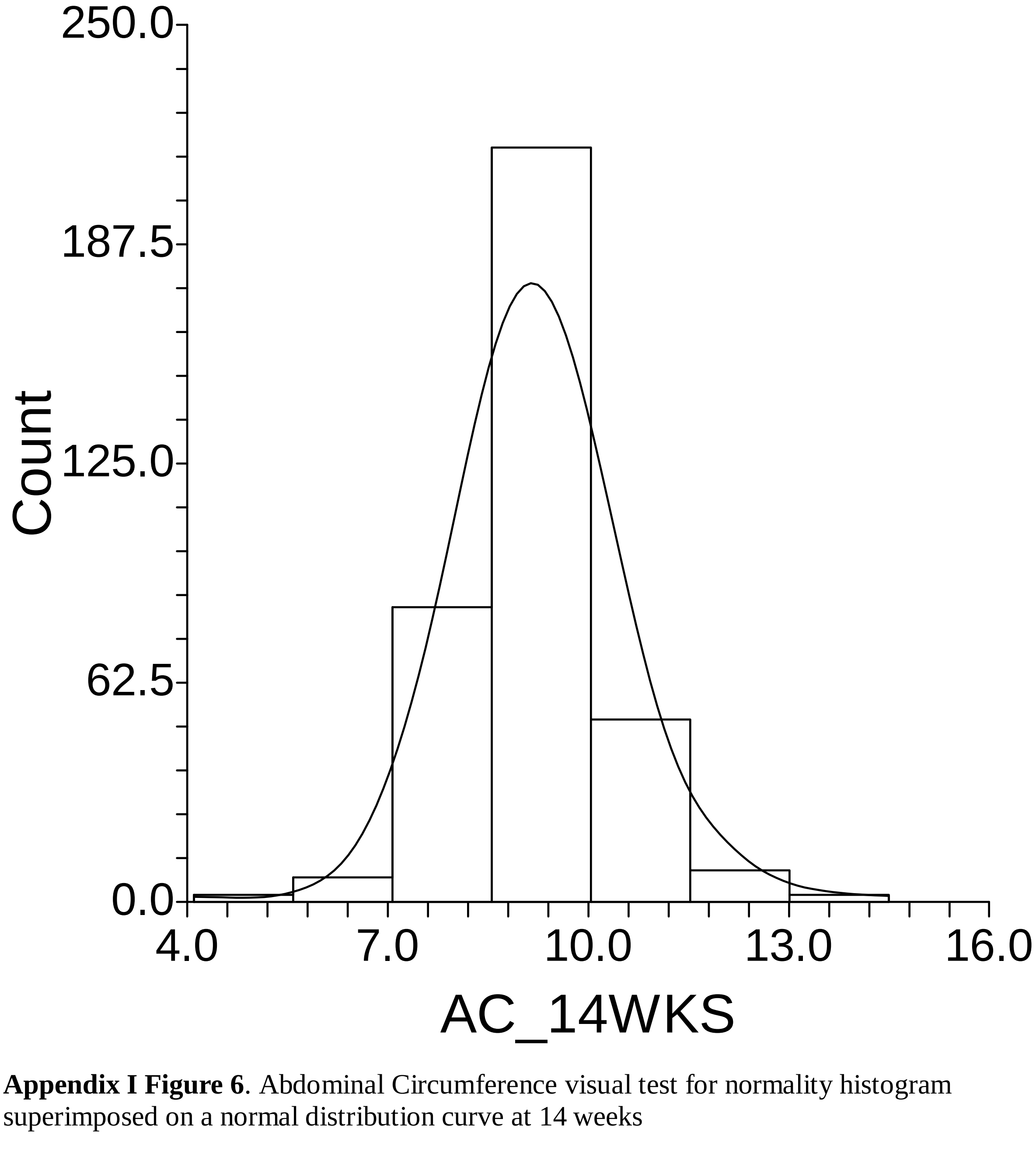
Appendix I Figure 3. Occipitofrontal Diameter visual test for normality histogram superimposed on a normal distribution curve at 13weeks



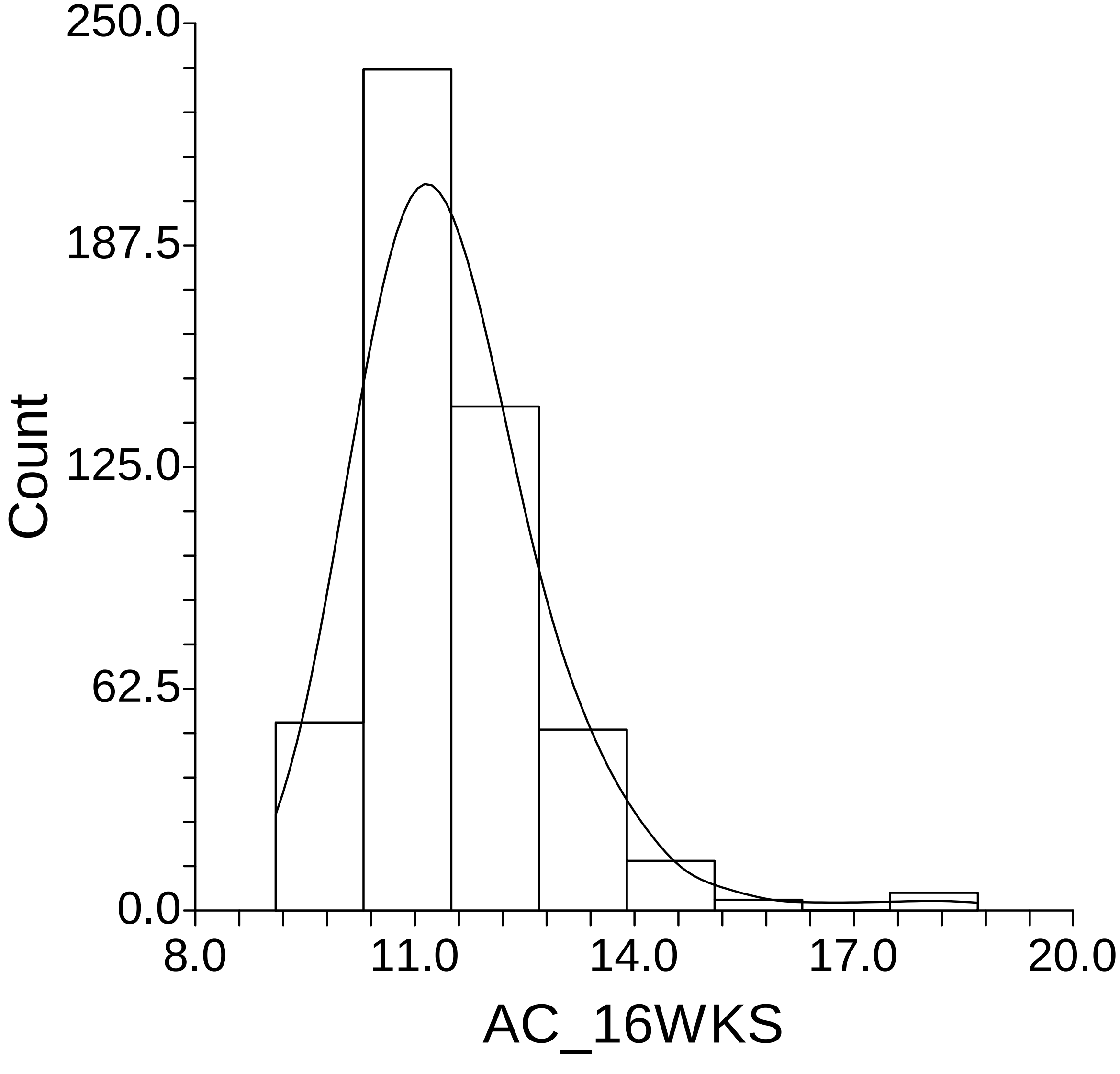
Appendix I Figure 4. Occipitofrontal Diameter visual test for normality histogram superimposed on a normal distribution curve at 18 weeks



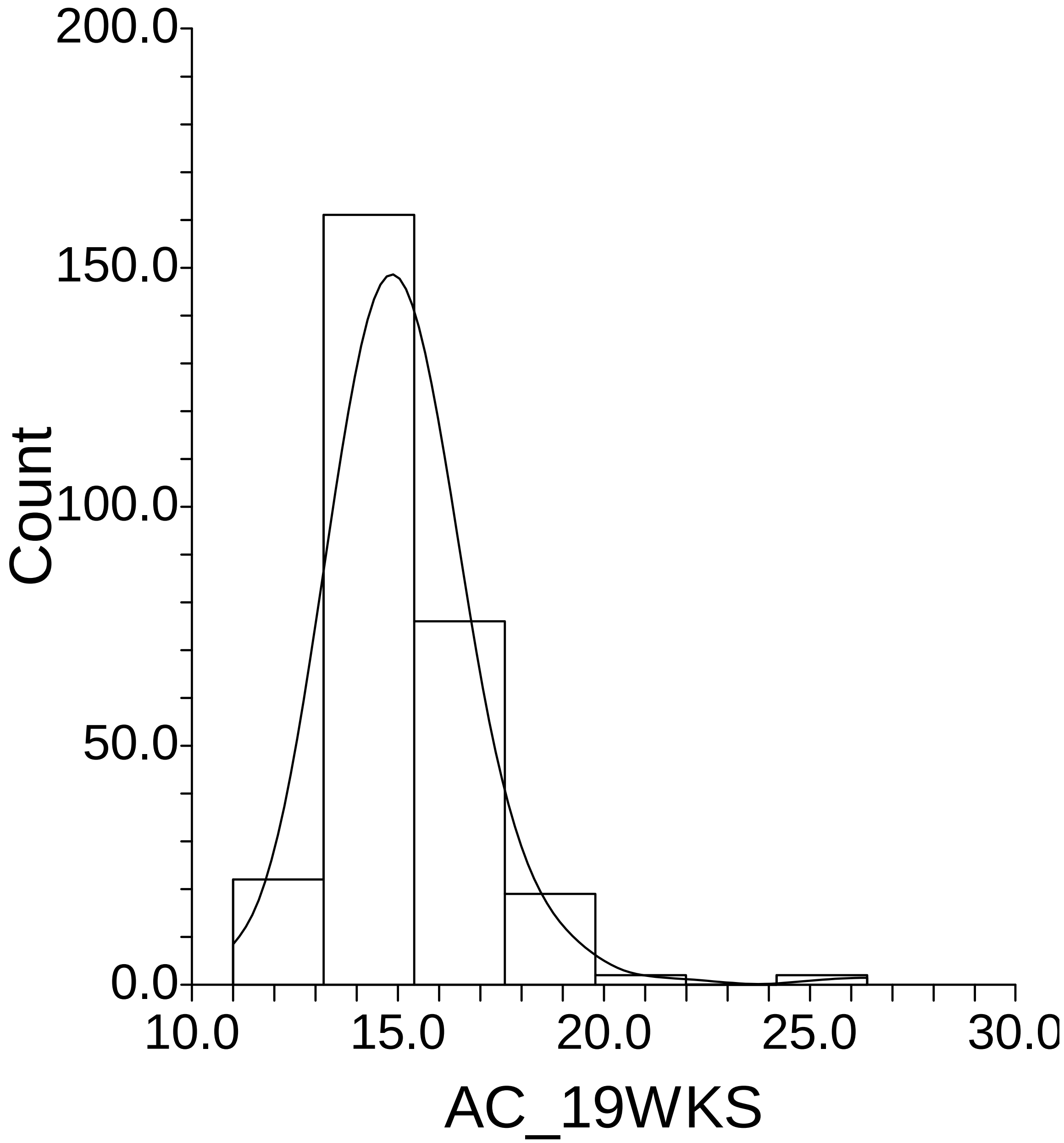
Appendix I Figure 5. Occipitofrontal Diameter visual test for normality histogram superimposed on a normal distribution curve at 21 weeks



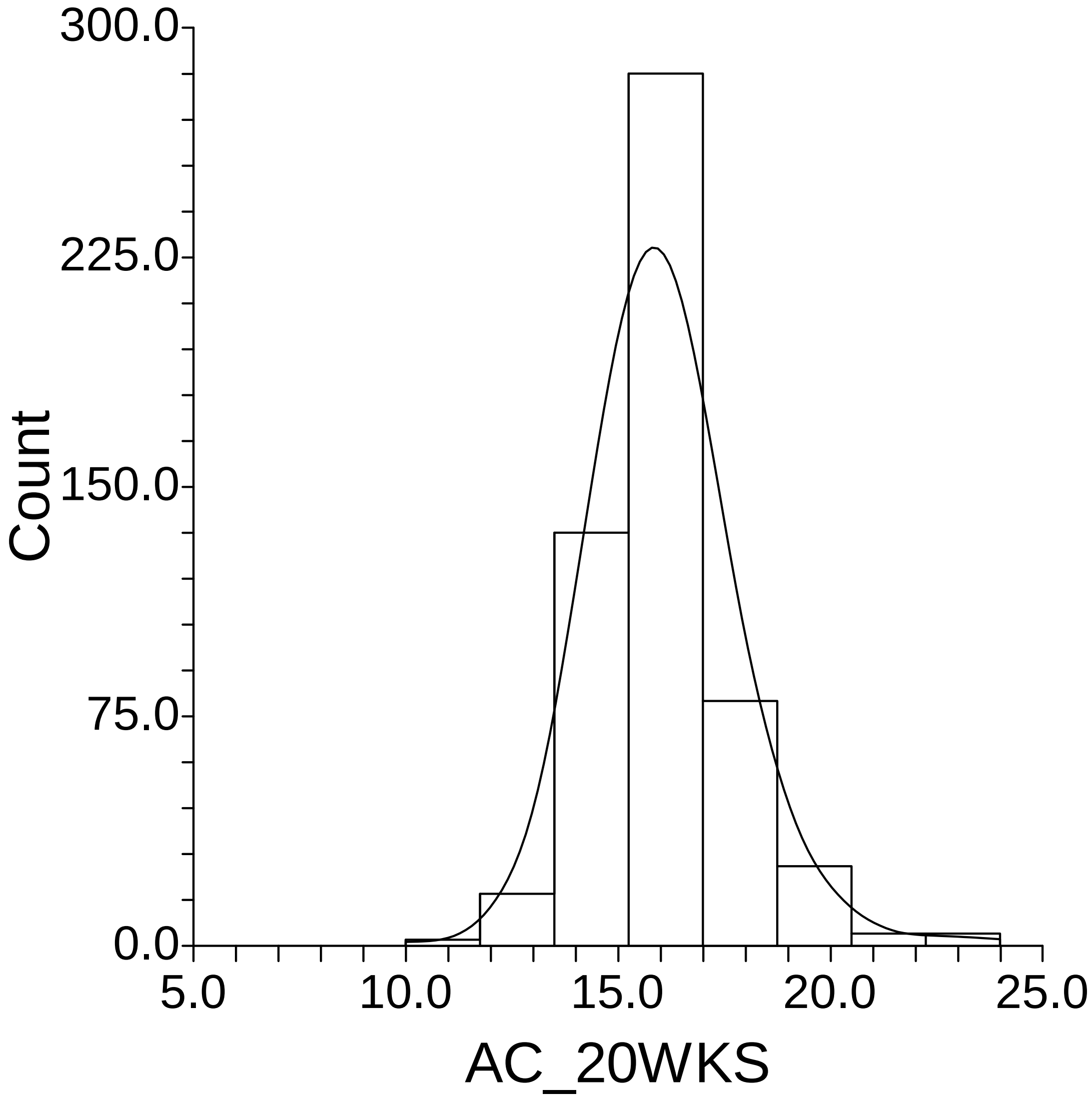
Appendix I Figure 6. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 14 weeks



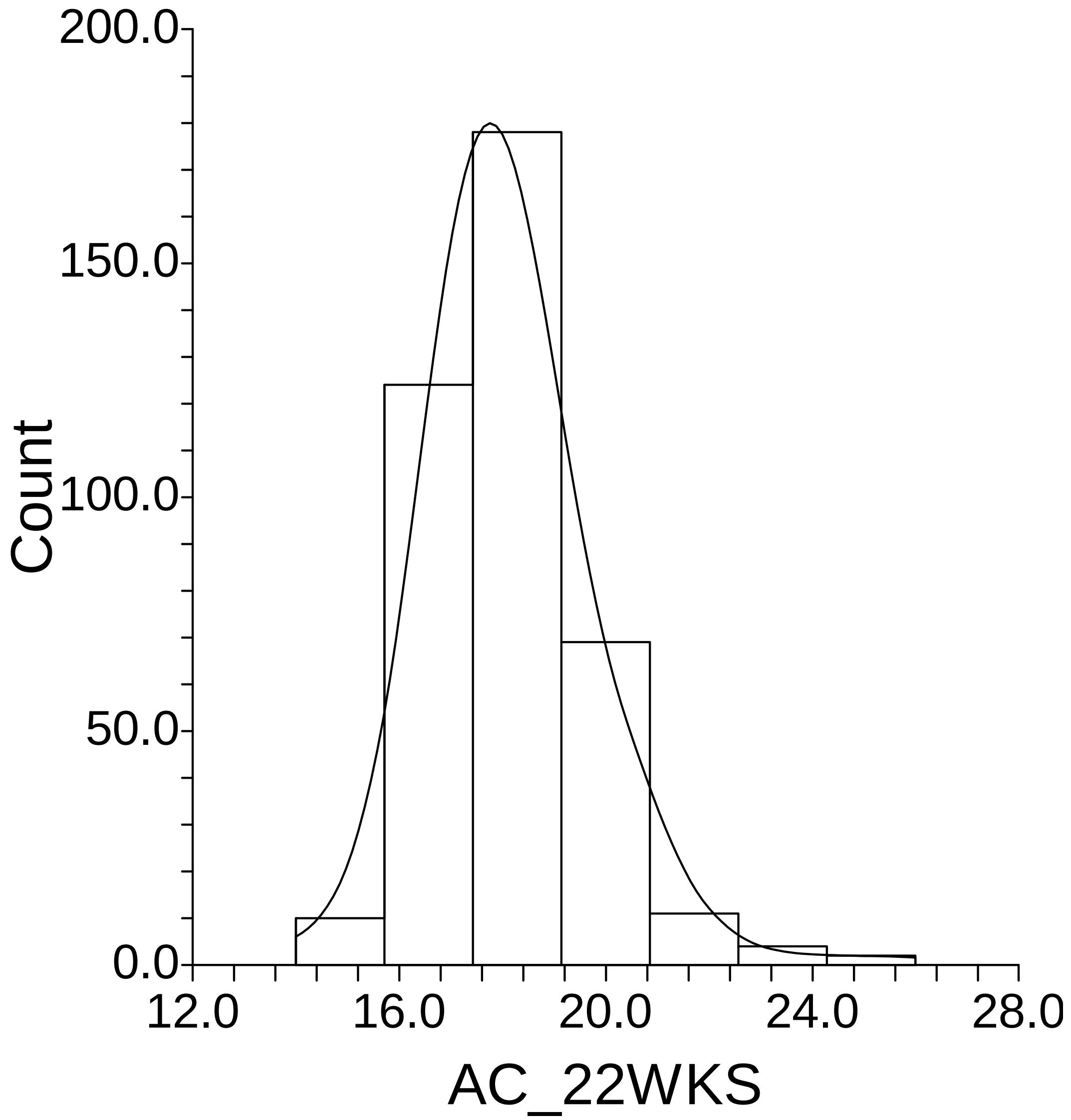
Appendix I Figure 7. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 16weeks



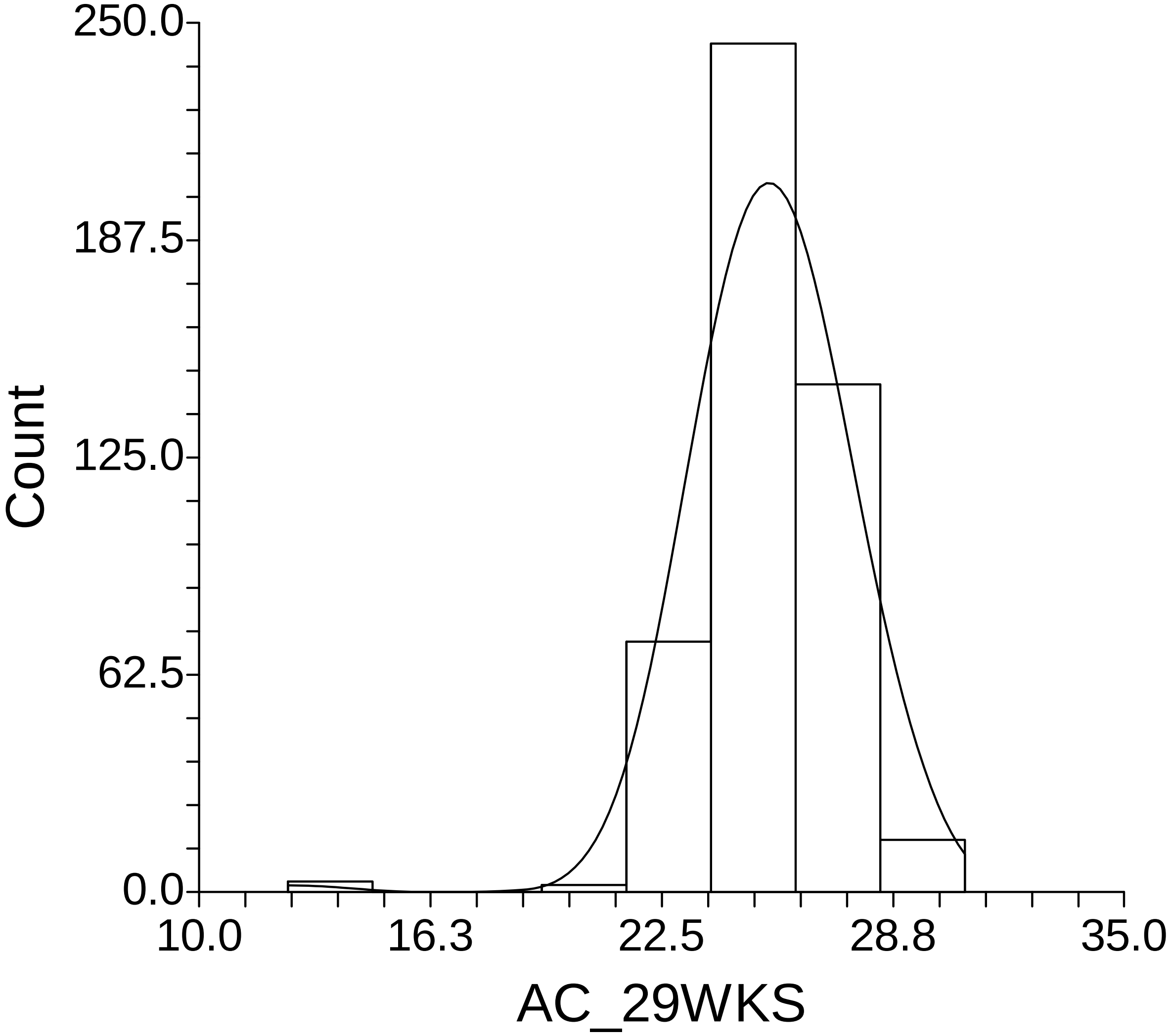
Appendix I Figure 8. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 19 weeks



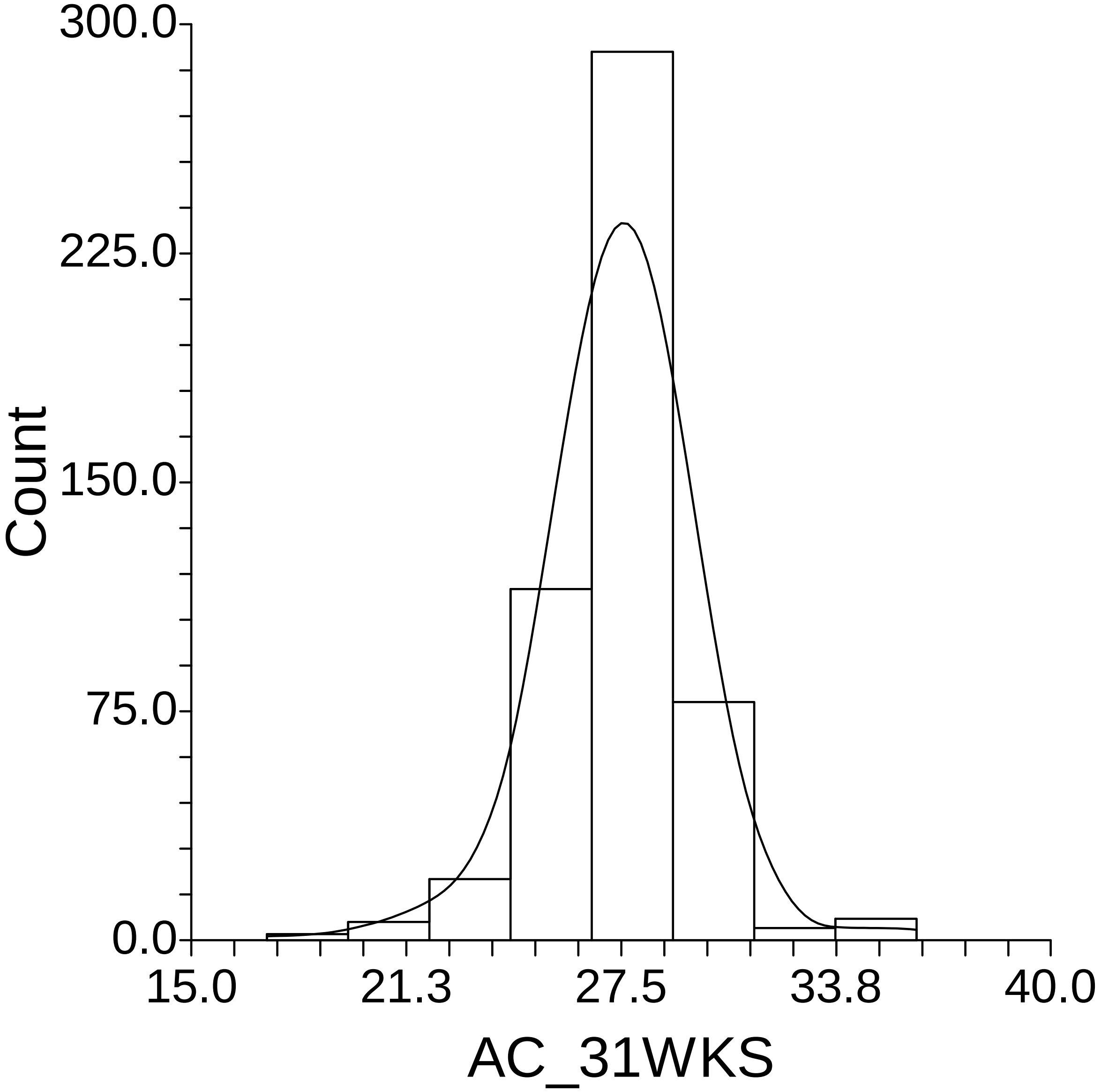
Appendix I Figure 9. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 20 weeks



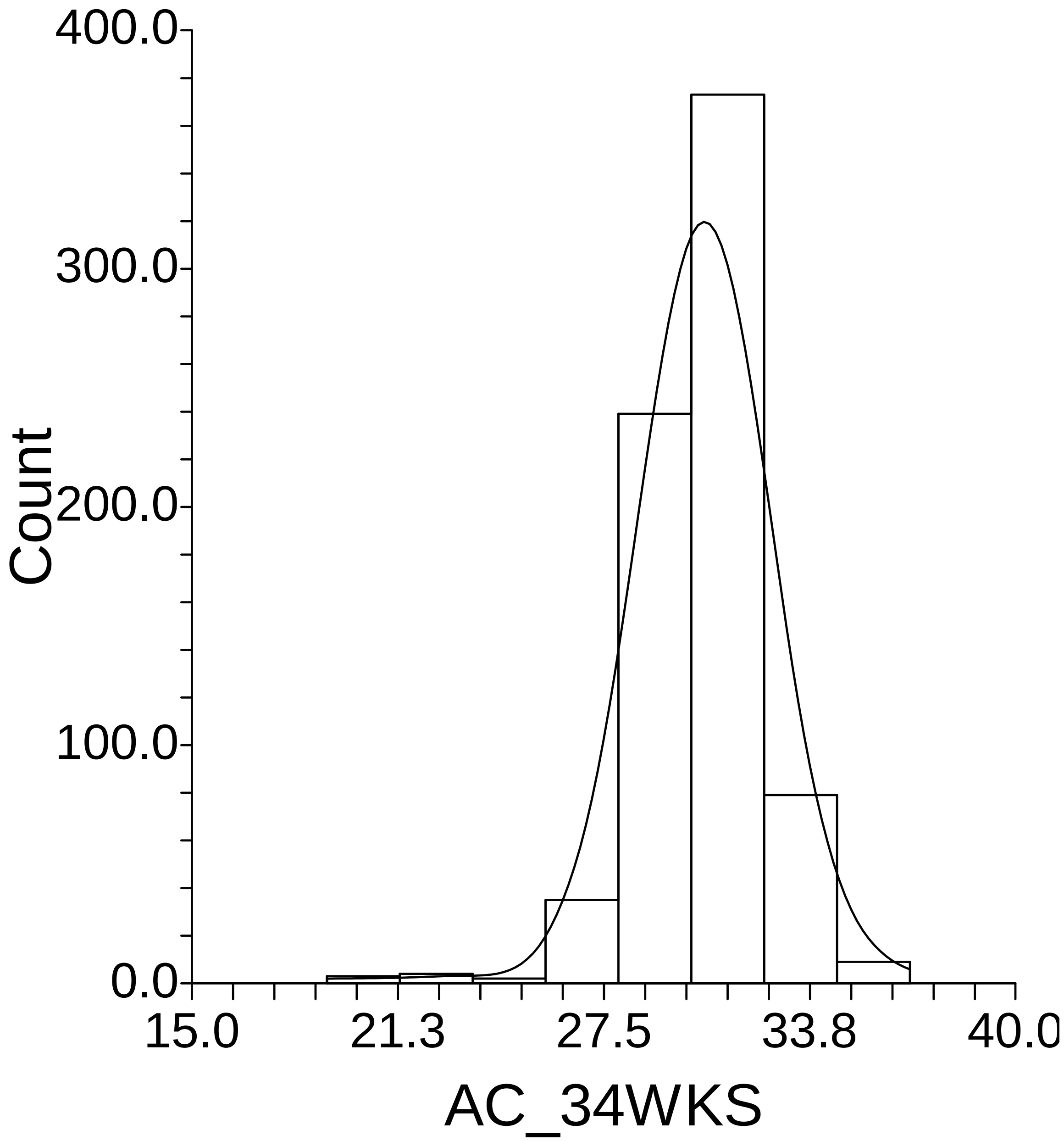
Appendix I Figure 10. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 22 weeks



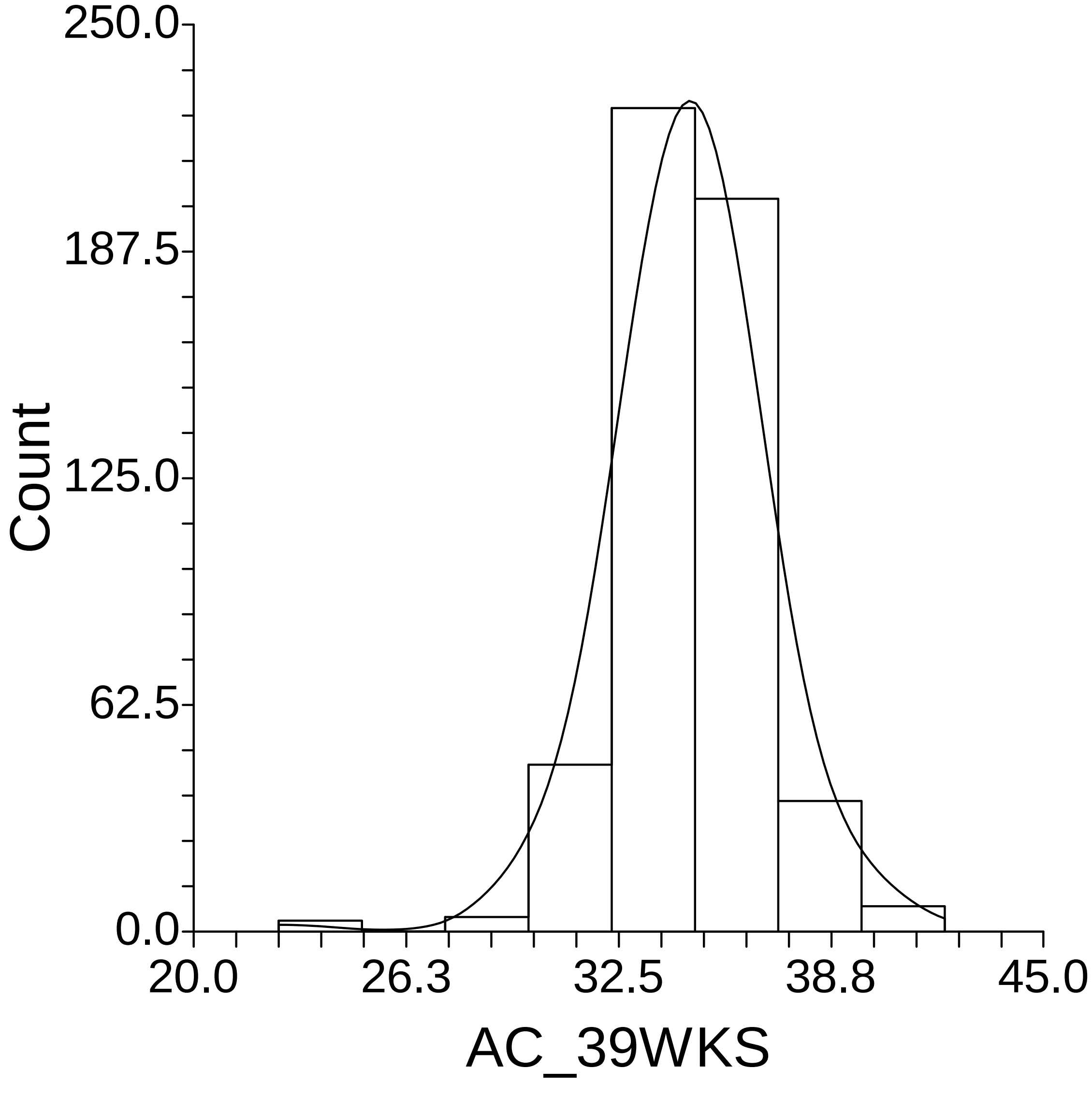
Appendix I Figure 11. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 29 weeks



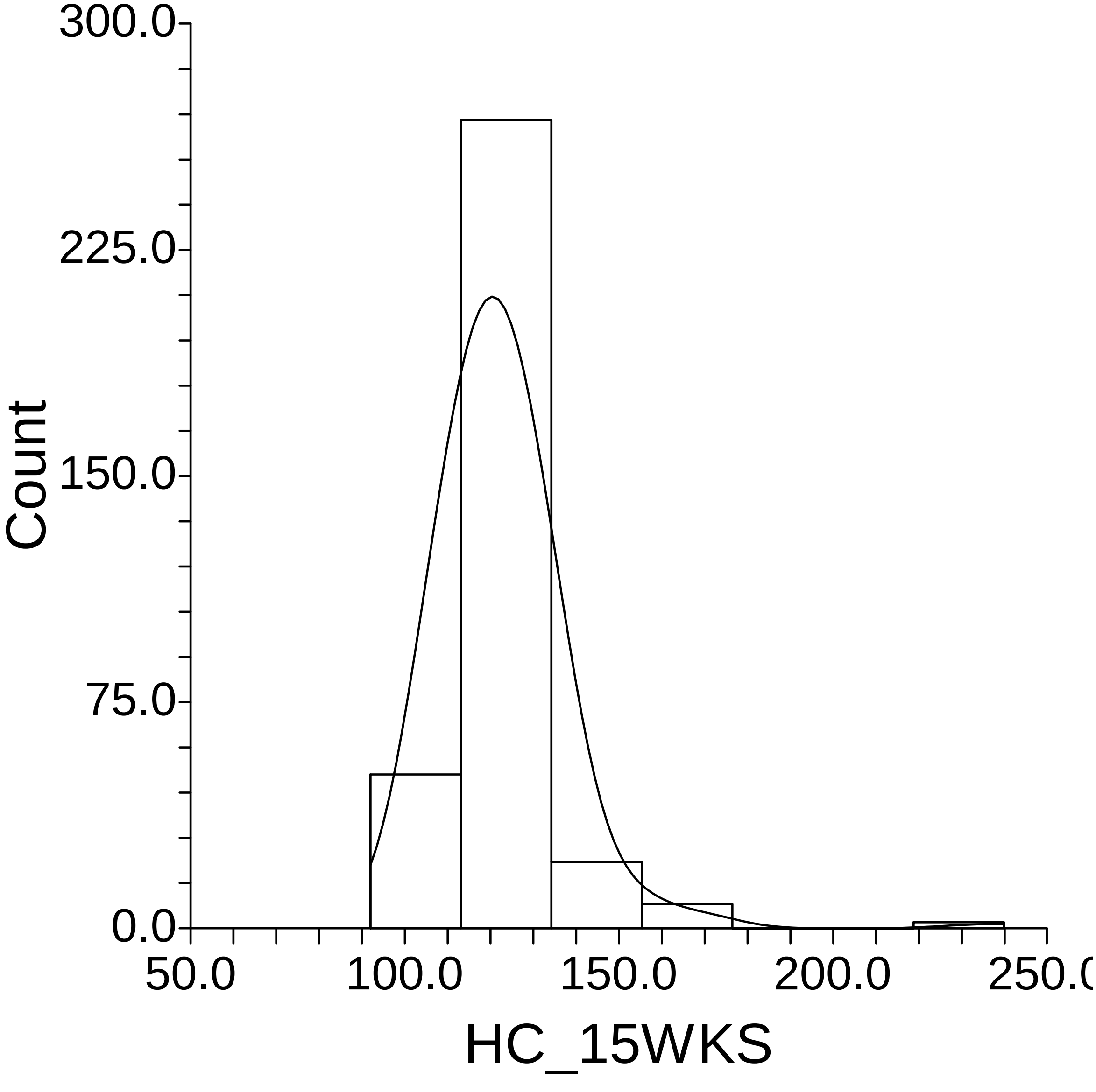
Appendix I Figure 12. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 31 weeks



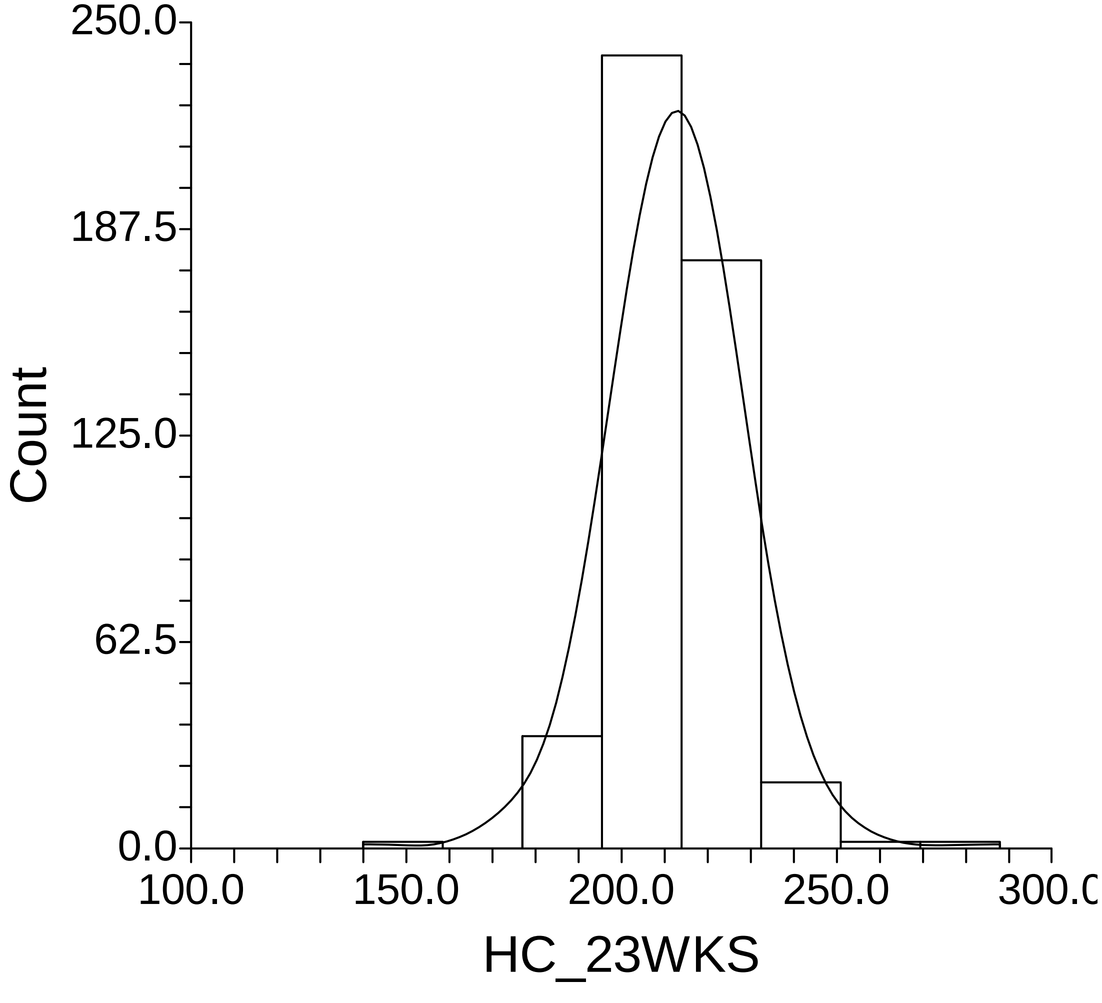
Appendix I Figure 13. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 34weeks



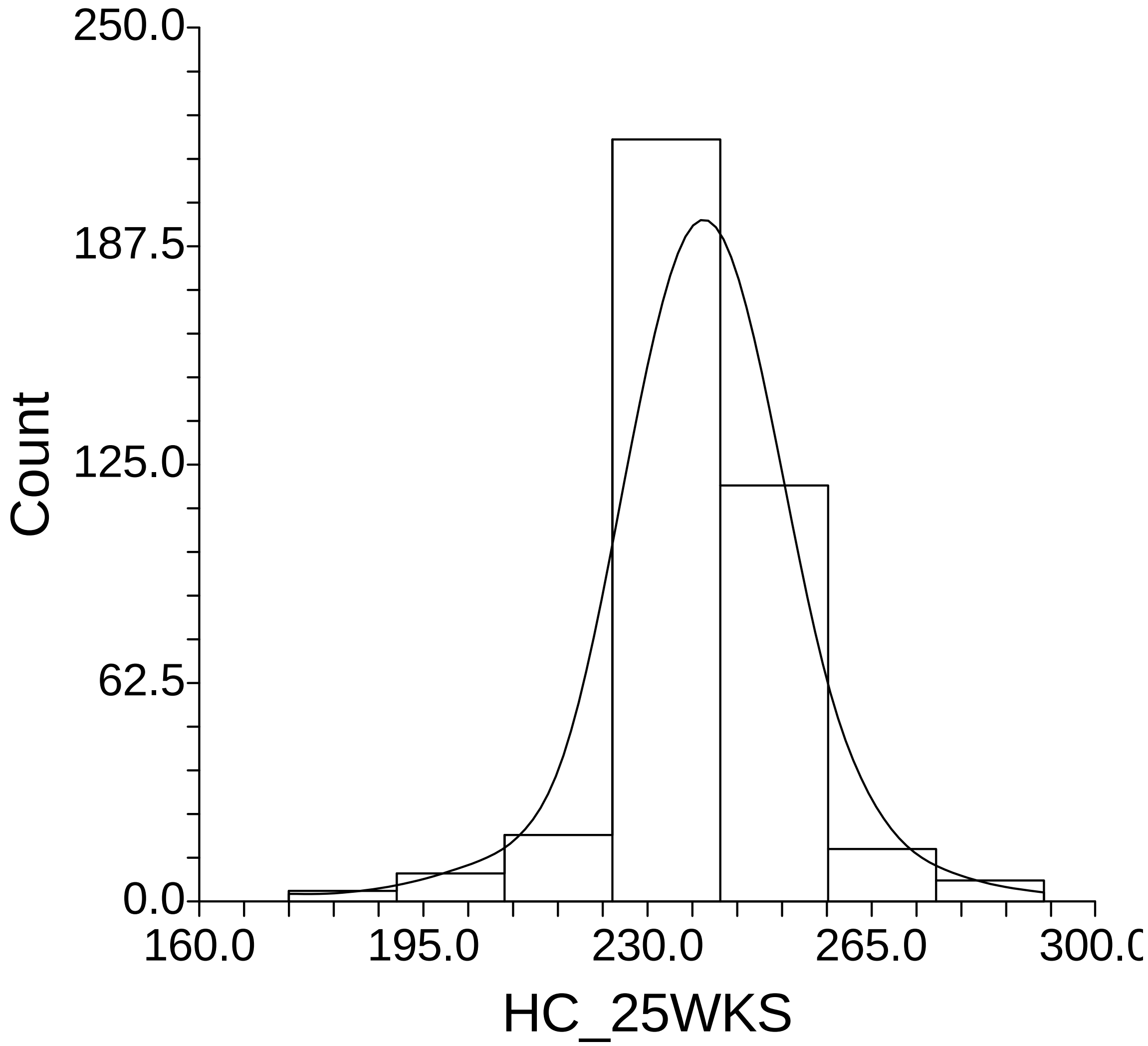
Appendix I Figure 14. Abdominal Circumference visual test for normality histogram superimposed on a normal distribution curve at 39weeks



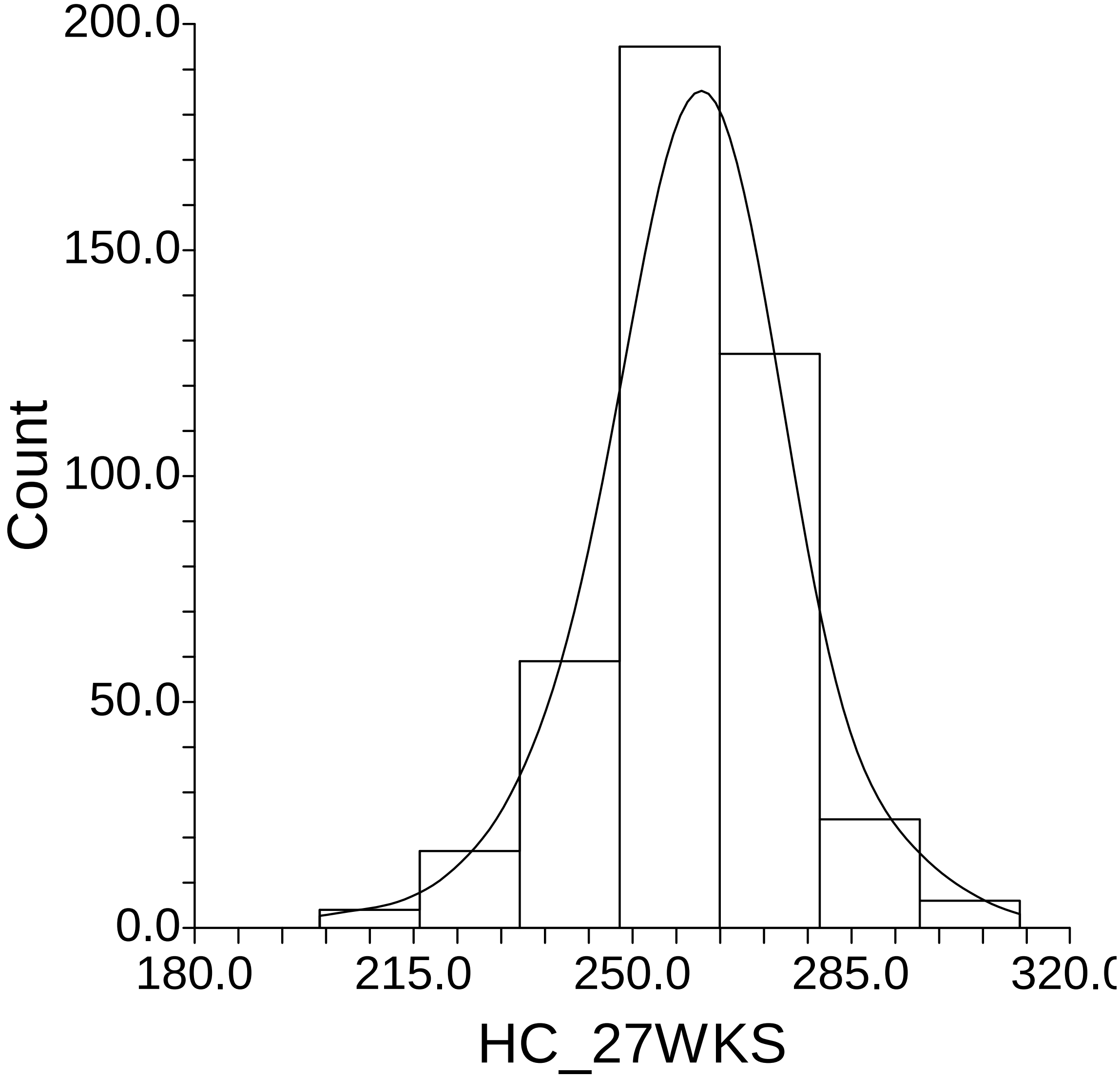
Appendix I Figure 15. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 15weeks



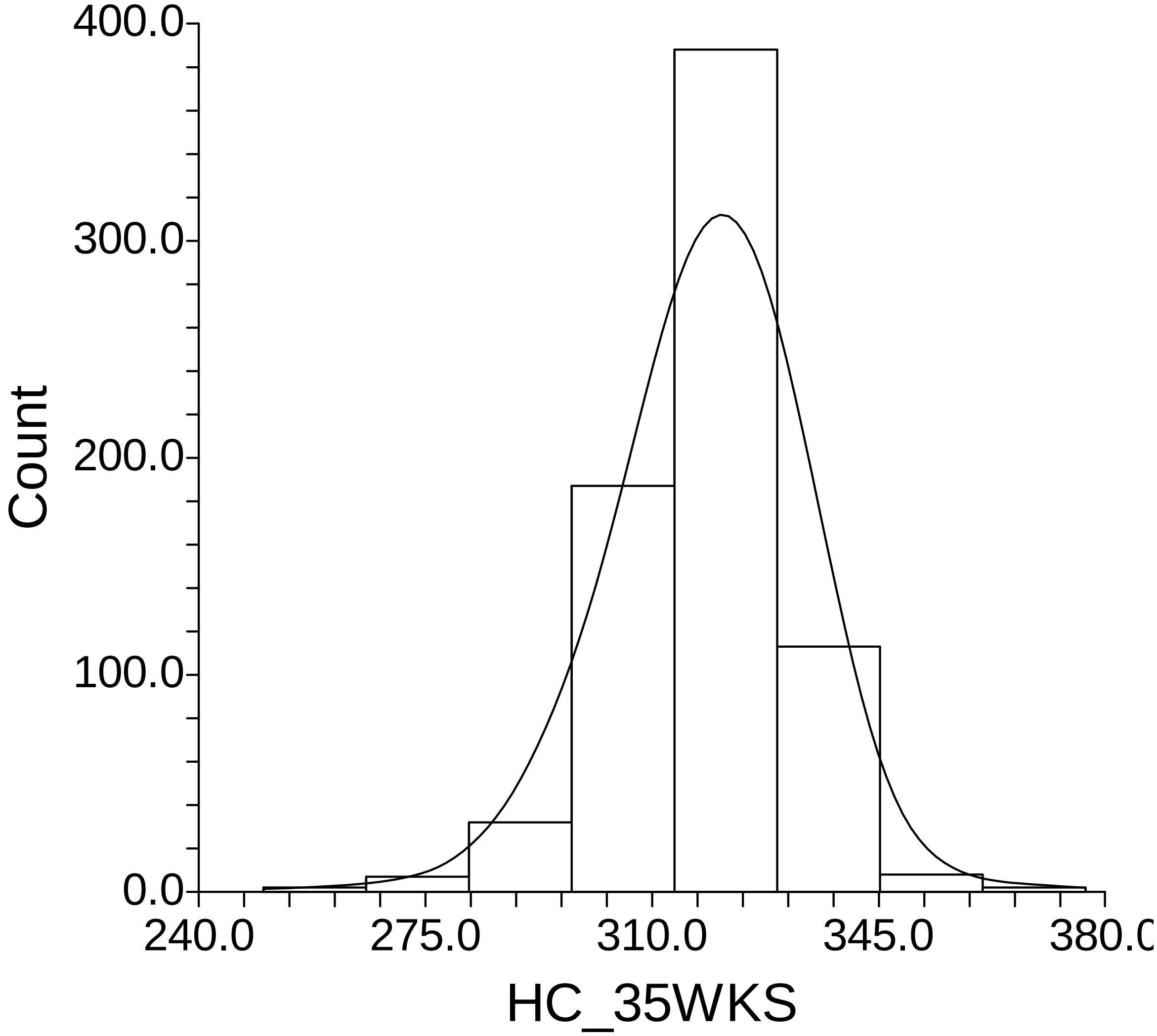
Appendix I Figure 16. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 23 weeks



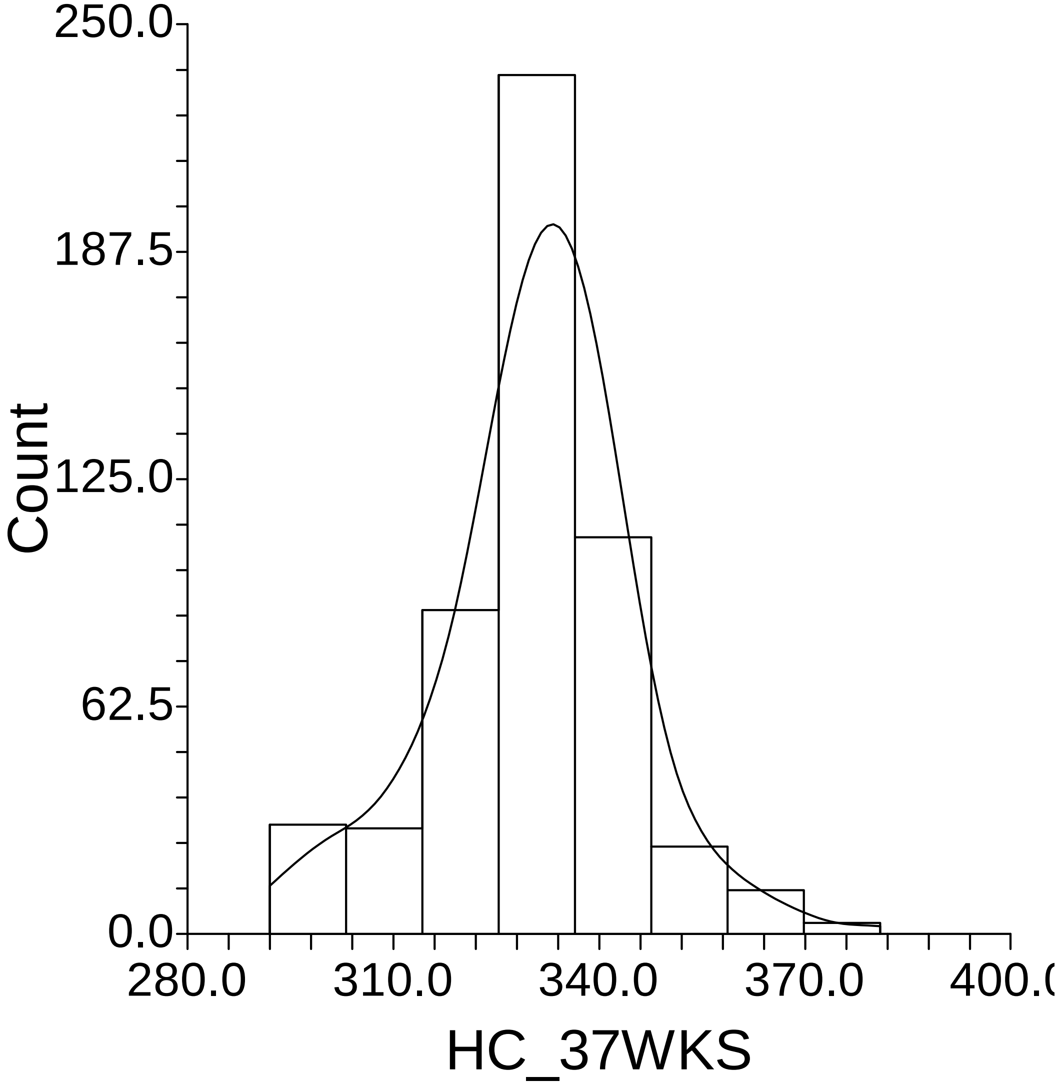
Appendix I Figure 17. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 25 weeks



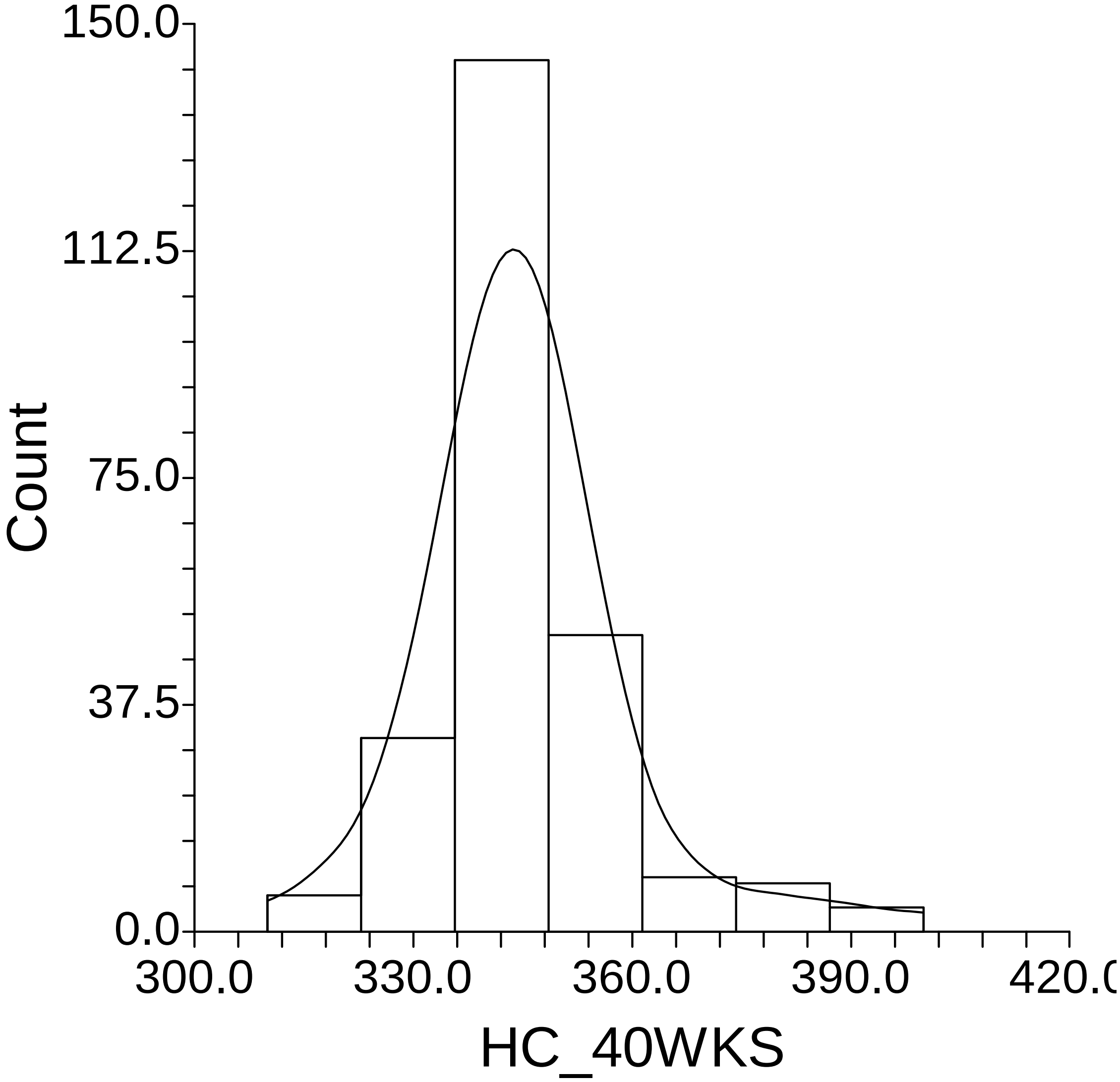
Appendix I Figure 18. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 27 weeks



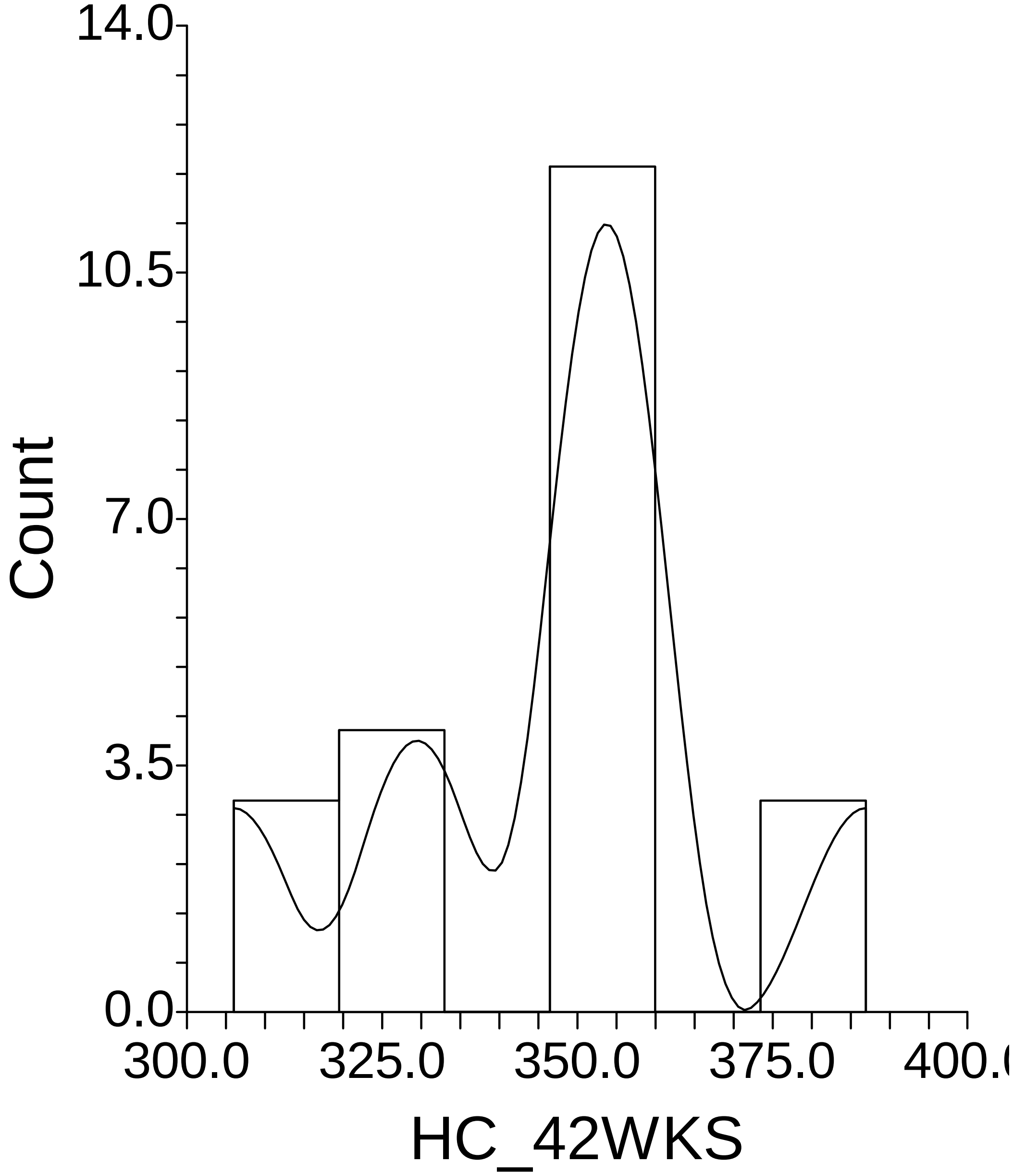
Appendix I Figure 19. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 35weeks



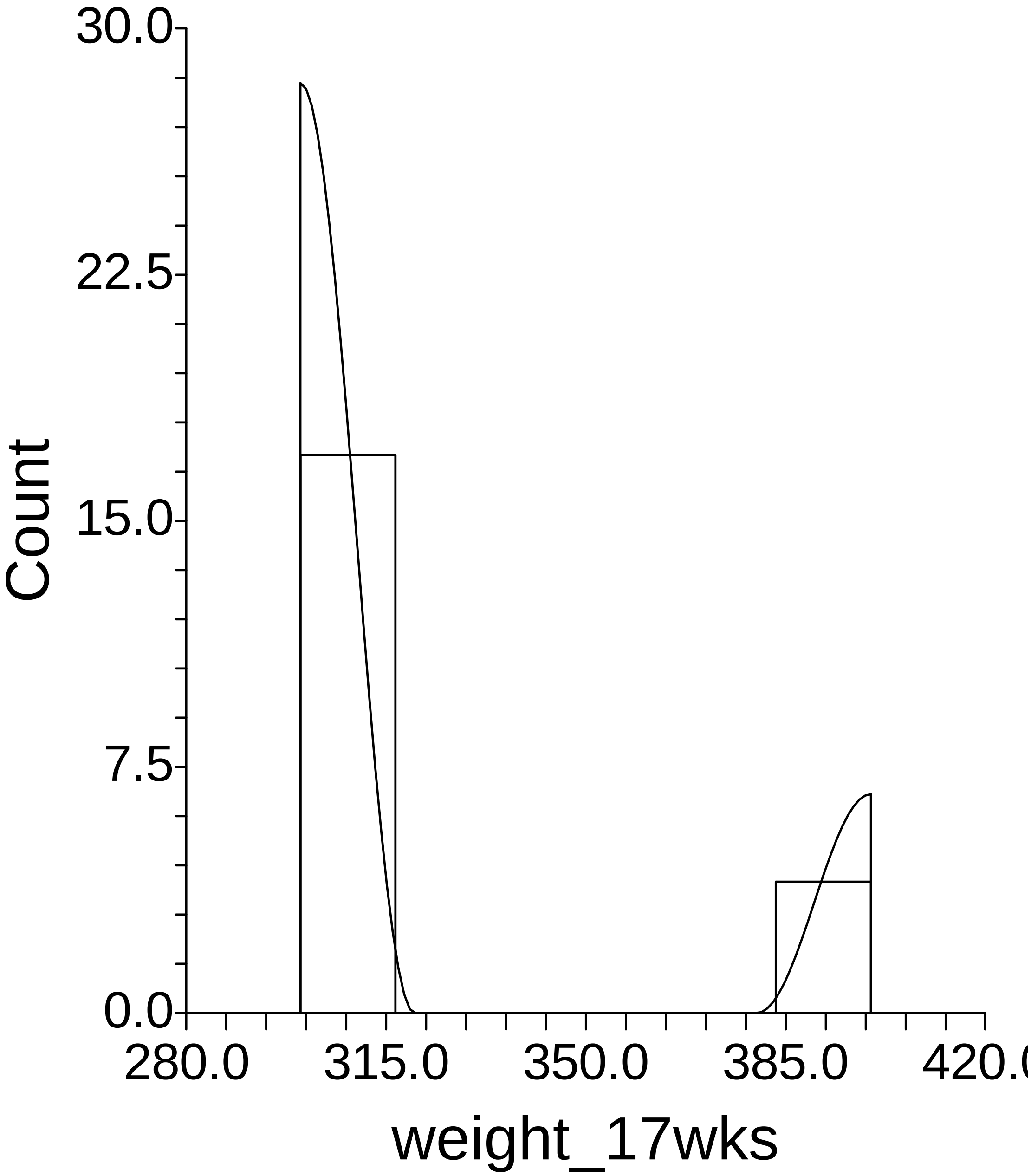
Appendix I Figure 20. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 37weeks



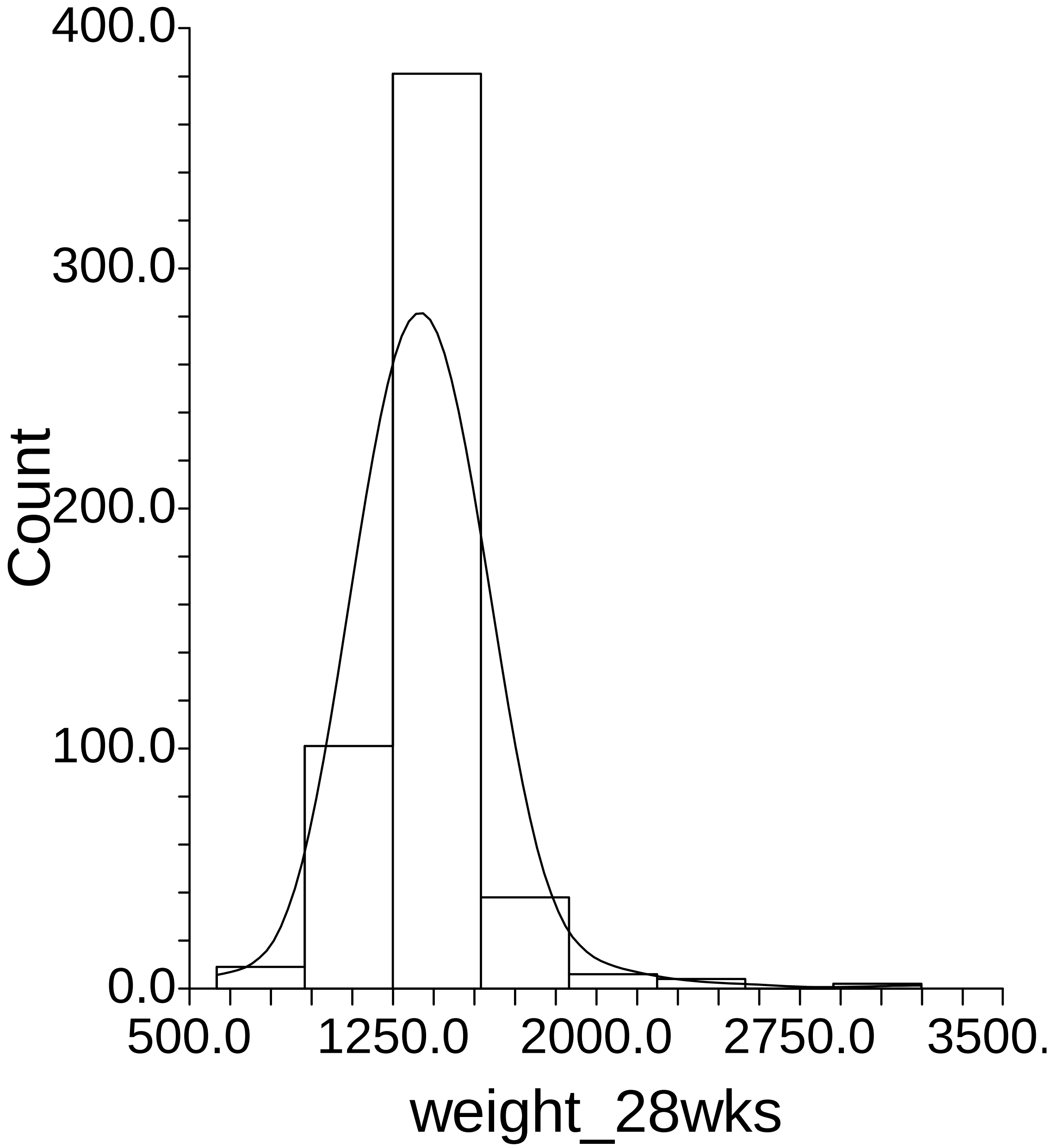
Appendix I Figure 21. Head Circumference visual test for normality histogram superimposed on a normal distribution curve at 40weeks



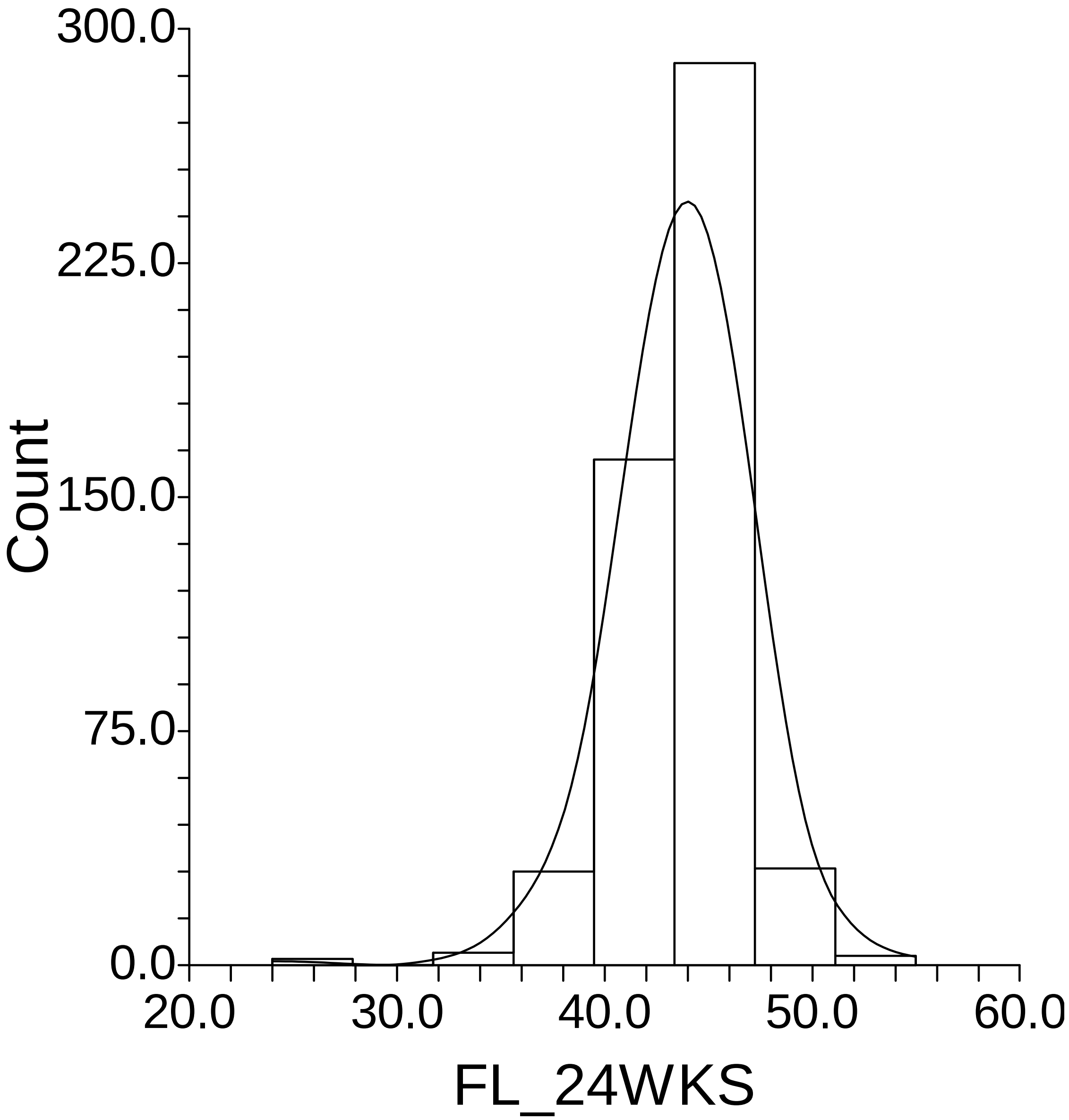
Appendix I Figure 22. Head Circumference Visual test for normality histogram superimposed on a normal distribution curve at 42weeks



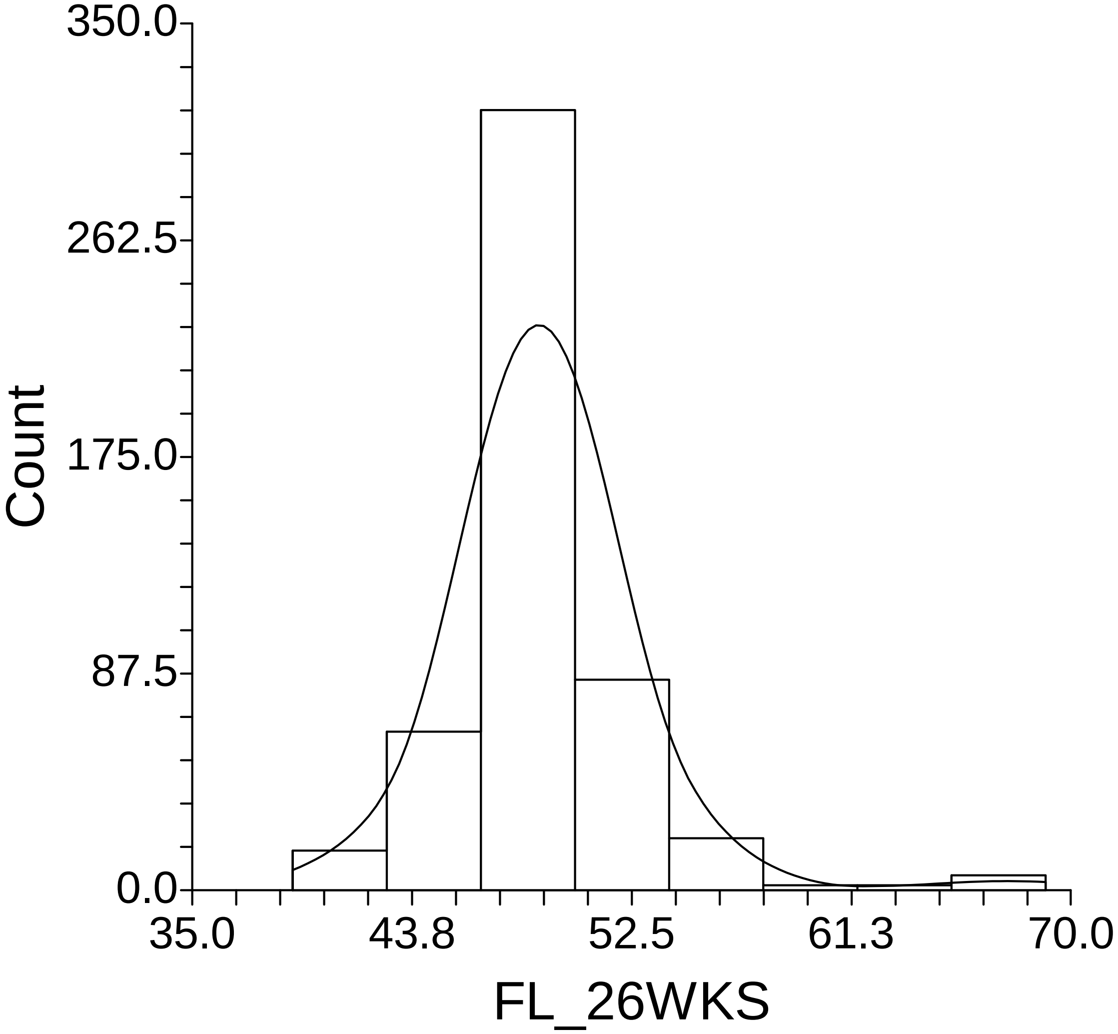
Appendix I Figure 23. Weight visual test for normality histogram superimposed on a normal distribution curve at 17 weeks



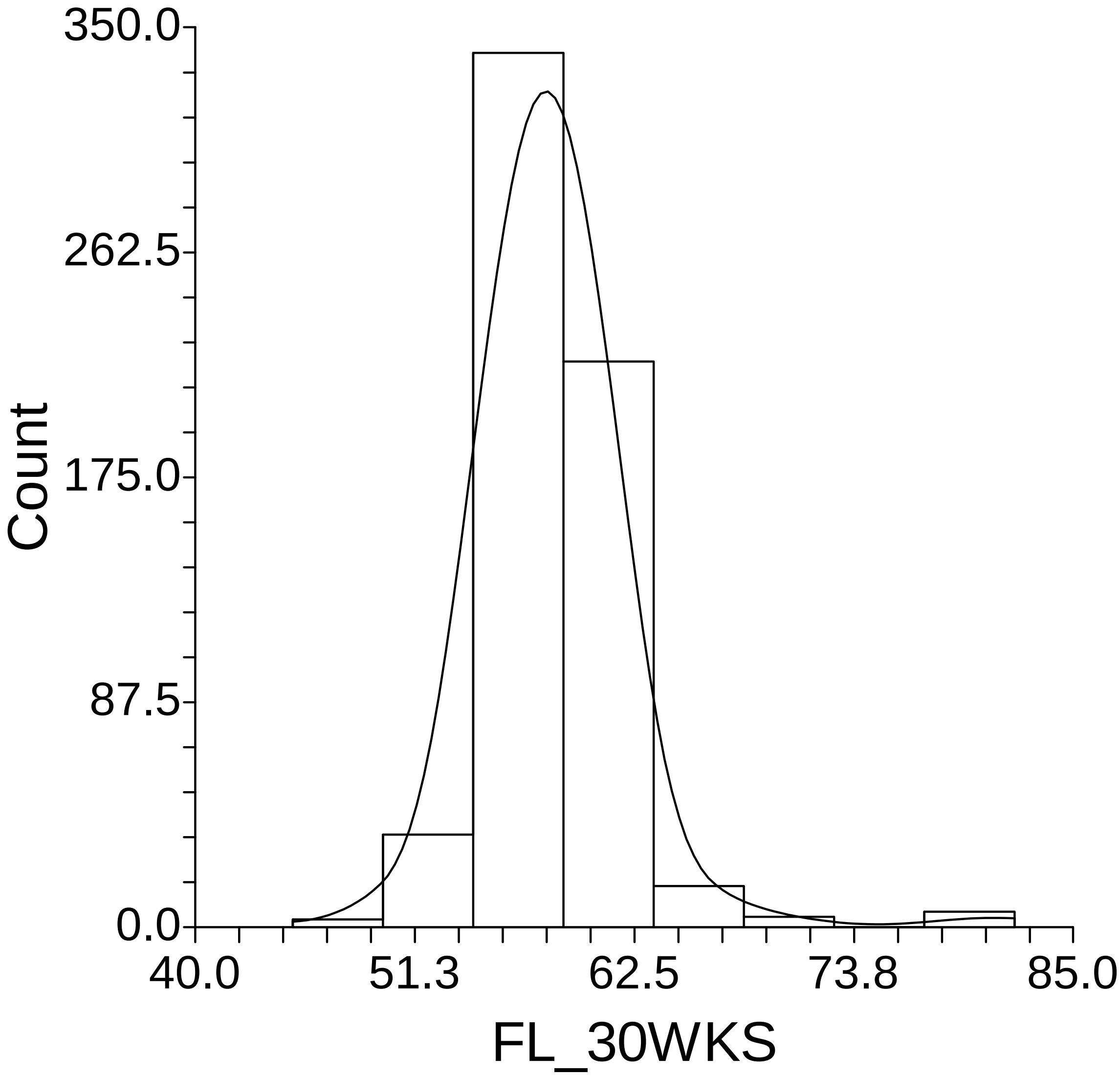
Appendix I Figure 24. Weight visual test for normality histogram superimposed on a normal distribution curve at 28weeks



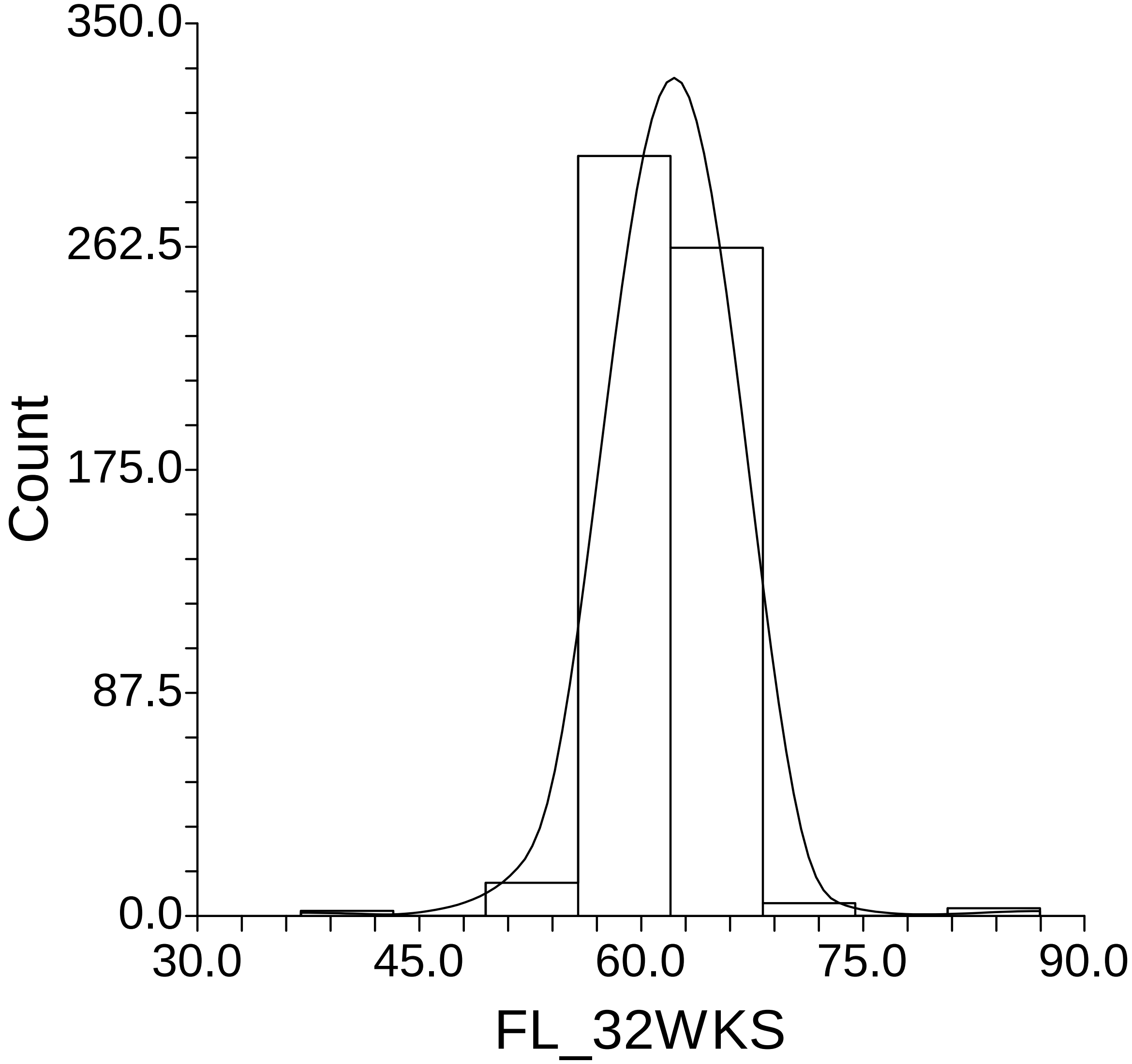
Appendix I Figure 25. Femur Length visual test for normality histogram superimposed on a normal distribution curve at 24 weeks



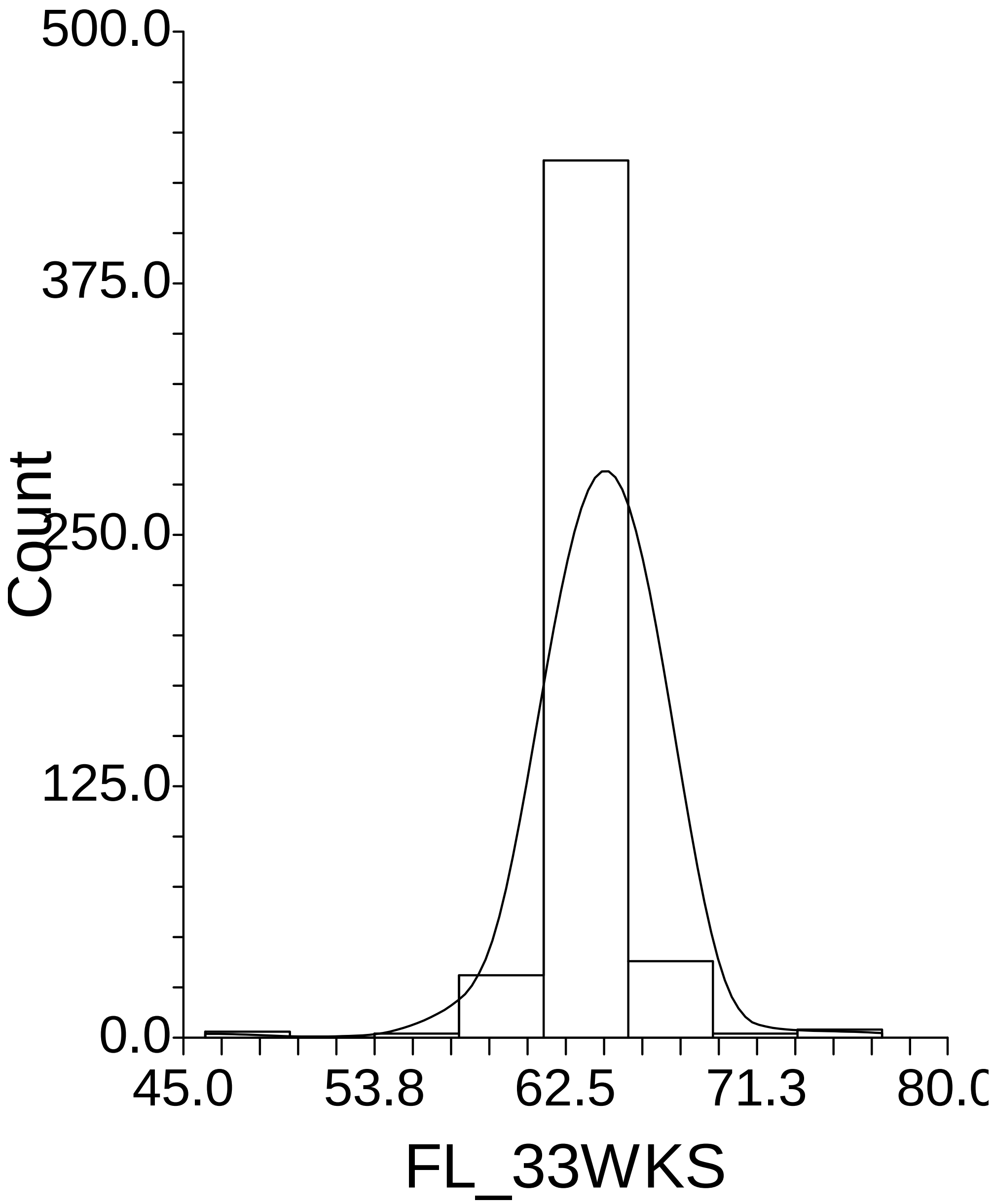
Appendix I Figure 26. Femur Length visual test for normality histogram superimposed on a normal distribution curve at 26 weeks



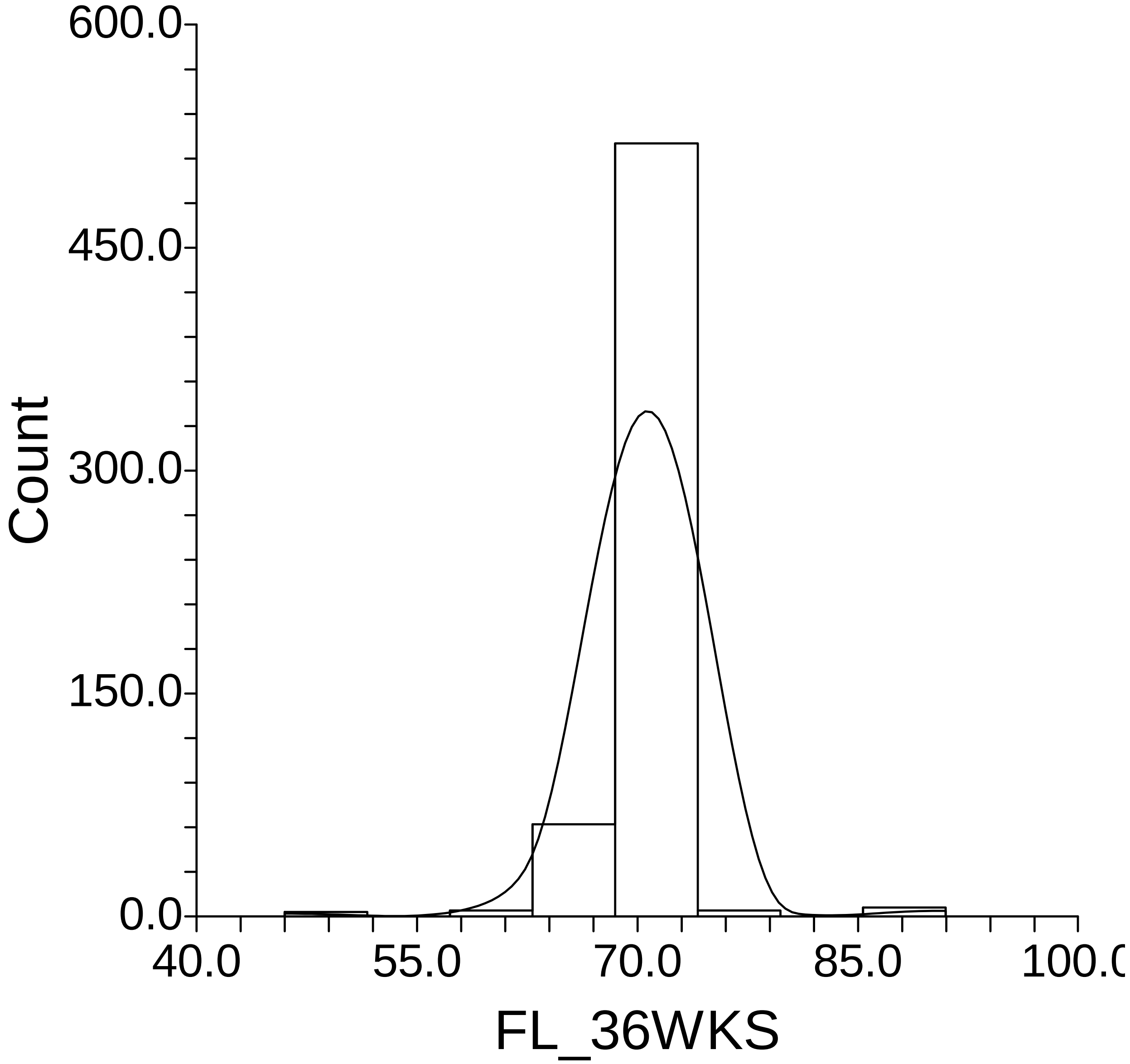
Appendix I Figure 27. Femur Length Visual test for normality histogram superimposed on a normal distribution curve at 30 weeks



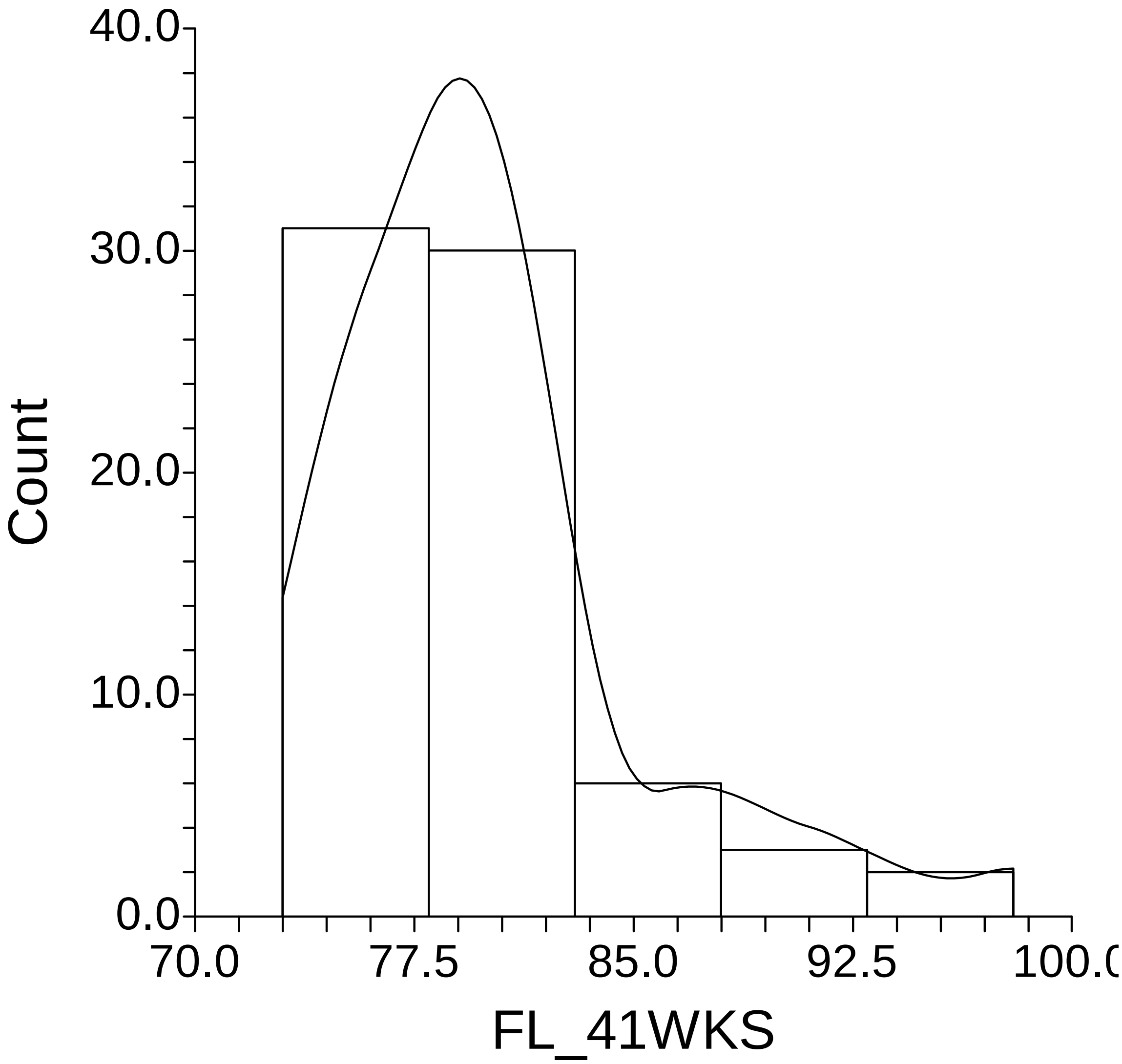
Appendix I Figure 28. Femur Length visual test for normality histogram superimposed on a normal distribution curve at 32 weeks



Appendix I Figure 29. Femur Length visual test for normality histogram superimposed on a normal distribution curve at 33weeks



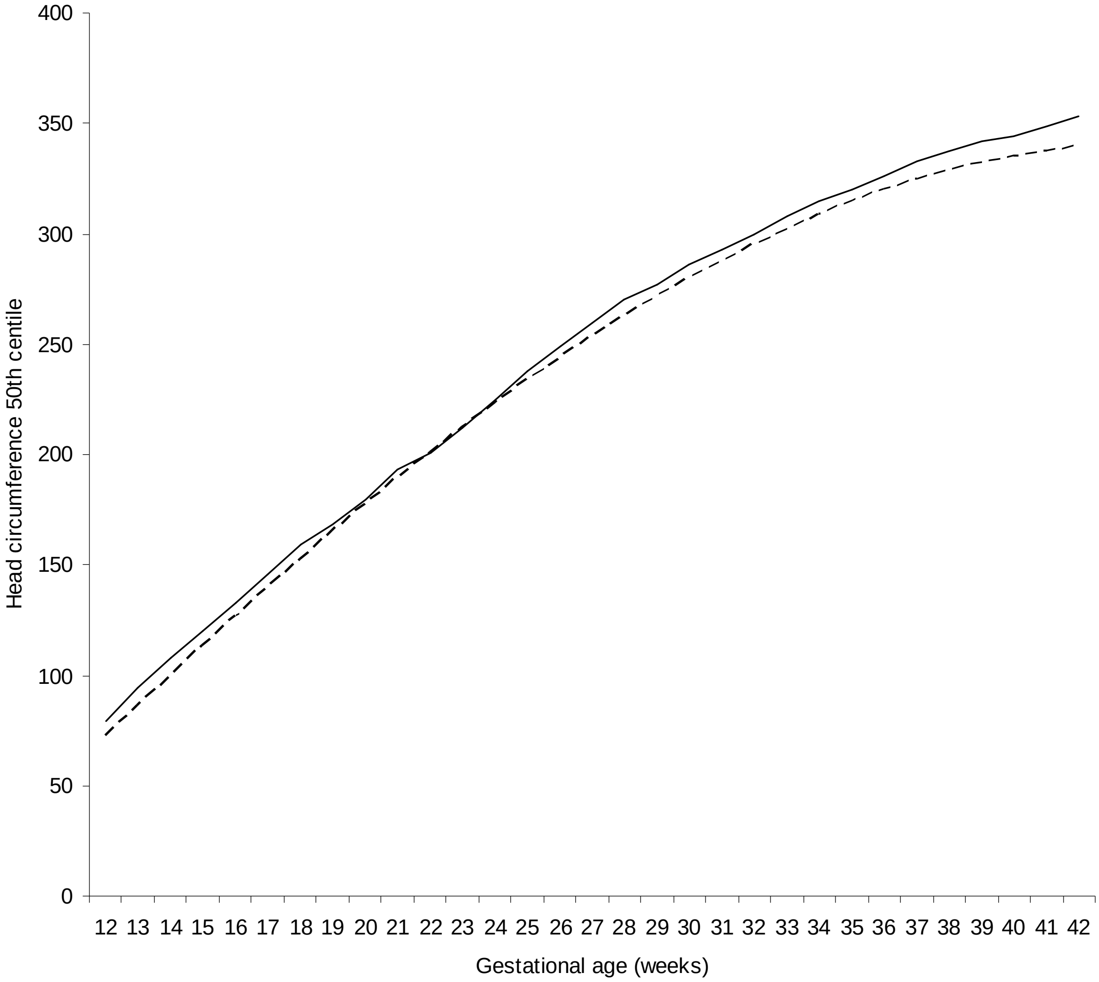
Appendix I Figure 30. Femur Length visual test for normality histogram superimposed on a normal distribution curve at 36weeks



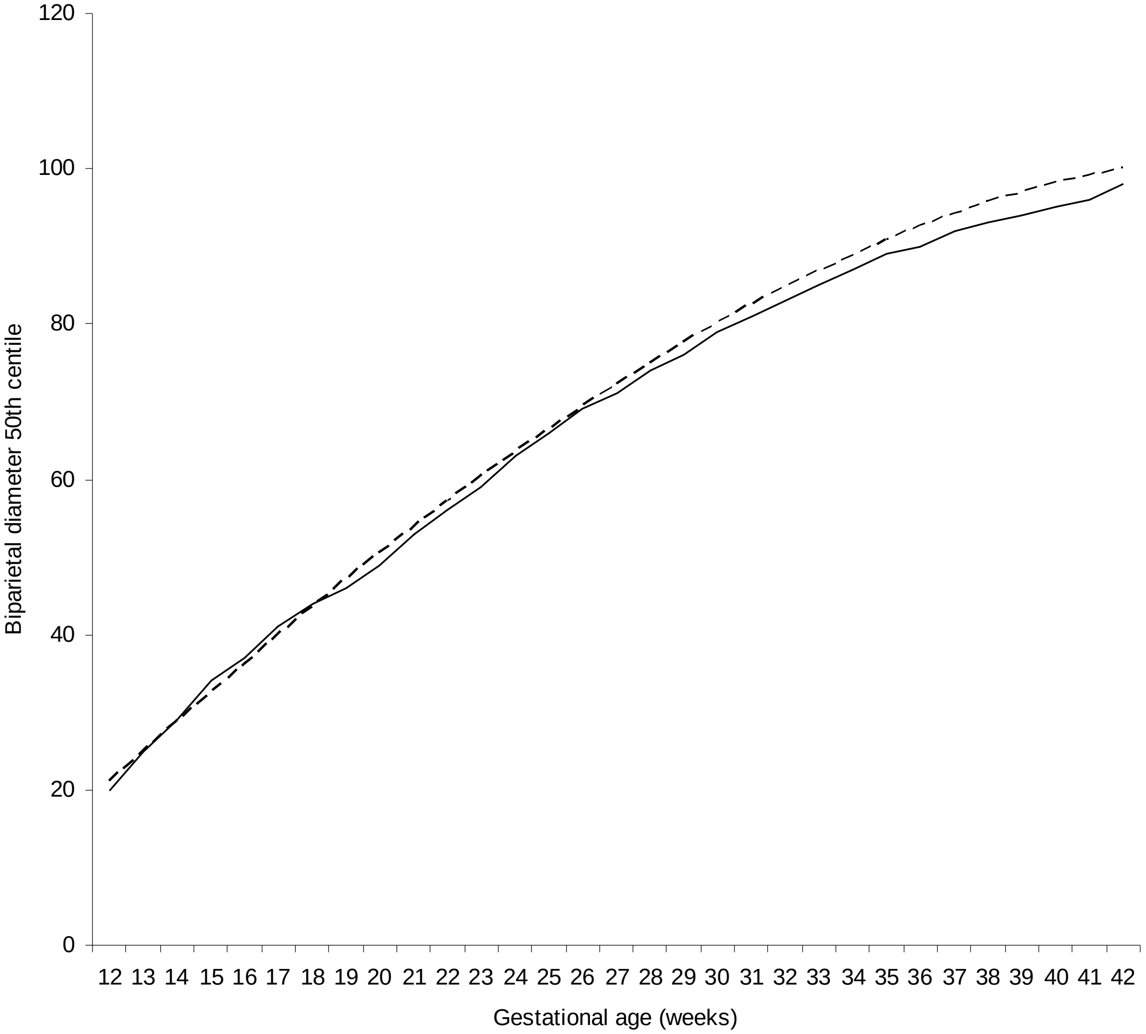
Appendix I Figure 31. Femur Length visual test for normality histogram superimposed on a normal distribution curve at 41weeks

APPENDIX II

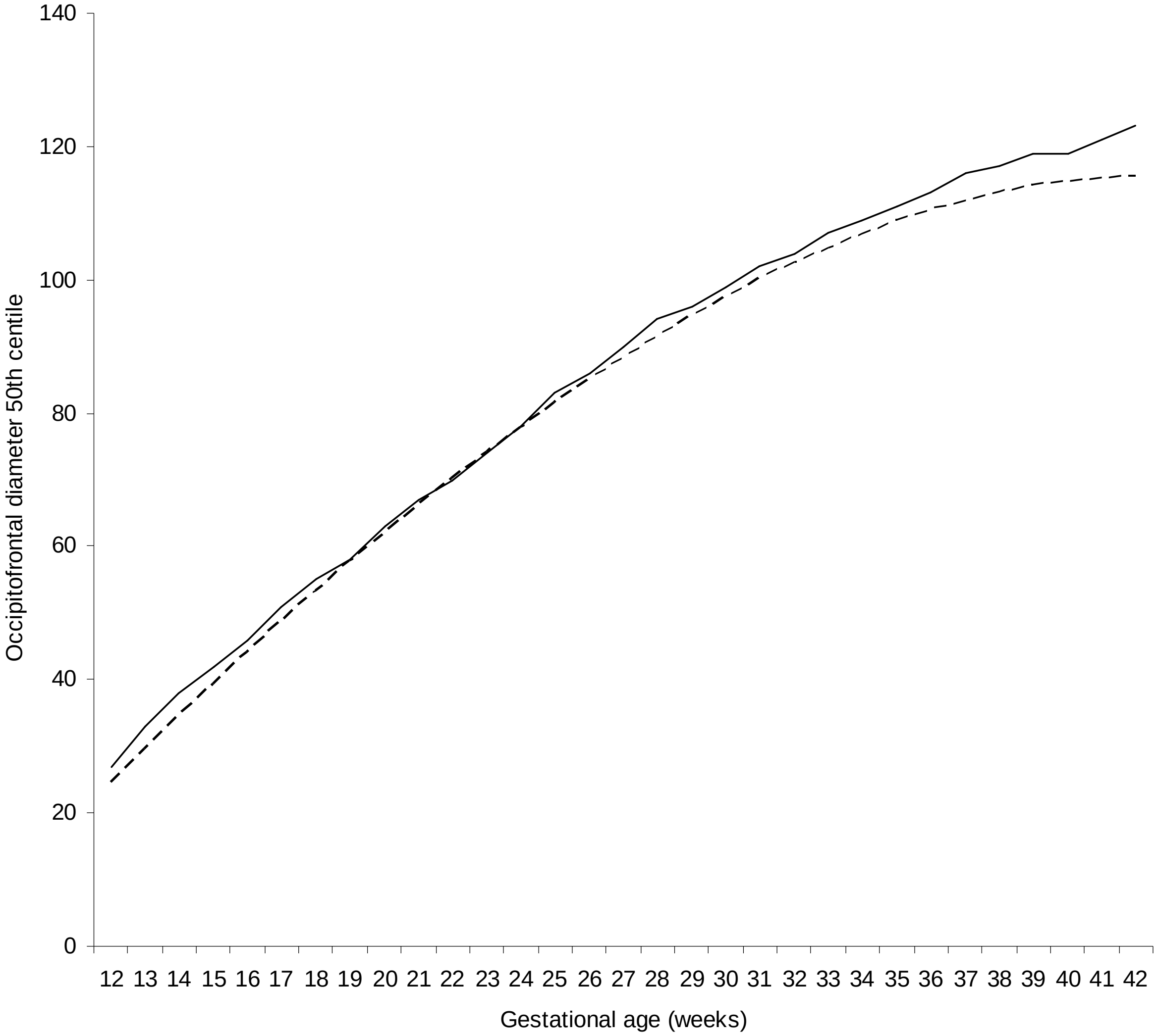
COMPARISON GRAPHS



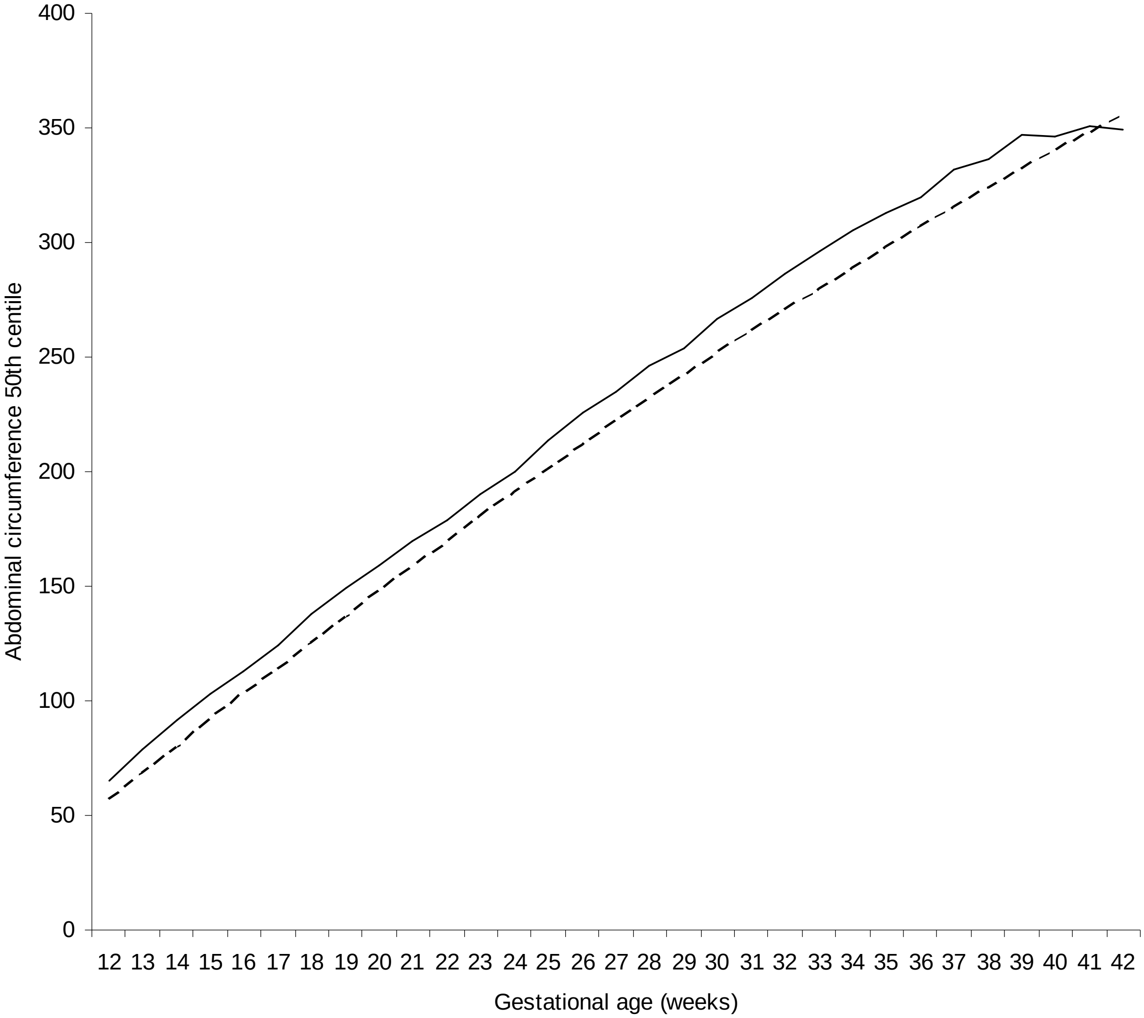
Appendix II Figure 1. Comparison of African (Nigerian fetuses in Jos) head circumference 50th centile values of study population (solid lines) with those of Western population -Kurmanavicius *et al*., 1999 (dashed line).



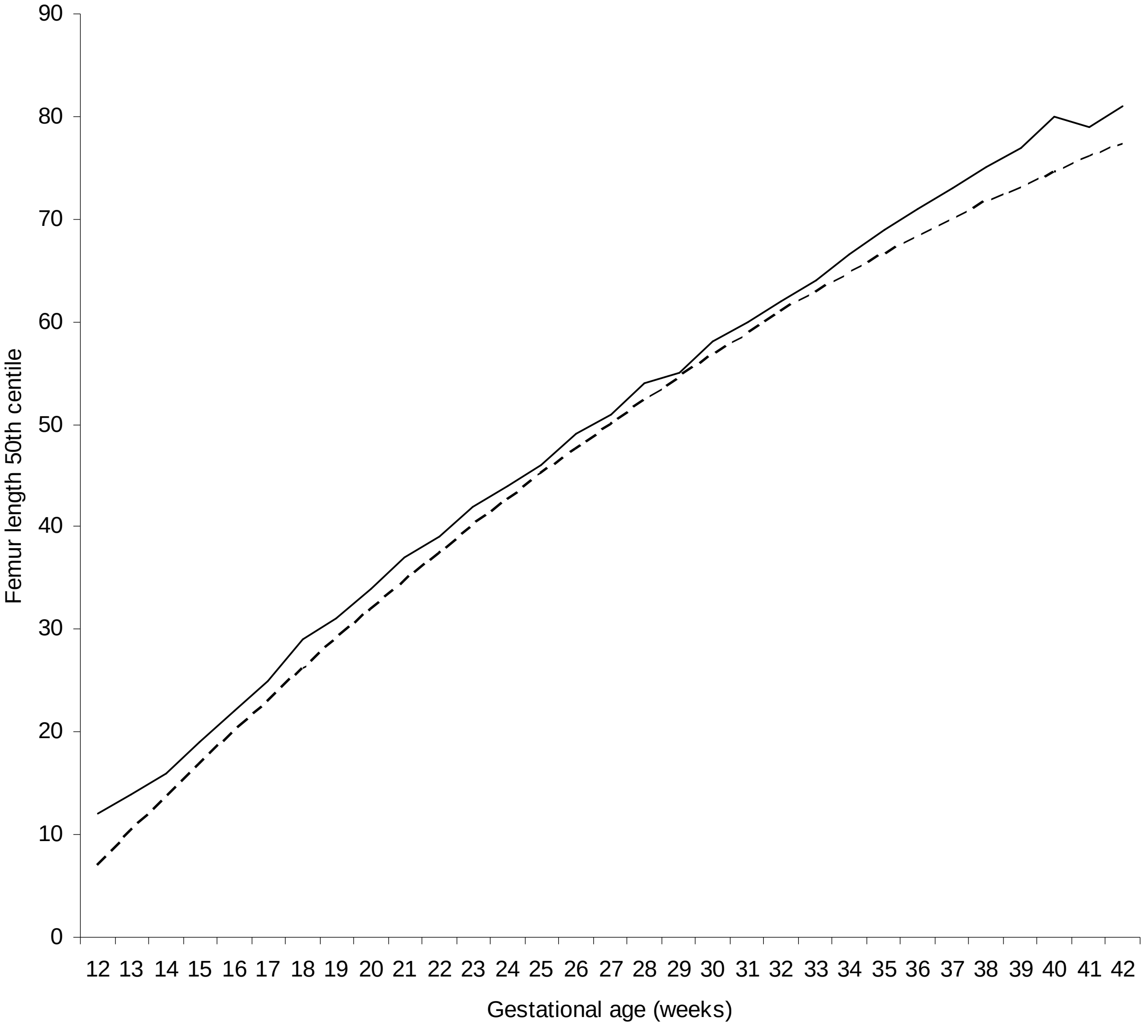
Appendix II Figure 2. Comparison of African (Nigerian fetuses in Jos) biparietal diameter 50th centile values of study population (solid lines) with those of Western population -Kurmanavicius *et al.*, 1999 (dashed line).



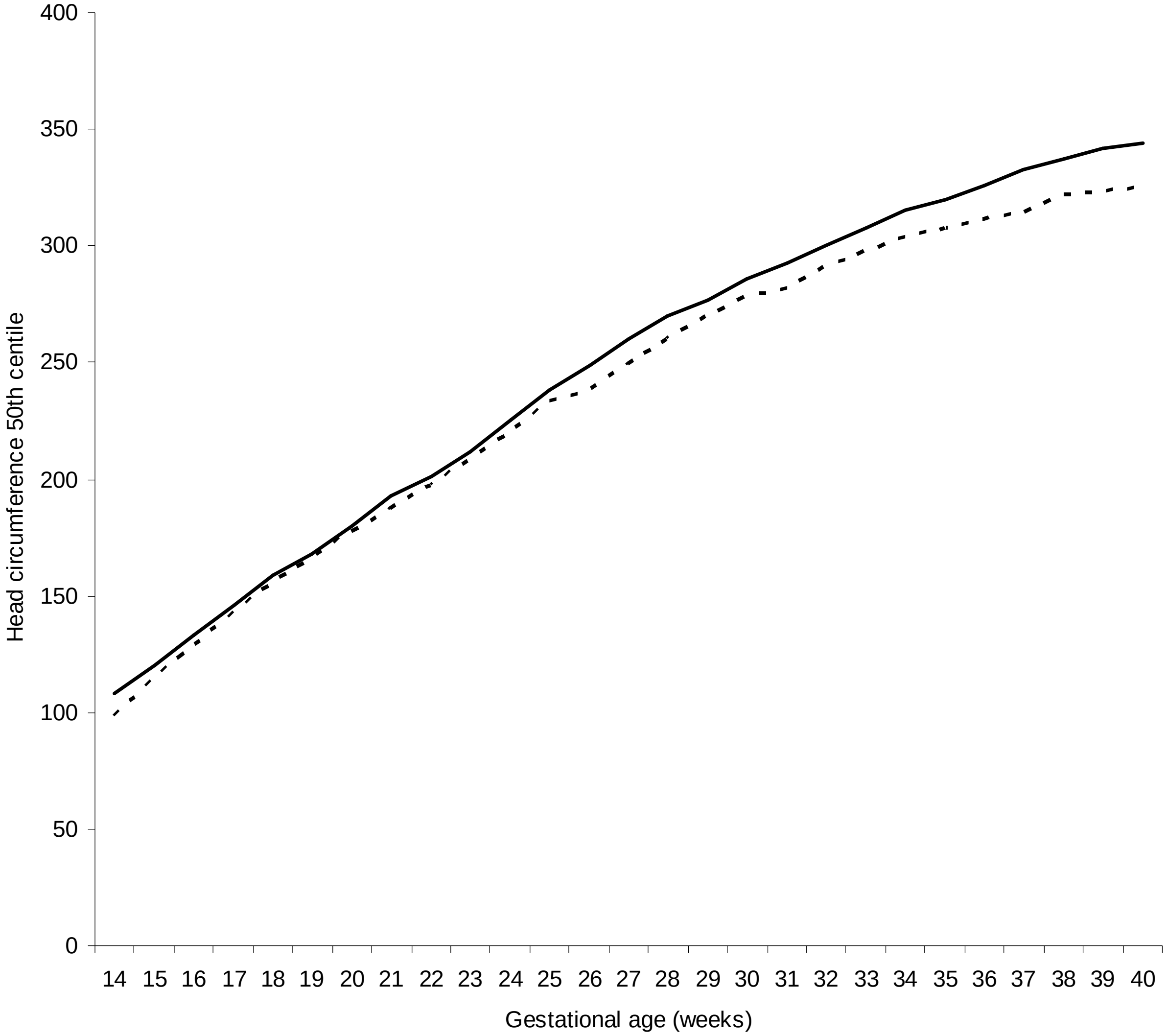
Appendix II Figure 3. Comparison of African (Nigerian fetuses in Jos) occipitofrontal diameter 50th centile values of study population (solid lines) with those of Western population -Kurmanavicius *et al.*, 1999 (dashed line).



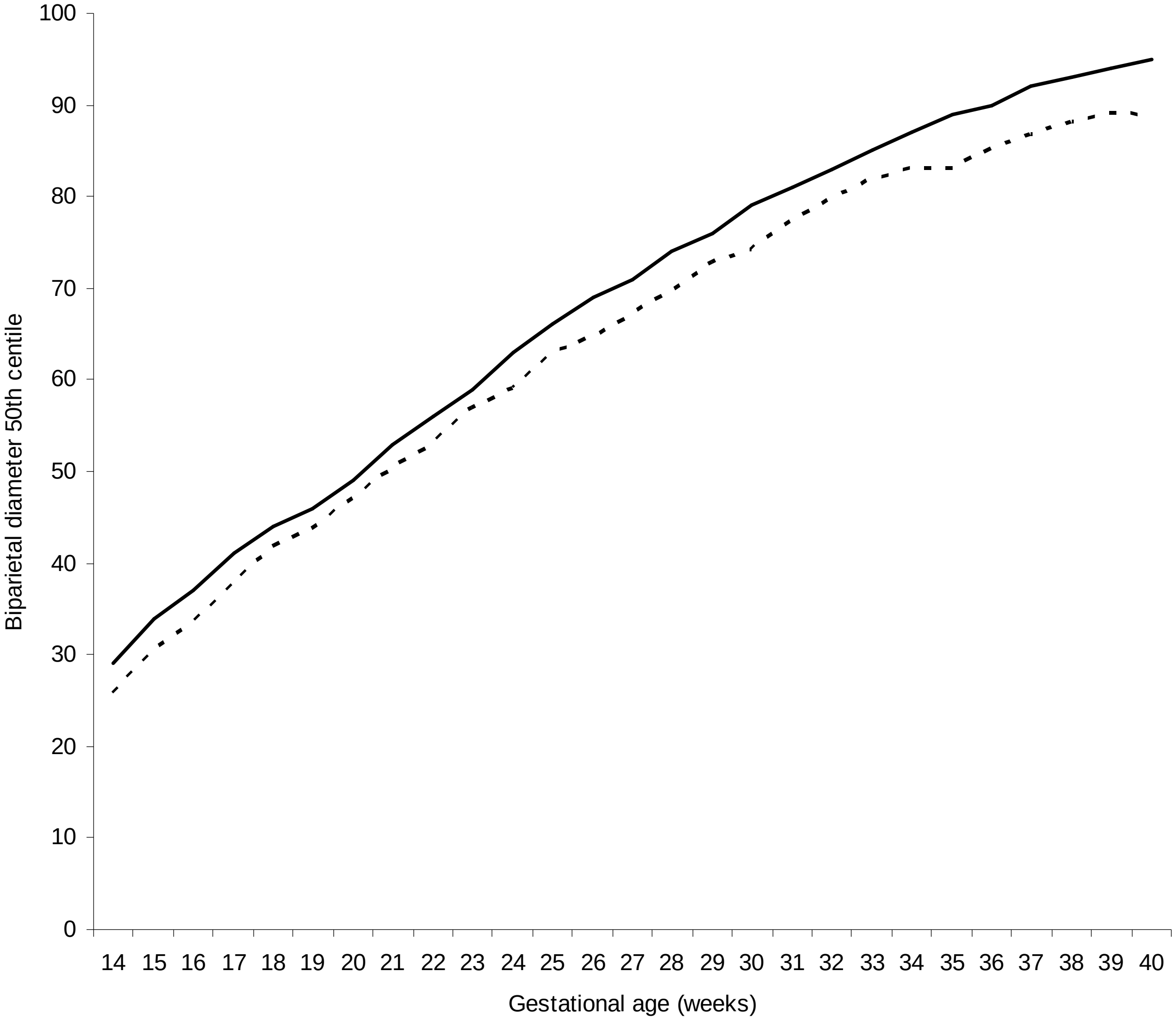
Appendix II Figure 4. Comparison of African (Nigerian fetuses in Jos) abdominal circumference 50^{th} centile values of study population (solid lines) with those of Western population -Kurmanavicius *et al*., 1999 (dashed line).



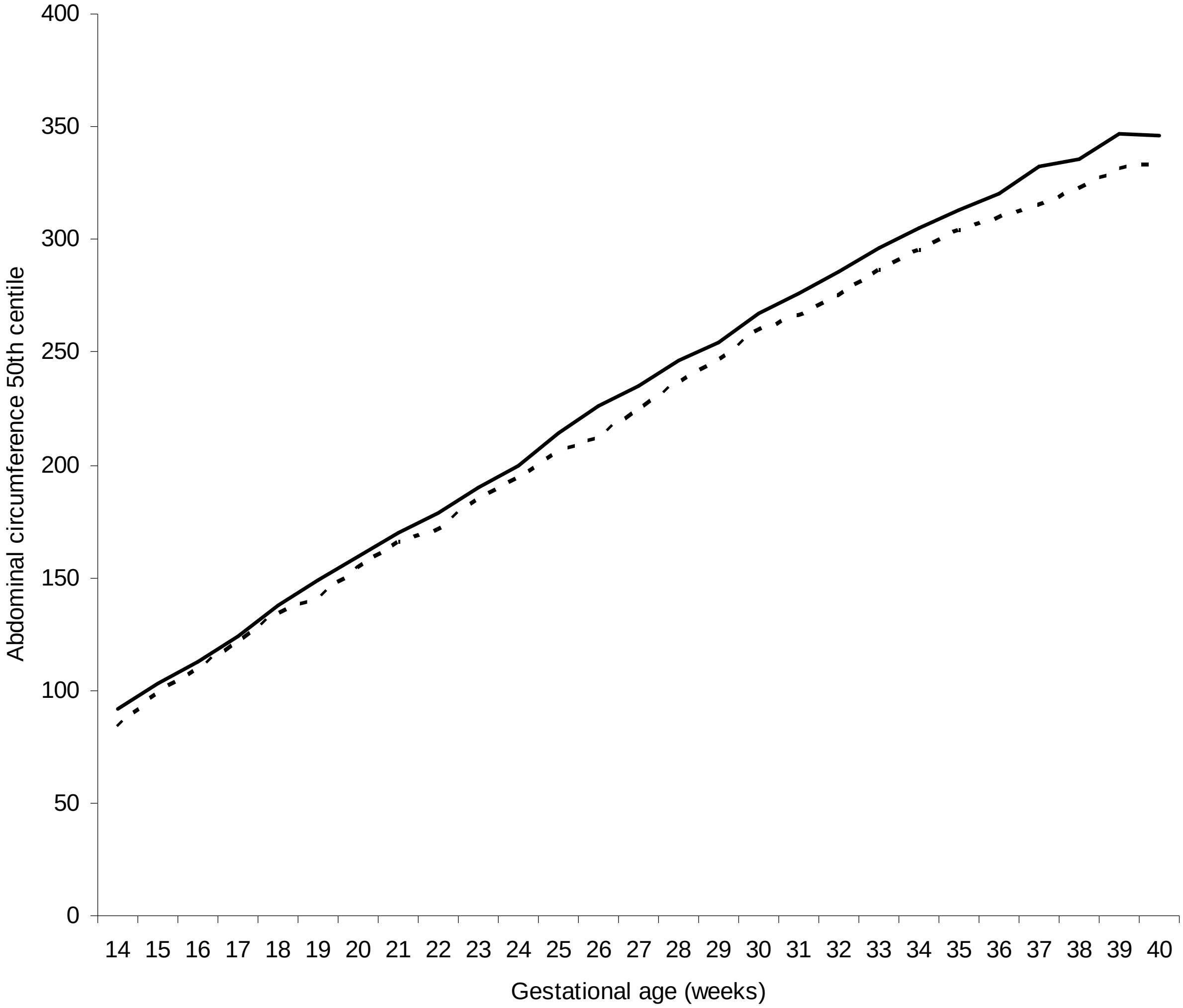
Appendix II Figure 5. Comparison of African (Nigerian fetuses in Jos) femur length 50th centile values of study population (solid lines) with those of Western population - Kurmanavicius *et al*., 1999 (dashed line).



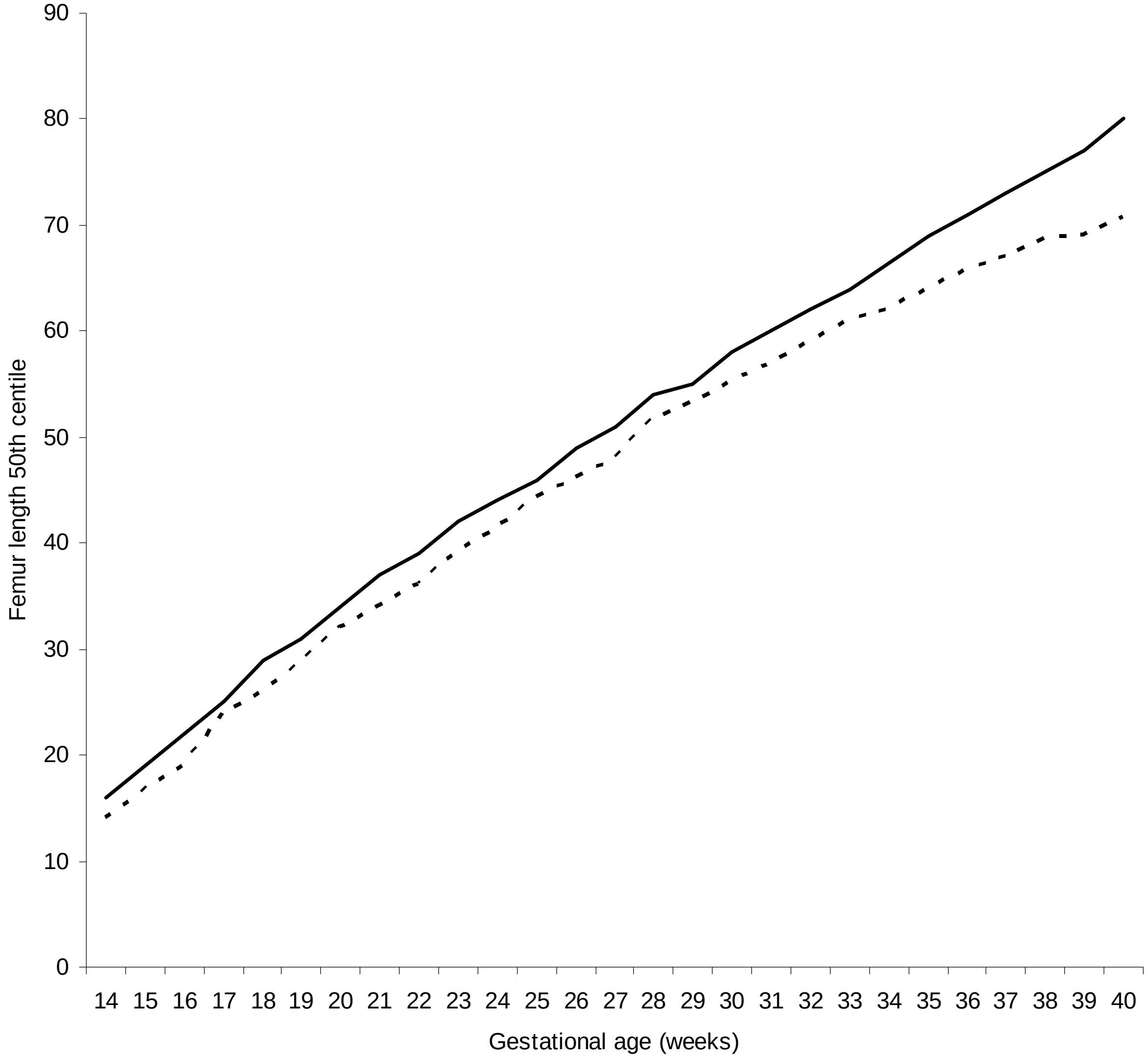
Appendix II Figure 6. Comparison of African (Nigerian fetuses in Jos) head circumference 50th centile values of study population (solid lines) with those of Asian population -Kankeow (dashed line).



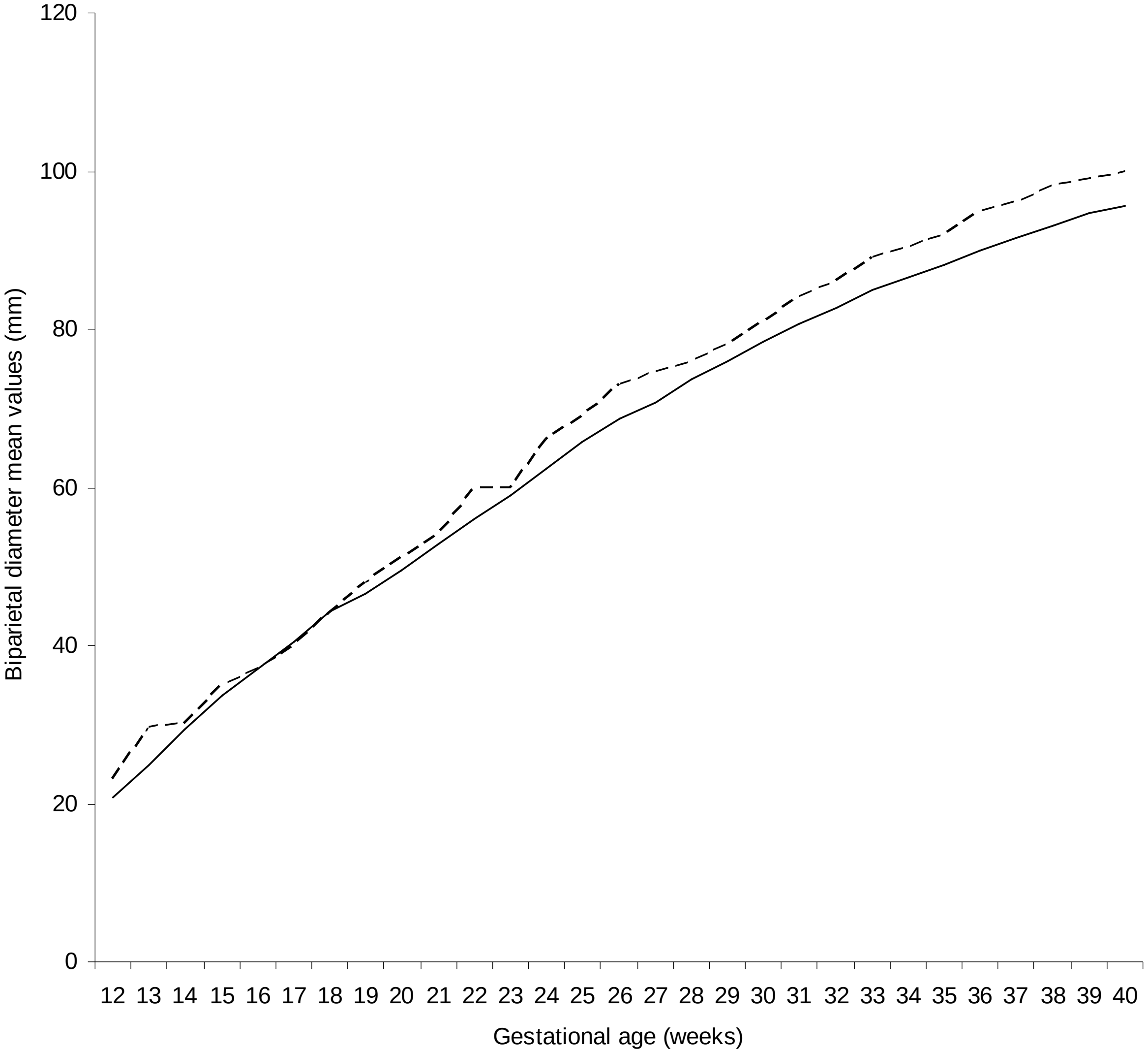
Appendix II Figure 7. Comparison of African (Nigerian fetuses in Jos) biparietal diameter 50th centile values of study population (solid lines) with those of Asian population -Kankeow (dashed line).



Appendix II Figure 8. Comparison of African (Nigerian fetuses in Jos) abdominal circumference 50th centile values of study population (solid lines) with those of Asian population -Kankeow (dashed line).



Appendix II Figure 9. Comparison of African (Nigerian fetuses in Jos) femur length 50th centile values of study population (solid lines) with those of Asian population -Kankeow (dashed line).



Appendix II Figure 10. Comparison of biparietal diameter mean values of present study (solid lines) with those of Okupe *et al*., 1984 (dashed line).

APPENDIX III

FETAL BIOMETRY PREDICTIVE FORMULAE

In the prediction of fetal biometric parameters from symphysio-fundal height (SFH), there were six predictive formulae. These formulae are as follows:

Appendix III Formula 1

$$HC = -2E\text{-}05SFH^6 + 0.0037SFH^5 - 0.2533SFH^4 + 9.0473SFH^3 - 177.54SFH^2 + 1823.4SFH - 7544.3$$

$$r^2 = 0.9954$$

A fetus's head circumference could be predicted using symphysis-fundal height. Symphysis-fundal height could explain the prediction of a fetus's head circumference by 99.54 percent ($r^2 = 0.9954$) in the 13,740 fetuses scanned during this study

Appendix III Formula 2

$$BPD = -5E\text{-}06SFH^6 + 0.0009SFH^5 - 0.0628SFH^4 + 2.2514SFH^3 - 44.398SFH^2 + 458.64SFH - 1907.6$$

$$r^2 = 0.9958$$

A fetus's biparietal diameter could be predicted using symphysis-fundal height. Symphysis-fundal height could explain the prediction of a fetus's biparietal diameter by 99.58 percent ($r^2 = 0.9958$) in the 13,740 fetuses scanned during this study

Appendix III Formula 3

$$OFD = -8E\text{-}06SFH^6 + 0.0013SFH^5 - 0.0917SFH^4 + 3.2678SFH^3 - 63.988SFH^2 + 655.77SFH - 2708.8$$

$$r^2 = 0.9954$$

A fetus's occipitofrontal diameter could be predicted using symphysis-fundal height. Symphysis-fundal height could explain the prediction of a fetus's occipitofrontal diameter by 99.54 percent ($r^2 = 0.9954$) in the 13,740 fetuses scanned during this study

Appendix III Formula 4

$AC = -0.054SFH^2 + 12.926SFH - 71.554$

$r^2 = 0.9942$

A fetus's abdominal circumference could be predicted using symphysis-fundal height. Symphysis-fundal height could explain the prediction of a fetus's abdominal circumference by 99.42 percent ($r^2 = 0.9942$) in the 13,740 fetuses scanned during this study

Appendix III Formula 5

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

$r^2 = 0.9941$

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

Appendix III Formula 6

$Wt = 0.0409SFH^3$

$r^2 = 0.9951$

A fetus's weight could be predicted using symphysis-fundal height. Symphysis-fundal height could explain the prediction of a fetus's weight by 99.51 percent ($r^2 = 0.9951$) in the 12,080 fetuses scanned during this study

In the prediction of fetal biometric parameters from gestational age (GA), there were six predictive formulae. After analysis by correlation and regression, the equation for all fetal parameters collected in this study were:

Appendix III Formula 7

$HC = -3.3238GA^2 + 85.755GA - 177.78$

$r^2 = 0.9991$

A fetus's head circumference could be predicted using fetal gestational age. Gestational age could explain the prediction of a fetus's head circumference by 99.9 percent ($r^2 = 0.9991$) in the 13,740 fetuses scanned during this study

Appendix III Formula 8

$\text{OFD} = -0.001\text{GA}^3 + 0.01337\text{GA}^2 + 4.671\text{GA} - 27.99$

$r^2 = 0.9996$

A fetus's occipitofrontal diameter could be predicted using fetal gestational age. Gestational age could explain the prediction of a fetus's occipitofrontal diameter by 99.96 percent ($r^2 = 0.9991$) in the 13,740 fetuses scanned during this study

Appendix III Formula 9

$\text{BPD} = -0.511\text{GA}^2 + 5.3221\text{GA} - 35.51$

$r^2 = 0.9996$

A fetus's biparietal diameter could be predicted using fetal gestational age. Gestational age could explain the prediction of a fetus's biparietal diameter by 99.96 percent ($r^2 = 0.9996$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 10

$\text{AC} = -0.0004\text{GA}^4 + 0.0349\text{GA}^3 - 1.2485\text{GA}^2 + 30.598\text{GA} - 172.03$

$r^2 = 0.9995$

A fetus's abdominal circumference could be predicted using fetal gestational age. Gestational age could explain the prediction of a fetus's abdominal circumference by 99.95 percent ($r^2 = 0.9995$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 11

$\text{FL} = -0.017\text{GA}^2 + 3.2794\text{GA} - 25.282$ ($R^2 = 0.999$)

$r^2 = 0.999$

A fetus's femur length could be predicted using fetal gestational age. Gestational age could explain the prediction of a fetus's femur length by 99.9 percent ($r^2 = 0.999$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 12

$$Wt = 0.038\ GA^3$$

$$r^2 = 0.9951$$

A fetus's weight could be predicted using fetal gestational age. Gestational age could explain the prediction of a fetus's weight by 99.51 percent ($r^2 = 0.9951$) in the 12,080 fetuses scanned during this study.

When fetal occipitofrontal diameter measurement is known, it can be used to predict the other parameters through the following formulae:

Appendix III Formula 13

$$HC = 2.882OFD + 0.1487$$

$$r^2 = 1$$

A fetus's head circumference could be predicted using occipitofrontal diameter. Occipitofrontal diameter could explain the prediction of a fetus's head circumference by 100 percent ($r^2 = 1$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 14

$$BPD = 0.8046OFD - 0.9072$$

$$r^2 = 0.9997$$

A fetus's biparietal diameter could be predicted using occipitofrontal diameter. Occipitofrontal diameter could explain the prediction of a fetus's biparietal diameter by 99.97 percent ($r^2 = 0.9997$) in the 13,740 fetuses scanned during this study

Appendix III Formula 15

$$FL = 0.0025OFD^2 + 0.3313OFD + 1.5192$$

$$r^2 = 0.9945$$

A fetus's femur length could be predicted using occipitofrontal diameter. Occipitofrontal diameter could explain the prediction of a fetus's femur length by 99.45 percent ($r^2 = 0.9945$) in the 13,740 fetuses scanned during this study

Appendix III Formula 16

$AC = 0.0092OFD^2 + 1.6208\ OFD + 19.582$

$r^2 = 0.9993$

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

Appendix III Formula 17

$Wt = 0.0071OFD^3 – 1.0218OFD^2 + 57.868OFD – 925.93$

$r^2 = 0.9989$

A fetus's weight could be predicted using occipitofrontal diameter. Occipitofrontal diameter could explain the prediction of a fetus's weight by 99.89 percent ($r^2 = 0.9989$) in the 12, 080 fetuses scanned during this study

When fetal biparietal diameter measurement is known, it can be used to predict the other parameters through the following formulae:

Appendix III Formula 18

$HC = 3.5811BPD + 3.1775$

$r^2 = 0.9997$

A fetus's head circumference could be predicted using biparietal diameter. Biparietal diameter could explain the prediction of a fetus's head circumference by 99.97 percent ($r^2 = 0.9997$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 19

$OFD = 1.2425BPD + 1.1552$

$r^2 = 0.9997$

A fetus's occipitofrontal diameter could be predicted using biparietal diameter. Biparietal diameter could explain the prediction of a fetus's occipitofrontal diameter by 99.97 percent ($r^2 = 0.9997$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 20

$FL = 5E\text{-}06BPD^4 – 0.0011BPD^3 + 0.0855BPD^2 – 2.0951BPD + 27.664$

$r^2 = 0.9986$

A fetus's femur length could be predicted using biparietal diameter. Biparietal diameter could explain the prediction of a fetus's femur length by 99.86 percent ($r^2 = 0.9986$) in the 13,740 fetuses scanned during this study

Appendix III Formula 21

$AC = 0.0144BPD^2 + 2.0241BPD + 21.816$

$r^2 = 0.9994$

A fetus's abdominal circumference could be predicted using biparietal diameter. Biparietal diameter could explain the prediction of a fetus's abdominal circumference by 99.94 percent ($r^2 = 0.9994$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 22

$Wt = 45.141e^{0.0461BPD}$

$r^2 = 0.9989$

A fetus's weight could be predicted using biparietal diameter. Biparietal diameter could explain the prediction of a fetus's weight by 99.89 percent ($r^2 = 0.9989$) in the 12, 080 fetuses scanned during this study

When fetal head circumference measurement is known, it can be used to predict the other parameters through the following formulae:

Appendix III Formula 23

$BPD = 0.2792HC – 0.8656$

$r^2 = 0.9997$

A fetus's biparietal diameter could be predicted using head circumference. Head circumference could explain the prediction of a fetus's biparietal diameter by 99.97 percent ($r^2 = 0.9997$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 24

$OFD = 0.347HC + 0.0528$

$r^2 = 1$

A fetus's occipitofrontal diameter could be predicted using head circumference. Head circumference could explain the prediction of a fetus's occipitofrontal diameter by 100 percent ($r^2 = 1$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 25

$FL = 50.046HC^{1.2897}$

$r^2 = 0.9962$

A fetus's femur length could be predicted using head circumference. Head circumference could explain the prediction of a fetus's femur length by 99.62 percent ($r^2 = 0.9962$) in the 13,740 fetuses scanned during this study

Appendix III Formula 26

$AC = 1.0644HC – 29.032$

$r^2 = 0.994$

A fetus's abdominal circumference could be predicted using head circumference. Head circumference could explain the prediction of a fetus's abdominal circumference by 99.4 percent ($r^2 = 0.994$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 27

$Wt = 57.144e^{0.012HC}$

$r^2 = 0.9699$

A fetus's weight could be predicted using head circumference. Head circumference could explain the prediction of a fetus's weight by 96.99 percent ($r^2 = 0.9699$) in the 12, 080 fetuses scanned during this study

When fetal abdominal circumference measurement is known, it can be used to predict the other parameters through the following formulae:

Appendix III Formula 28

$BPD = 0.0003AC^2 + 0.3777AC – 3.6302$

$r^2 = 0.9995$

A fetus’s biparietal diameter could be predicted using abdominal circumference. Abdominal circumference could explain the prediction of a fetus’s biparietal diameter by 99.95 percent ($r^2 = 0.9995$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 29

$OFD = – 0.0003AC^2 + 0.4671AC – 3.1666$

$r^2 = 0.9996$

A fetus’s occipitofrontal diameter could be predicted using abdominal circumference. Abdominal circumference could explain the prediction of a fetus’s occipitofrontal diameter by 99.96percent ($r^2 = 99.96$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 30

$FL= 0.2381AC – 5.0199$

$r^2 = 0.9952$

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

Appendix III Formula 31

$HC = 1.0644AC – 29.032$

$r^2 = 0.994$

A fetus’s head circumference could be predicted using abdominal circumference. Abdominal circumference could explain the prediction of a fetus’s head circumference by 99.4 percent ($r^2 = 0.994$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 32

$$Wt = 0.065AC^2 – 16.072AC + 1355.5$$

$$r^2 = 0.9982$$

A fetus's weight could be predicted using abdominal circumference. Abdominal circumference could explain the prediction of a fetus's weight by 99.82 percent ($r^2 = 0.9982$) in the 12, 080 fetuses scanned during this study

When fetal femur length measurement is known, it can be used to predict the other parameters through the following formulae:

Appendix III Formula 33

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

$$r^2 = 0.9993$$

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

Appendix III Formula 34

$$OFD = – 0.007FL^2 + 2.0251FL + 4.2448$$

$$r^2 = 0.9973$$

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

Appendix III Formula 35

$$AC = 4.179FL + 22.077$$

$$r^2 = 0.9952$$

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

Appendix III Formula 36

$HC = -0.0004FL^{3} + 0.0429FL^{2} + 3.1567FL + 43.238$

$r^{2} = 0.9989$

A fetus’s head circumference could be predicted using femur length. Femur length could explain the prediction of a fetus’s head circumference by 99.89 percent ($r^{2} = 0.9989$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 37

$Wt = 0.0575FL^{2.534}$

$r^{2} = 0.9944$

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

Gestational age can also be used to predict ratios of fetal biometric parameters as follows:

Appendix III Formula 38

$HC/AC = 0.0072GA + 1.2037$

$r^{2} = 0.9807$

A fetus’s head circumference to abdominal circumference ratio could be predicted using gestational age. Gestational age could explain the prediction of a fetus’s head circumference to abdominal circumference ratio by 98.07 percent ($r^{2} = 0.9807$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 39

$FL/AC = 7E\text{-}09GA^{6} - 7E\text{-}07GA^{5} + 2E\text{-}5GA^{4} - 0.005GA^{3} - 0.0039GA^{2} - 0.0098GA + 0.1892$

$r^{2} = 0.9545$

A fetus’s femur length to abdominal circumference ratio could be predicted using gestational age. Gestational age could explain the prediction of a fetus’s femur length to abdominal circumference ratio by 95.45 percent ($r^{2} = 9545$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 40

$$FL/HC = 7E\text{-}06GA^3 - 0.0003GA^2 + 0.0075GA + 0.1407$$

$$r^2 = 0.976$$

A fetus's femur length to head circumference ratio before 33 weeks could be predicted using gestational age. Gestational age could explain the prediction of a fetus's femur length to head circumference ratio before 33 weeks by 97.6 percent ($r^2 = 0.976$) in the fetuses scanned during this study

Appendix III Formula 41

$$BPD/FL = -6E\text{-}07GA^6 + 5E\text{-}05GA^5 - 0.0014GA^4 + 0.0201GA^3 - 0.1461GA^2 + 0.422GA + 1.4531$$

$$r^2 = 0.9945$$

A fetus's biparietal diameter to femur length ratio could be predicted using gestational age. Gestational age could explain the prediction of a fetus's biparietal diameter to femur length ratio by 99.45 percent ($r^2 = 0.9945$) in the 13,740 fetuses scanned during this study.

Appendix III Formula 42

$$BPD/OFD = 1.3GA + 59.88$$

$$r^2 = 0.9844$$

A fetus's biparietal diameter to occipitofrontal diameter ratio before 17 weeks could be predicted using gestational age. Gestational age could explain the prediction of a fetus's biparietal diameter to occipitofrontal diameter ratio before 17 weeks by 98.44 percent ($r^2 = 0.9844$) in the fetuses scanned during this study

APPENDIX IV