A CORRELATIVE STUDY OF FOETAL SONOGRAPHIC PARAMETERS AND PLACENTAL THICKNESS WITH MATERNAL ANTHROPOMETRY AMONG PREGNANT WOMEN IN ZARIA, NIGERIA

BY

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DECLARATION

I,Abdullahi, Shehu hereby declare that the work in this Dissertation titled "***A Correlative Study of Foetal Sonographic Parameters and Placental Thickness with Maternal Anthropometry Among Pregnant Women in Zaria, Nigeria"*** was performed by me in the Department of Human Anatomy, Faculty of Basic Medical Sciences, College of Health Sciences, ABU, Zaria, under the supervision of Prof. S. S. Adebisi and Dr.B. Danborno. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree at any institution.

Abdullahi, Shehu   Date

CERTIFICATION

The dissertation entitled *"**A Correlative Study of Foetal Sonographic Parameters and Placental Thickness with Maternal Anthropometry Among Pregnant Women in Zaria, Nigeria**"* by Shehu Abdullahi meets the regulations governing the award of the degree of Master of Science in Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literacy presentation.

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DEDICATION

To my Creator for the wisdom, inspiration and patience in completing this work, to my family for their patience and understanding, and to the diligent sonographers who strive daily unrelentingly in their pursuit of excellence.

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ABSTRACT

Recent studies have suggested an association of placenta thickness with gestational age in the second and third trimester of pregnancy. But the relationship of placenta thickness according to sex, its relationship to other foetal characteristic within the second and third trimester and somematernal anthropometric variables has not been evaluated. This study consisted of 921 normal pregnancies divided into second (n = 468) and third (n = 453) trimester. Information on maternal age, weight, height and menarcheal age, digit length of hands, hand breadth, hand length, leg breadth and leg length were obtained including foetal parameters such as femoral length (FL), biparietal diameter (BPD), head circumference (HC), occipitofrontal diameter (OFD), abdominal circumference (AC), gestational age (GA), foetal weight (FW) and placenta thickness (PT). Foetal parameters and gestational age were measured in compliance with the Hadlock methodand placenta thickness with the method of Hoddick.Maternal hand and foot measurements were done according to the method of Manning. Independent sample t-test, one-way Analysis of variance (ANOVA), Pearson's correlation, partial correlation and multiple linear regression were used. $P < 0.05$ was set at the level of significance. The mean of maternal weight and foetal parameters between second and third trimester gestation showed significant difference ($p < 0.05$). Subjects were divided into groups based on their parity, level of education and ethnicity. Foetal parameters were classified according to sex. Foetal parameters and placenta thickness showed no significant difference according to parity. Level of education and ethnicity showed significant difference on AC, FW and PT. But there was also no significant difference in foetal and placenta thickness according to sex of the foetus even though male foetuses had higher values except for placenta PT where that of female foetuses was a few millimetres higher. There was significant positive relationship between placenta thickness and foetal growth parameters including foetal weight ($p< 0.001$). 2D:4D ratio of the right hand showed a significant relationship with some foetal growth parameters in the third trimester. Also, foot breadth showed significant relationship with some foetal growth parameters in both second and third trimester. Placenta thickness could predict gestational age ($R^2 = 0.045$) and ($R^2 = 0.156$) in the second and third trimester gestation respectively.Also, placenta thickness was a good predictor of foetal weight ($R^2 = 0.057$) and ($R^2 = 0.158$) for second and third trimester gestation respectively. In conclusion, the relationship between placenta thickness, gestational age and foetal weight has been established, sex differences exist in foetal growth parameters, there is no significant difference when foetal growth parameters were grouped according to parity, but level of education and ethnicity had significance on foetal growth parameters, some maternal parameters showed significant relationship with foetal growth parameters, while placenta thickness will be able to predict gestational age and foetal weight among Nigerian pregnant women.

1.0 INTRODUCTION

1.1 Background of the Study

Placental dysfunction has been implicated in the development of a variety of commonly encountered obstetric complications (Schwartz *et al.*, 2011; Holroyd*et al.*, 2012; Mathai*et al*., 2013; Miwa *et al*., 2014). In fact, most reproductive biologists agree that many adverse pregnancy outcomes, such as preeclampsia, foetal growth restriction, and stillbirth, are often the result of abnormal trophoblastic invasion and placental implantation, which are largely completed by the end of the first trimester (Holroyd*et al*., 2012; Miwa *et al*., 2014; Veerbeek*et al*., 2014). In fact, there is increasing evidence linking placental development to long-term health consequences in the offspring, even into adulthood (Barker *et al*., 2011; Eriksson *et al*., 2011; Misra*et al*., 2012; Ouyang*et al*., 2013; Balla*et al*., 2014).

The in utero environment and its impact on neonatal health are of increasing interest in relation to adult health outcomes(Barker *et al*., 2013; Suri*et al*., 2013).There is a growing body of evidence that birth weight and placental insufficiency are important risk factors for later development of the so-called metabolic syndrome such as hypertension, diabetes, and coronary heart disease(Schwartz *et al*., 2011; Barker *et al*., 2013).The placenta is the principal influence on foetal birth weight, and it is thought that abnormalities of placental growth may precede abnormalities in fetal growth (Afrakhteh*et al*., 2013; Miwa *et al*., 2014).Studies have shown that diminished placental size precedes foetal growth retardation as intrauterine growth restriction (IUGR) isassociated with impoverished villous development and fetoplacental angiogenesis (Jones*et al*., 2013; Morgan*et al*., 2013).

Placenta is a foetal organ with important metabolic, endocrine and immunological functions and provides the physiological link between a pregnant woman and the foetus. The placenta is the primary site of nutrient and gas exchange between the mother and embryo/foetus.The placenta develops from chorionic villi at the implantation site at about the fifth week of gestation and by the tenth week the granular echotexture of placenta is apparent on ultrasonography (Sadler, 2012; Gasser *et al*., 2014; Moore *et al*., 2016).Historically, a placenta of greater than 4 cm in thickness has been regarded as abnormal (Hoddick*et al*., 1985) and associated with various poor outcomes (Dombrowski *et al*., 1992; Miwa *et al*., 2014).

Because the placenta may be the first organ to manifest changes of disease in pregnancy, placental features may have a role in screening for pregnancy complications (Lee *et al*., 2012; Warrander*et al*., 2012; Miwa *et al*., 2014).Thick placenta is associated with maternal diabetes mellitus, foetal hydrops and intrauterine foetal infections and adverse clinical outcome (Elchalal*et al*., 2000; Raio*et al*., 2004; Miwa *et al*., 2014). Perinatal morbidity and neonatal conditions were worse in cases with thick placenta rather than without thick placenta (Raio*et al*., 2004; Karthikeyan *et al*., 2012; Miwa *et al*., 2014).

Sonography has provided a safe and non-invasive means to evaluate the placenta. Its size and growth pattern have a bearing on foetal outcome (Holroyd*et al*., 2012; Afrakhteh*et al*., 2013; Kaushal *et al*., 2015). Placental thickness (PT) also helps in differentiating normal from abnormal pregnancy (Suri*et al*., 2013; Ptacek*et al*., 2014). Small and thin placenta is associated with intrauterine growth retardation of the foetus(Longtineand Neslson, 2011; Veerbeek*et al*., 2014).

The gestational age (GA) is of utmost importance in providing the best possible ante partum care andsuccessful deliveries of babies (Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; Yee and Grobman, 2016). Virtually, all theimportant clinical decisions, which include caesarean section, elective labour induction, etc, depend on the knowledge of the gestational age (Sanders and Winter, 2012; Yee and Grobman, 2016).Ultrasonography (USG) is commonly used to estimate the gestational age by measuring foetal dimensions like the biparietal diameter (BPD), abdominal circumference (AC), head circumference (HC) and the femur length (FL) (Hadlock *et al*., 1984; Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; Khambalia*et al*., 2013).

Placental thickness is the easiest placental dimension to measure, yet little is known about the “normal” PT as measured by sonography. Also, placental thickness appears to be a promising parameter for estimation of gestational age of the foetus because of increase in placental thickness with gestational age (Mathai *et al*., 2013; Nagwani*et al*., 2014; Adhikari*et al*., 2015). Studies by some authors have reported the use of placental thickness as an indicator of gestational age (Jain*et al*., 2001; Tiwari and Chandnani, 2013; Ahmed *et al*., 2014;Kapoor and Dudhat, 2016).Currently, the routine prenatal sonographic examination includes only a limited and qualitative assessment ofthe in utero placenta, with no quantitative method to evaluateplacental growth and development (AIUM, 2013; ACOG, 2014).

In fact, there is evidence that placental thickness may vary with the implantation site and that anterior placentas tend to be thinner than posterior placentas (Lee *et al*., 2012; Ali *et al*., 2013), casting further doubt on the relevance of a categorical 4-cm cutoff. An Israeli prospective cross-sectional study (Elchalal*et al*., 2000) found a linear increase in placental thickness with gestational age throughout pregnancy. That study also suggested a correlation between an abnormally thick placenta (defined as >90th percentile) and a poor outcome in terms of perinatal mortality and growth restriction (Elchalal*et al*., 2000).Studies over time have shown that the maternal ethnic group impacts not only the foetal weight, but also influences placental weight, volume and surface of implantation(Freeman *et al*., 1970; Jackson *et al*., 1987; Zhan, 1989; Sivarao*et al*., 2002; Gomes *et al*., 2005; Ouyang*et al*., 2013; Balla*et al*., 2014).AlsoOhagwu and his colleagues demonstrated a placental thickness of about 4.5 cm for a normal Nigerian pregnant woman(Ohagwu*et al*., 2009).

Thick placentas have been associated with various maternal and foetal conditions, including toxoplasmosis, rubella, cytomegalovirus, herpes simplex virus, and other infections(TORCH infections), diabetes, and hydrops (Hoddick*et al*., 1985; Miwa *et al*., 2014). Small placentas have also been associated with perinatal complications. In a prospective study involving 712 women, Thame*et al* showed that a low birth weight was often preceded by small placental volumes in the second trimester (Thame*et al*., 2001). Similarly, Hafner's group (Hafner *et al*., 2003) determined that small for gestational age placentas were already significantly smaller than the placentas of non–small for gestational age foetuses at 12 weeks, indicating that placental growth is already reduced in these foetuses in the first trimester.

Despite these studies, the clinical importance of abnormally large or small placentas remains unclear (Hoddick*et al*., 1985; Hafner *et al*., 2003; Lee *et al*., 2012). PT is the easiest placental measurement to obtain and could therefore play a potential role in screening for complications during routine ante natal sonography, (Habib, 2002; Hafner *et al*., 2003; Lee *et al*., 2012; Miwa *et al*., 2014) while also being able to estimate fetal weight and gestational age (Afrakhteh*et al*., 2013; Suri*et al*., 2013; Tiwari and Chandnani, 2013; Baghel*et al*., 2015).

1.2 Statement of theResearch Problem

Routine sonographic prenatal evaluation lays most emphasis on the quality and ignores the impact of the quantitative aspect of placental morphology. Sonographic research data and awarenessare scarce in Nigeria in particular and the African continent in general and even where available have not been properly harnessed for its medical and research purposes. The base value of placenta thickness is 4 cm reported more than 25 years ago in a study conducted among Caucasians. A study conducted in Nigeria was able to show that a normal PT could be up to 4.5 cm. Also, nowhere in the literature to best of our knowledge has the relationship between maternal anthropometry and foetal sonographic growth parameters been investigated. This current study will increase the sample size, investigate the sexual dimorphism of PT for a more generalization of our findings, investigate the effect of ethnicity on PTand foetalsonographic characteristics, the possibility of using PT to predict foetal weight and gestational age, while the relationship between maternal anthropometry and foetalsonographic characteristics will also be investigated.

1.3 Justification of the Study

PT is the easiest placental dimension to measure yet little is known about the normal thickness among Nigerian pregnant women. The possibility of using the PT as a means of dating foetusesand the ethnic variation in placental thickness measured sonographically has never been explored anywhere in the literature to the best of our knowledge. Even though a normal placenta thickness of 4 cm has been established over 25 years ago, the effect of an abnormally thick placenta on foetal parameters remains clinically unclear. It will also be the first study to investigate the relationship between maternal anthropometry and foetal sonographic growth characteristics.

The results of this study will enlighten clinicians, scientists and healthcare providers on using PT measured sonographically as a means of assessing foetal health and predicting gestational age. This study will also provide a reference value for PT among Nigerian pregnant women. Finally, this study will add to the scanty literature available on sonographic research in Nigeria and Africa in general.

1.4Aimand Objectivesof the Study

1.4.1 Aim of the study

The aim of the present study was to determine placental thickness according to sex and its relationship to other foetal characteristics in second and third trimesters using ultrasonography.

1.4.2 Objectives of the study

This study was designed with the following objectives:

i. investigate the sex differences in biparietal diameter (BPD), head circumference (HC), occipitofrontal diameter (OFD), femoral length (FL), abdominal circumference (AC) and placental thickness (PT) in male and female foetuses.

ii. determine PT across trimesters in Nigerian pregnant women.

iii. investigate the relationship between PT, foetal weight and gestational age.

iv. assess the possibility of using the PT as a means of dating foetuses and correlating PT with gestational age.

v. use PT measurement to correlate with other standard dating parameters like FL, BPD, HC and AC.

vi. use PT to predict FL, BPD, HC, AC, foetal weight and FHR.

vii. investigate the effect of ethnicity on foetal characteristics obtained by ultrasonography.

viii. investigate the relationship between maternal anthropometry and foetal sonographic growth parameters.

1.5StudyHypotheses

The study was conducted with the following hypotheses in mind:

i. placenta thickness will correlate with foetal characteristics such as FL, BPD, HC and AC and predict gestational age (GA) and fetal weight (FW).

ii. maternal characteristics such as age, weight, and heightwill have no relationship with placenta thickness and PT will be less than 4 cm in the study population.

2.0 LITERATURE REVIEW

2.1 Ultrasound

2.1.1 Basic physics

Ultrasound is the term used to describe sound of frequencies above 20 000 Hertz (Hz), beyond the range of human hearing. Frequencies of 1–30 megahertz (MHz) are typical for diagnostic ultrasound (Lutz and Buscarini, 2011).Understanding the physical principles of ultrasound is essential for a basic knowledge of instrument control and also for understanding safety and bioeffects of this technology (Buscarini*et al*., 2013).

Diagnostic ultrasound imaging depends on the computerized analysis of reflected ultrasound waves, which non-invasively build up fine images of internal body structures (Lutz and Buscarini, 2011; Sanders and Winter, 2012; Buscarini*et al*., 2013). The resolution attainable is higher with shorter wavelengths, with the wavelength being inversely proportional to the frequency(Sanders and Winter, 2012; Buscarini*et al*., 2013). However, the use of high frequencies is limited by their greater attenuation (loss of signal strength) in tissue and thus shorter depth of penetration. For this reason, different ranges of frequency are used for examination of different parts of the body (Chudleigh and Thilaganathan, 2004; Lutz and Buscarini, 2011; Sanders and Winter, 2012; Buscarini*et al*., 2013).

2.1.2 Generation of ultrasound

The ultrasound waves are generated by piezoelectric transducer which is capable of changing electrical signals into mechanical (ultrasound) waves. The same transducer can also receive the reflected ultrasound and change it back into electrical signals.

Transducers are both transmitters and receivers of ultrasound (Palmer, 2003; Chudleigh and Thilaganathan, 2004; Lutz and Buscarini, 2011; Sanders and Winter, 2012).

2.1.3 Ultrasoundtechniques

The echo principle forms the basis of all common ultrasound techniques (Lutz and Buscarini, 2011). The distance between the transducer and the reflector or scatterer in the tissue is measured by the time between the emission of a pulse and reception of its echo. Additionally, the intensity of the echo can be measured (Lutz and Buscarini, 2011; Sanders and Winter, 2012). The various techniquesdescribes the different ways in which the returning echoes are displayed (Palmer, 2003; Chudleigh and Thilaganathan, 2004; Lutz and Buscarini, 2011; Sanders and Winter, 2012). The various ultrasound techniques used are described below:

2.1.3.1 A-mode

A-mode (A-scan, amplitude modulation) is a one-dimensional examination technique in which a transducer with a single crystal is used. The echoes are displayed on the screen along a time (distance) axis as peaks proportional to the intensity (amplitude) of each signal. The method is rarely used today, as it conveys limited information, e.g. measurement of distances (Palmer, 2003; Lutz and Buscarini, 2011; Sanders and Winter, 2012).

2.1.3.2 B-mode

B-mode (brightness modulation) is a similar technique, but the echoes are displayed as points of different grey-scale brightness corresponding to the intensity (amplitude) of each signal (Palmer, 2003; Lutz and Buscarini, 2011; Sanders and Winter, 2012).

2.1.3.3 M-mode or TM-mode

M-mode or TM-mode (time motion) is used to analyze moving structures, such as heart valves. The echoes generated by a stationary transducer (one-dimensional B-mode) arerecorded continuously over time (Palmer, 2003; Lutz and Buscarini, 2011; Sanders and Winter, 2012).

2.1.3.4 B-scan, two-dimensional

The arrangement of many (e.g. 256) one-dimensional lines in one plane makes it possible to build up a two-dimensional (2D) ultrasound image (2D B-scan). The single lines are generated one after the other by moving (rotating or swinging) transducers or by electronic multielement transducers. Rotating transducers with two to four crystals mounted on a wheel and swinging transducers ('wobblers') produce a sector image with diverging lines (Palmer, 2003; Lutz and Buscarini, 2011; Sanders and Winter, 2012).

2.1.4 Ultrasound in obstetrics and gynaecology

The history of sonography in obstetrics and gynaecology dates from the classic 1958 Lancet paper of Ian Donaldand his team (Donald *et al*., 1958)from Glasgow and fifty years on it is impossible to conceive of practicingobstetrics and gynaecologywithout one of the many forms of ultrasound available today (Campbell, 2013).Technological developments such as solid state circuitry, real time imaging, colour and power Doppler, transvaginal sonography and 3/4D imaging have been seized by clinical researchers to enhance the investigation and management of patients in areas as diverse as assessment of foetal growth and wellbeing, screening for foetal anomalies, prediction of pre-eclampsia and preterm birth, detectionof ectopic gestation, evaluation of pelvic masses, screening for ovarian cancer and fertility management. Ultrasound guided procedures are now essential components of fetal therapy and in vitro fertilisation (IVF) treatment (Campbell and Wilkin, 1975; Campbell *etal*., 1983; Hadlock *et al*., 1984;Ewigman*et al*., 1993; Jurkovic*et al*., 1995; Mari *et al*., 2000; Raine-Fenning*et al*., 2009; Nicolaides, 2011; Akolekar*et al*., 2013; Campbell, 2013).

The importance of the introduction of ultrasound into the practice of Obstetrics and Gynaecology has risen exponentially to a point where it is rare even for a low risk, uncomplicated, patient to make it through pregnancy without having at least two ultrasound examinations and a high risk patient to have less than four scans (Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; AIUM, 2013; Buscarini*et al*., 2013; Yee and Grobman, 2016). Most important is the potential role ultrasound plays in obstetrical decision-making and in gynaecology (GYN) one rarely hangs one's hat on a diagnosis made by a pelvic exam alone (Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; AIUM, 2013; Reddy *et al*., 2014).

2.1.5 Application of ultrasound in obstetrics

There are various application of ultrasound in obstetrics which include; dating of pregnancy including foetal and placental position, assessment of foetal growth, identification and management of foetalmalformation, intrauterine blood transfusion, emptying of excessive amniotic fluid, measurement of cervical length to assess risk of preterm labour, identification of multiple pregnancies, invasive procedures such as sampling of amniotic fluid, umbilical blood and placenta.

2.1.5.1Dating of pregnancy

This is the sonographic procedure carried out to estimate the age of the foetus (gestational age) and the due date for delivery (expected date of delivery). Pregnancy duration(gestation) is divided into three periods called trimesters. The first trimester is the gestational period between conception and 13 weeks + 6 days of gestational age, second trimester is the gestational period from 14 weeks and 26 weeks + 6 days gestational age, while third trimester is from 27 weeks and 41 weeks + 6days of gestational age (Sanders and Winter, 2012; AIUM, 2013; Buscarini*et al*., 2013).

2.1.5.1.1First Trimester Ultrasound

First trimester ultrasound is often done to assess pregnancy location and thus it overlaps between an obstetric and gynaecologic ultrasound examination (Prashant *et al*., 2012; Buscarini*et al*., 2013).Accurate performance of an ultrasound examination in the first trimester is important given its ability to confirm an intrauterine gestation, assess viability and number of embryo(s) and accurately date a pregnancy including assigning an expected date of delivery (EDD), all of which are critical for the course of pregnancy (Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; AIUM, 2013; Reddy*et al*., 2014).

Deciding gestational age (GA) by ultrasound in the first trimester is by measuring the gestational sac (GS) when the pregnancy is between 4 weeks to 6 weeks (Prashant *et al*., 2012). By above 6 weeks and up to 13 weeks when the foetal pole is seen, the estimation of GA will be by measurement of the crown-rump length (CRL). From above 13 weeks,the estimation of GA is by measurement of the biparietal diameter (BPD) (Hadlock *et al*., 1985; Prashant *et al*., 2012; Sanders and Winter, 2012; AIUM, 2013; ACOG, 2014).

The main objectives of the first trimester ultrasound examination are: to confirm pregnancy, intrauterine localisation of gestational sac, confirmation of viability (cardiac activity in embryo/foetus), detection of signs of early pregnancy failure, single vs multiple pregnancy (define chorionicity in multiples), assess gestational age (pregnancy dating), assess normal embryo and gestational sac before 10 weeks and assessment of basic anatomy after 11 weeks (Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; AIUM, 2013; Buscarini*et al*., 2013; Reddy*et al*., 2014).

2.1.5.1.2 Second Trimester Ultrasound

It is generally accepted that the "second trimester/mid-trimester" refers to the period of 14-28 weeks of gestation, but in countries where access to ultrasound clinics is difficult or limited, the time period can be extended to 16-25 weeks gestation, with some caveats(Buscarini*et al*., 2013; Reddy*et al*., 2014). The main objective of a second trimester ultrasound examination is to accurately date the pregnancy, evaluate foetal anatomy and assess placental location and the adnexae(Chudleigh and Thilaganathan, 2004; Buscarini*et al*., 2013; Reddy *et al*., 2014).

Gestational age (dating of pregnancy), unless already estimated in the first trimester, is based on the biparietal diameter and other biometric parameters (femur length, cranial circumference, transverse diameter of cerebellum). All these parameters should be compared to reference curves. If the discrepancy between anamnestic (i.e. menstrual) gestational age and ultrasound-derived gestational age is ≥ 2 weeks, the pregnancy should be re-dated (Buscarini*et al*., 2013; Reddy*et al*., 2014).

Components of a basic second trimester ultrasound examination include:foetal presentation and position, cardiac activity, foetal number (and chorionicity if multiple pregnancy), foetal age/size assessment, placental appearance and location, basic foetal anatomy and assessment of the adnexae(Chudleigh and Thilaganathan, 2004; Sanders and Winter, 2012; AIUM, 2013; Buscarini*et al*., 2013; Reddy*et al*., 2014).

2.1.5.1.3 Third Trimester Ultrasound

The main objective of a third trimester obstetrical ultrasound is to provide accurate diagnostic information is order to optimise antenatal care and improve outcome for the mother and the foetus. The investigation is primarily focused on foetal growth, position of the placenta and the assessment of amniotic fluid(Buscarini*et al*., 2013; Campbell, 2013).

Ultrasound examination performed beyond the 28th week of gestation is considered in the third trimester and the assessment of fetal growth is commonly initiated at or around 28-32 weeks in at-risk pregnancies (Buscarini*et al*., 2013; Reddy*et al*., 2014).

Components of a third trimester ultrasound examination include evaluation of cardiac activity, foetal size (biometry and estimation of foetal weight), foetal presentation and lie, foetal anatomy, placental localization, amniotic fluid assessment and evaluation ofadnexae (Reddy*et al*., 2014).

2.1.5.2 Assessmentfoetal growth

Foetal growth is assessed by taking the estimated foetal weight (EFW) of the foetus (Kaimal and Kuppermann, 2012). A variety of formulas and parameters havebeen correlated with foetal weight (Thompson and Makowski, 1971; Suzuki*et al*., 1974; Campbell and Wilkin, 1975). The two most commonly used and widely accepted formulas are that of Shepard and Hadlock (Pinette*et al*., 1999; Adam *et al*., 2013).

Foetal parameters such as abdominal circumference (AC), femoral length (FL) and biparietal diameter (BPD) are either combined in twos or all three are used to get the EFW. Shepard's formula combines the BPD and AC (Shepard *et al*., 1982). Although an initial version of Hadlock formula combined two foetal parameters which are FL and AC (Hadlock *et al*., 1984). A better formula was later developed which combined three foetal parameters i.e. FL, BPD and AC,and over time has proven to be the most reliable (Hadlock *et al*., 1985; Pinette*etal*., 1999; Kaimal and Kuppermann, 2012; Spong*et al*., 2012; Adam *et al*., 2013).

2.1.5.3Identification and management of foetal malformation

Foetal malformations are usually an unexpected finding during sonographic examination of an apparently healthy pregnant woman, as in most cases they are found in women with no risk factors (Buscarini*et al*., 2013).Even though accomplished sonographers and sonologists can detect foetal anomalies as small as an extra digit or an abnormal little finger, it has to be emphasised that antenatal ultrasound diagnosis of fetal malformations is the most difficult task in the field of obstetrics. The number of foetal malformationsdetectable by ultrasound is high and increasing with the developmentof technology and interest in the field of antenatal medicine (Sanders and Winter, 2012; Buscarini*et al*., 2013; Fodor*et al*., 2014).

Anomalies should, if possible, be discovered before the foetus is 23 to 34 weeks old. For this reason, in developed countries, ultrasonic examination of foetalanatomy has become a standard screening procedure, usually between 19 and 22 gestational weeks.This short interval has been chosen because: the development of foetalorgans is almost complete; the amount of amniotic fluid is higher than the foetal body, allowing a good acoustic window for penetration of the ultrasound beam; and, if a foetal malformation is detected, it is still possible to plan other diagnostic procedures, such as amniocentesis, or offer the woman the option of terminating the pregnancy in the case of a severe anomaly (Mailath-Pokorny*et al*., 2012; Sanders and Winter, 2012; Buscarini*et al*., 2013).

Discovery of an anomaly at a later stage of pregnancy is of practical importance because the optimal fashion and time of delivery can be arranged, and the patient can, if necessary, be transferred to a hospital that has neonatal care and paediatric surgical facilities. Foetuses with anomalies that may rupture at the time of delivery (such as an encephalocoele) may be best delivered by caesarean section. If the foetal prognosis is very poor, those with a fluid-distended abdomen or head may be decompressed under ultrasound control before delivery in order to avoid needless caesarean section (Bianchi*etal*., 2012; Sanders and Winter, 2012; Buscarini*et al*., 2013).

The aim of a routine foetal anatomy surveyby sonographers and sonologists, is to look for clues that could raise the suspicion of a congenital malformation and then a targeted foetal anomaly scan by a specialist is suggested for further evaluation (Goetzinger*et al*., 2012; Sanders and Winter, 2012; Buscarini*et al*., 2013).

2.1.5.4 Intrauterine blood transfusion

Intrauterine transfusion (IUT) was introduced in 1963 by Liley, who used an intraperitoneal approach (Liley, 1963). Almost 20 years later, the procedure was improved to a transfusion into the umbilical vein under constant ultrasonographic guidance (Berkowitz and Hobbins, 1981; Clewell*et al*., 1981). The intravascular approach compared to the intraperitoneal route turned out to be especially advantageous to the hydropic foetus because the absorption of red blood cells is less effective from a peritoneal cavity filled with ascites (Merchant*et al*., 1995; Dias *et al*., 2012; Pasman*etal*., 2015).

Indications for IUT are foetalanaemia and thrombocytopenia, although the latter has become an increasingly rare indication since the introduction of immunoglobulins for foetal and neonatal alloimmune thrombocytopenia (Bussel*et al*., 1988; Van Den Akker *etal*., 2007). The majority of IUTs were previously performed for foetal anemia caused by Rhesus-D antibodies. Nowadays, despite a large decrease because of prophylactic administration of anti-D immune globulins in Rhesus negative patients, maternal red blood cell (RBC)- alloimmunization remains an important cause of foetalanaemia (Moise, 2008).However, indications have shifted to a diversity of other antibodies than those against the Rhesus-D antigen. Timely referral is now ensured since irregular antibodies are routinely checked for in maternal blood in the first trimester and repeated later in gestation for Rhesus negative mothers. This has led to a lower number of hydrops in foetuses requiring IUT (Merchant*et al*., 1995; Dias *et al*., 2012; Pasman*etal*., 2015).

Risk factors for severe foetalanaemia include:relevant obstetric history, presence of maternal red blood cell antibodies, ultrasound markers as cardiomegaly, hepatomegaly and splenomegaly and signs of hydrops and diminished foetal movements (Van Kamp *et al*., 2001; Pasman*et al*., 2015).

Timing of transfusion used to require amniocentesis for determining delta OD450 indicating levels of bilirubin and thus hemolysis (Pasman*et al*., 2008) but this changed with the introduction of MCAPSV (middle cerebral artery peak systolic velocity) Doppler measurement in 2000 (Mari *et al*., 2000). Anaemiais predicted by assessment of the MCA PSV, which is then converted to multiple of the median (MoM) (Mari *et* *al*., 2000). An MCA PSV above 1.5 MoM was considered an indication for IUT. Sonographic features related to foetal hydrops are also indications for foetal blood sampling. A foetuswith a hemoglobin value of at least two standard deviations (SD) below the mean for gestational age at foetal blood sampling is regarded as anaemic(Nicolaides *et al*., 1988).

Because of the accuracy and non-invasiveness of MCA PSV measurement, this new technique quickly became the standard (Oepkes*et al*., 2006). It can be used weekly or more frequently when required and is a reliable diagnostic tool between 16 and 36 weeks gestation in experienced hands. Furthermore, Doppler measurements can be used for timing of subsequent IUTs (Scheier*et al*., 2006) instead of planning the subsequent IUTs by a standard schedule. Therefore, although the technique of IUT has not significantly changed, the management of these pregnancies has evolved significantly in the last 14 years (Pasman*et al*., 2015).

About two or three operators are required to perform andIUT. Antenatal corticosteroids will be given to women carrying foetuses with at least 26 weeks of gestation age before IUT to anticipate the need foran emergency caesarean section. For the same reason,IUT after 28 weeks of gestation are performed under combined spinal epidural analgesia (CSE). Foetal pain relief and immobilisationis achieved by either intravenous or intramuscular injection of a curare derivative (pancuronium or cisatracurium) in combination with atropine and fentanyl. A 20 or 22G spinal needle is used for the IUT. The volume of packed cells to be given (V) is calculated using the Moise formula (Moise *et al*., 1997). The target haematocrit (Ht) is usually 40%. The haematocrit of the foetal blood sample is assessed through a Sysmex pocH-100i (Sysmex NV Belgium). The donor blood will be O Rhesus D-negative or compatible with the antibody of the mother. It will then beleucodepleted and obtained from cytomegalovirus (CMV) negative donours, collected within 72 hours before the procedure. The blood is concentrated to a hematocrit between 75 and 80% and will undergogamma irradiation less than six hours before administration (Pasman*et al*., 2015).

IUT is usually performed into the umbilical vein either at the placental cord root, into its intrahepatic course or into a free loop of cord, by choice of the operator. After completion of the IUT, a second blood sample is taken to confirm adequate transfusion. In some cases, blood was transfused into the peritoneal cavity as an addition to the IV transfusion. Usually, the aim is to diminish the direct burden on the cardiovascular system, or to prolong the period until the next procedure. Delivery is usually planned 2 weeks after the last IUT. Neonatal follow-up will beconducted until discharge from the hospital in good condition, including ambulant controls during the first 6 weeks of life (Dias *et al*., 2012; Pasman*etal*., 2015).

Mild procedure related adverse events are usually considered e.g. transient contractions requiring tocolysis and transient bleeding from the puncture site (Dias *et al*., 2012; Pasman*etal*., 2015). Severe adverse events were defined as (1) rupture of membranes or preterm birth within sevendays after transfusion, (2) intrauterine infection, (3)emergency caesarean section for foetal distress within 24 hours after procedure, (4) foetal death and (5) neonatal death. Long-term neurodevelopmental outcome have also been studied by some authors with favourable outcome (Van Kamp *et al*., 2005; Lindenburg*et al*., 2012; Lindenburg*et al*., 2013; Santos *et al*., 2013).

2.1.5.5 Emptying of excessive amniotic fluid

Polyhydramnios is the term used to describe an excess accumulation of amniotic fluid (Sanders and Winter, 2012; Buscarini*et al*., 2013). This clinical condition is associated with a high risk of poor pregnancy outcomes (Gasser*et al*., 2014; Reddy *et al*., 2014). The reported prevalence of polyhydramnios ranges from 0.2 to 1.6 % of all pregnancies (Sanders and Winter, 2012; Hamza *et al*., 2013).

Under physiological conditions there is a dynamic equilibrium between the production and resorption of amniotic fluid. Fluid levels are influenced by foetal urination and foetal lung liquid production. Amniotic fluid is reabsorbed by foetal swallowing and intramembranous and intravascular absorption. The relative attribution of each of these mechanisms varies over the course of the pregnancy. A disturbed equilibrium can be the result of compromised swallowing function or increased urination and can lead to polyhydramnios (Syngelaki*et al*., 2011; Norton*et al*., 2012; Agathokleous*et al*., 2013).

A foetus close to term will produce between 500–1200 ml urine and swallow between 210–760 ml of amniotic fluid per day. Even small changes in this equilibrium can result in significant changes in amniotic fluid volumes (Sanders and Winter, 2012; Hamza *et al*., 2013).

Ultrasound and subjective or semi-quantitative assessment is used to evaluate amniotic fluid volumes. With the subjective method, the examiner estimates the volume of amniotic fluid based on personal impressions of the amniotic fluid depot. The sonographer’s experience plays an important role here (Sanders and Winter, 2012; Hamza *et al*., 2013). When evaluating cases of oligo- or polyhydramnios, the use of biometric measurements and references is more accurate when examiners are less experienced, while evaluation based solely on subjective assessment is associated with good results if done by an experienced examiner (Sanders and Winter, 2012; Reddy *et al*., 2014).

Various semi-quantitative methods to measure amniotic fluid volumes have been described and the two most applied during routine ultrasound scan are the single deepest pocket (SDP) and the amniotic fluid index (AFI) (Sanders and Winter, 2012).

In the SDP measurement, the uterus is divided into four quadrants. The amniotic fluid volume is measured vertically in the deepest amniotic fluid pocket. Values below 2 cm indicate oligohydramnios, values over 8 cm indicate polyhydramnios (Sanders and Winter, 2012; Reddy *et al*., 2014). While for the AFI method, the deepest amniotic pocket in each of the four quadrants is measured vertically and the values added together. The uterus is divided vertically into two halves by an imaginary line along the lineanigra. An imaginary horizontal line through the umbilicus divides the uterus into an upper and a lower half. During measurement the transducer is held at right angles to the sagittal plane of the patient's abdomen. The transducer should not be tilted along the maternal abdomen, i.e. it must be kept at a right angle. The measured amniotic fluid pockets must be free of foetal extremities and the umbilical cord and must be at least 0.5 cm wide. The Amniotic Fluid Index (AFI) is the sum of measurements of all four quadrants. According to one study group, AFI values between 8.1 and 18 cm are normal, values between 5.1 und 8.0 cm indicate oligohydramnios, an AFI value of less than 5.0 cm indicates severe oligohydramnios and a value above 18 cm is classified as polyhydramnios (Sanders and Winter, 2012; Buscarini*et al*., 2013; Reddy *et al*., 2014).

Amnioreduction is the method used to empty excess amniotic fluid. But to date, this method has not been evaluated in randomized or controlled studies, but it offers a clear clinical benefit if done after careful diagnostic evaluation (Hamza *et al*., 2013). However, there is no consensus regarding the volume of aspirated amniotic fluid, the speed of aspiration and the use of tocolytics or antibiotics. The intervention is usually concluded when ultrasound examination shows an AFI of 15 to 20 cm or if intra-amniotic pressure drops to < 20 mmHg. In some cases, the intervention had to be terminated due to maternal discomfort or premature placental abruption. Tocolytics are routinely used as prophylaxis to prevent onset of preterm labour (Sanders and Winter, 2012; Hamza*et al*., 2013).

Complications occur in 1–3 % of cases and can include premature labour, placental abruption, premature rupture of membranes, hyperproteinaemia and amniotic infection syndrome. After the procedure, regular monitoring of amniotic fluid volumes is recommended, with monitoring done every 1 to 3 weeks (Fayyaz and Rafi, 2012; Hamza *et al*., 2013).

2.1.5.6Measurement of cervical length to assess risk of preterm labour

The cervix is the most inferior segment of the uterus. It is more than 3.5 cm long during a normal pregnancy but decreases (effaces) in length during labour (Sanders and Winter, 2012; Moore *et al*., 2016). The main aim of ultrasonographic evaluation of the cervix is to identify women at risk for preterm labourbased on a previous history, women with symptoms of preterm labour and follow-up of women after cervical cerclage positioning. It can also be used before medical induction of labour, with a clinical examination, to evaluate the probability of successful induction. A studywith transvaginal ultrasound of the relation between placental insertion and uterine internal os is recommended in all cases of placenta praevia or low-lying placenta suspected on transabdominal ultrasound (Sanders and Winter, 2012; Timor-Tritsch andMonteagudo, 2012; Bronsteen*et al*., 2013; Buscarini*et al*., 2013).

For a differential diagnosis of complete placenta praevia, incomplete placenta praevia and low-lying placenta, transvaginal ultrasound of the uterine neck and its relation to the lower placental edge is advised between 32 and 37weeks' gestational age in all cases suspected earlier. Ifbleeding occurs, transvaginal ultrasound can be used at any time during gestation, but the diagnosis must be confirmed after 32 weeks (McLean *et al*., 2011; Sanders and Winter, 2012; Bronsteen*et al*., 2013; Buscarini*et al*., 2013).

2.1.5.7 Identification of multiple pregnancies

The incidence of multiple pregnancies is 3%. Over the past 20 years, the number of twin births has increased by 50% and the number of multiple deliveries by 400%, primarily because of the availability and increased use of ovulation-inducing drugs and assisted reproductive techniques. The increase is also related to advanced maternal age, with the rate of dizygotic twinning peaking between 35 and 40 years of age, mainly in multiparous women (Sanders and Winter, 2012; Martin *et al*., 2017).

Heredity and maternal history of twinning (either dizygotic or monozygotic) are particularly important for twinning, while the father's history plays little or no part. Race is also a factor: the percentage of dizygotic twins is 1% in whites, lower in blacks and higher in Asians (Sadler, 2012;Moore *et al*., 2016). Nigerians, especially those from the south western part have been shown to have the highest rate of twinning in the world (Akinboro*et al*., 2008; Obiechina*et al*., 2011; Yakasai and Rabiu, 2013).

Thereare two kinds of twins. Dizygotic twins are the result of simultaneous fertilization of two different oocytes by two different spermatozoa. Monozygotic or identical twins result from duplication of a single conceptional product. As dizygotic twins originate from multiple ovulations, they reflect the incidence of genetic and ethnic factors, whereas monozygotic twins result from duplication of a single zygote, with a constant frequency in all ethnic groups. Dizygotic twins have two different placentas and amniotic membranes in two amniochorionic membranes (dichorionic twins). They are the same sex in 50% of cases. In monozygotic twins, who are always the same sex, placentation depends on the time of embryo duplication (Sadler, 2012; Sanders and Winter, 2012; Buscarini*et al*., 2013; Moore *et al*., 2016).

Ultrasound is an integral part of the diagnosis and management of twin pregnancies. Ultrasound has indeed revolutionised the care of pregnancies with twins from the initial diagnosis to guiding the delivery of the neonates. The benefits of ultrasound in multiple pregnancies include: diagnosis of twin/triplets etc., determining of chorionicity of placenta (s), evaluation of foetal anatomy, detection of foetal growth abnormalities and discordance, assessment of the presence of complications such as twin-twin transfusion and cord entanglement, determining foetal presentation in labour and guiding of foetal interventions (Sanders and Winter, 2012; Buscarini*et al*., 2013; Reddy *et al*., 2014).

2.1.5.8 Amniotic fluid sampling (Amniocentesis)

Amniocentesis for chromosomal, microbial and viral analysis is usually performed between 15 and 18 weeks of gestation. It is safe, with a less than 0.5 % abortion rate; cell growth occurs within 6 to 17 days. Alpha-feto protein can be measured in the amniotic fluid (DiGiulio, 2012; Sanders and Winter, 2012; Collado*et al*., 2016). Second trimester amniocentesis is generally performed to rule out chromosomal and congenital defects at a stage early enough to give the parents the option of termination if a foetal anomaly is found (Sanders and Winter, 2012; Buscarini*et al*., 2013).

In the third trimester, amniocentesis is performed to obtain fluid to determine whether the lungs are mature. There is relative oligohydramnios in the third trimester, and the procedure can be more difficult to perform (Sanders and Winter, 2012).

In the amniocentesis technique under ultrasound guidance, a 3 mL syringe is used to take off the first few millilitres of fluid collected so that any maternal blood is cleared from the main sample. Either a 20- or 22- gauge is used for amniocentesis; those with a roughened tip or echogenic coating can be seen in fluid with a 3.5- to 5 MHz transducer. Prepackaged amniocentesis sets are available. Opaque tubes are necessary to keep light from reaching fluid samples and breaking down the bilirubin pigments if an Rh problem is being investigated. Points to remember in choosing a site for amniocentesis are; to avoid the placenta, foetus, umbilical cord, a site that is too lateral, document the site of needle insertion and needle insertion should be done quickly particularly in second trimester amniocentesis to avoid tenting of the amniotic membrane (Sanders and Winter, 2012; Driggers*et al*., 2016; Matevosyan, 2016).

2.1.5.9 Chorionic villi sampling (CVS)

Chromosomal material can be obtained in the first trimester (about 11 – 14 weeks) by taking a sample from the placental implantation site. The most commonly used method is the transvesical approach where a transducer is used to follow the catheter as it is placed through the vagina and cervix. A sample of the chorion is then aspirated from the thickest portion of the gestational sac. Ultrasound is used to delineate the precise location of the catheter and monitors foetal heart rate. Small bleeds are not uncommon at the time of the CVS (Sanders and Winter, 2012; Aagaard*et al*., 2014).

A second method for CVS, the transabdominal approach is similar to the transvesical approach except that the needle is placed obliquely to the transducer and enters through the abdominal wall. With a full bladder which is a must, a needle is inserted just above the bladder and placed within the gestational sac. The transducer is then used to monitor the needle as it proceeds through the abdominal contents by viewing it through the bladder. This method is more commonly used for a gestational sac at an inaccessible site (e.g., in an acutely anteverted or retroverted uterus). This technique is similar to that used for ovum aspiration. The transabdominal route is less likely to introduce infection than the vaginal route and may be slightly more painful (Sanders and Winter, 2012; Aagaard*etal*., 2014; Khong*et al*., 2016).

CVS gives material that allows chromosomal analysis in 2 days to 2 weeks (depending on the technique used) at a very early stage of pregnancy; however, it is statistically slightly more hazardous than amniocentesis, alpha-feto protein amniotic fluid analysis cannot be performed, and maternal cells may occasionally be confused with foetal cells. Occasionally, persistent amniotic leakage may occur. CVS is a technique that requires a skilled operator and is best performed at a site where a maternal-foetal medicine specialist (perinatologist) is available. With the advent of more widespread first-trimester nuchal translucency screening programs for aneuploidy, the number of CVS procedures will likely increase (Sanders and Winter, 2012; Khong*et al*., 2016).

In addition to the early and quick availability of chromosomal information with CVS, it is also possible to take the tissue and extract DNA to test for certain specific diagnoses, such as cystic fibrosis and sickle cell anaemia (Sanders and Winter, 2012; Moore *et al*., 2016).

2.1.5.10 Percutaneous umbilical blood sampling (PUBS)

PUBS is performed later in pregnancy when access to the foetal circulation for diagnostic or therapeutic purposes is desired. This procedure requires careful cooperation between sonographer and physician. The cord insertion into the placenta is localised. Ideally the insertion site is anterior, but if it is posterior or lateral, the procedure can still be performed. The sonographer places the transducer at right angles to the needle insertion site. Needle is inserted into the cord at either the placental or, less often, the foetal end of the cord. The needle is carefully followed as it moves toward the umbilical artery and vein. The foetal heart is monitored at intervals to ensure that no damage has occurred in which case an attached biopsy guide may be useful (Sanders and Winter, 2012; Khong*et al*., 2016).

Cordocentesis is done either when the pregnancy is close to the abortion limit or when the foetus may be viable but has an anomaly that raises the question of a chromosomal abnormality. New diagnostic techniques like fluorescent in situ hybridisation that can be performed rapidly on amniotic fluid have decreased the necessity for diagnostic PUBS. PUBS is the most dangerous of the three techniques but is still surprisingly safe; Sanders and Winter quote a 1 % loss rate, but the exact hazard is unknown (Sanders and Winter, 2012;Khong*et al*., 2016; Moore *et al*., 2016).

Possible complications that could arise from the trio of amniocentesis, CVS and PUBS include: premature labour, vaginal fluid leakage, onset of infection after a delay, intrauterine bleeding, cord laceration and foetal damage or death (Sanders and Winter, 2012; Moore *et al*., 2016).

2.2 Placenta

The placenta is a fetomaternal organ that facilitates nutrient and gas exchange between the maternal and foetal compartments (Sadler, 2012). As the foetus develops, its demand for nutrition and other factors increases resulting in major changes in the placenta (Ouyang *et al*., 2013).

2.2.1 Development of the placenta

Early development is characterized by rapid proliferation of trophoblast and development of the chorionic sac and chorionic villi. Homeobox genes (HLX and DLX3) expressed in the trophoblast and its blood vessels regulate placental development. By the end of the third week, the anatomical arrangements necessary for physiologic exchanges between the mother and embryo/foetus are established. A complex vascular network is established in the placenta by the end of the fourth week, which facilitates maternal-embryonic exchanges of gases, nutrients, and metabolic waste products (Lala *et al*., 2012; Sadler, 2012; Miwa *et al*., 2014; Moore *et al*., 2016).

2.2.2 Components of the placenta

The placenta has two components:

2.2.2.1 A foetal part

This develops from the chorionic sac, the outermost fetal membrane. It is formed by the chorion frondosum and bordered by the chorionic plate(Sadler, 2012; Moore *et al*., 2016).

2.2.2.2A maternal part

This part is derived from the endometrium, the mucous membrane comprising the inner layer of the uterine wall(Sadler, 2012; Moore *et al*., 2016).

2.2.3 Structure of the placenta

By the beginning of the fourth month, the placentahas two components: (1) a foetal portion, formed by the chorion frondosum and (2) a maternal portion, formed by the decidua basalis. On the foetal side, the placenta is bordered by the chorionic plate; on its maternal side, it is bordered by the decidua basalis, of which the decidual plate is most intimately incorporated into the placenta. In the junctional zone, trophoblast and decidual cells intermingle. This zone, characterized by decidual and syncytial giant cells, is rich in amorphous extracellular material. By this time, most cytotrophoblast cells havedegenerated. Between the chorionic and decidual plates are the intervillous spaces, which are filled with maternal blood. They are derived from lacunae in the syncytiotrophoblast and are lined with syncytium of foetal origin. The villous trees grow into the intervillous blood lakes (Sadler, 2012; Knöfler and Pollheimer, 2013; Moore *et al*., 2016).

During the fourth and fifth months, the decidua forms a number of decidual septa, which project into intervillous spaces but do not reach the chorionic plate. These septa have a core of maternal tissue, but their surface is covered by a layer of syncytial cells, so that at all times, a syncytial layer separates maternal blood in intervillous lakes from foetal tissue of the villi. As a result of this septum formation, the placenta is divided into a number of compartments, or cotyledons. Because the decidual septa do not reach the chorionic plate, contact between intervillous spaces in the various cotyledons is maintained (Sadler, 2012; D'Antonio and Bhide, 2014; Moore *et al*., 2016).

As a result of the continuous growth of the foetus and expansion of the uterus, the placenta also enlarges. Its increase in surface arearoughly parallels that of the expanding uterus, and throughout pregnancy, it covers approximately 15% to 30% of the internal surface of the uterus. The increase in thickness of the placenta results from arborisation of existing villi and isnot caused by further penetration into maternaltissuesmaintained (Sadler, 2012; D'Antonio and Bhide, 2014; Moore *et al*., 2016).

2.2.4 Full term placenta

At full term, the placenta is discoid with a diameter of 15 to 25 cm, is approximately 3 cm thick, and weighs about 500 to 600 g. At birth, it is torn from the uterine wall and, approximately 30 minutes after birth of the child, is expelled from the uterine cavity as the afterbirth. When the placenta is viewed from the maternal side, 15 to 20 slightly bulging areas, the cotyledons, covered by a thin layer of decidua basalis, are clearly recognizable. Grooves between the cotyledons are formed by decidual septamaintained (Sadler, 2012; D'Antonio and Bhide, 2014; Moore *et al*., 2016).

The foetal surface of the placenta is covered entirely by the chorionic plate. A number of large arteries and veins, the chorionicvessels, converge toward the umbilical cord. The chorion, in turn, is covered by the amnion. Attachment of the umbilical cord is usually eccentric and occasionally even marginal. Rarely, however, does it insert into the chorionic membranes outside the placenta (velamentous insertion)(Iwarsson*et al*., 2011; Sadler, 2012; D'Antonio and Bhide, 2014; Moore *et al*., 2016).

2.2.5 Circulation of the placenta

Cotyledons receive their blood through 80 to 100 spiral arteries that pierce the decidual plate and enter the intervillous spaces at more or less regular intervals. Pressure in these arteries forces the blood deep into the intervillous spaces and bathes the numerous small villi of the villous tree in oxygenated blood. As the pressure decreases, blood flows back from the chorionic plate toward the decidua, where it enters the endometrial veins. Hence, blood from the intervillous lakes drains back into the maternal circulation through the endometrial veins (Sadler, 2012; D'Antonio and Bhide, 2014; Moore *et al*., 2016).

Collectively, the intervillous spaces of a mature placenta contain approximately 150 mL of blood, which is replenished about three or four times per minute. This blood moves along the chorionic villi, which have a surface area of 4 to 14 m^2. Placental exchange does not take place in all villi, however, only in those that have foetal vessels in intimate contact with the covering syncytial membrane. In these villi, the syncytium often has a brush border consisting of numerous microvilli, which greatly increases the surface area and consequently the exchange rate between maternal and foetal circulations (Plaisier, 2011; Sadler, 2012; Moore *et al*., 2016).

The placental membrane, which separates maternal and foetal blood, is initially composed of four layers: (1) the endothelial lining of foetal vessels, (2) the connective tissue in the villous core, (3) the cytotrophoblastic layer, and (4) the syncytium. From the fourth month on, the placental membrane thins because the endothelial lining of the vessels come in close contact with the syncytial membrane, greatly increasing the rate of exchange (Pooh *et al*., 2011; Sadler, 2012; Moore *et al*., 2016).

Sometimes called the placental barrier, the placental membrane is not a true barrier as many substances pass through it freely. Because the maternal blood in the intervillous spaces is separated from the foetal blood by a chorionic derivative, the human placenta is considered to be of the hemochorial type. Normally, there is no mixing of maternal and foetal blood. However, small numbers of foetal blood cells occasionally escape across microscopic defects in the placental membrane. Unfortunately, most drugs, drug metabolites, hormones and many viruses traverse the placenta without difficulty, and may cause serious damage to the embryo. In addition, maternal use of heroin and cocaine can cause habituation in the foetus (Sadler, 2012; Poon *et al*., 2013; Salihu*et al*., 2013; Fodor *et al*., 2014).

The welfare of the embryo/foetus depends more on the adequate bathing of the branch villi with maternal blood than any other factor. Reductions of uteroplacental circulation result infoetal hypoxia and intrauterine growth restriction (IUGR). Severe reductions of circulation may result in embryo/foetal death (Salihu*et al*., 2013; Tamblyn *et al*., 2013; Moore *et al*., 2016).

2.2.6 Placental changes at theend of pregnancy

At the end of pregnancy, a number of changes that occur in the placenta may indicate reduced exchange between the two circulations. These changes include (1) an increase in fibrous tissue in the core of the villus, (2) thickening of basement membranes in fetal capillaries, (3) obliterative changes in small capillaries of the villi, and (4) deposition of fibrinoid on the surface of the villi in the junctional zone and in the chorionic plate. Excessivefibrinoid formation frequently causes infarction of an intervillous lake or sometimes of an entire cotyledon. The cotyledon then assumes a whitish appearance (Morgan *et al*., 2013; Lepais*et al*., 2014; Moore *et al*., 2016).

2.2.7 Functions of the placenta

Main functions of the placenta are (1) exchange of metabolic and gaseous products between maternal and foetal bloodstreams and (2) production of hormones. The placenta and umbilical cord form a transport system for substances passing between the mother and embryo/foetus. Nutrients and oxygen pass from the maternal blood through the placenta to the embryo/foetal blood, and waste materials and carbon dioxide pass from the foetal blood through the placenta to the maternal blood (Pooh *et al*., 2011; Sadler, 2012; Moore *et al*., 2016).

The placenta and foetalmembranes perform the following functions and activities: protection, nutrition, respiration, excretion of waste products, and hormone production. Shortly after birth, the placenta and membranes are expelled from the uterus as the afterbirth(Sadler, 2012; Moore *et al*., 2016). The functions of the placenta are as follows:

2.2.7.1 Exchange of gases

Exchange of gases such as oxygen, carbon dioxide and carbon monoxide is accomplished by simple diffusion. At term, the foetus extracts 20 to 30 mL of oxygen per minute from the maternal circulation, and even a short-term interruption of the oxygen supply is fatal to the foetus. Placental blood flow is critical to oxygen supply, as the amount of oxygen reaching the foetus primarily depends on delivery, not diffusion (Pooh *et al*., 2011; Sadler, 2012; Moore *et al*., 2016).

2.2.7.2 Exchange of nutrients and electrolytes

Exchange of nutrients and electrolytes such as amino acids, free fatty acids, carbohydrates and vitamins, is rapid and increases as pregnancy advances throughdiffusion (Pooh *et al*., 2011; Sadler, 2012; Moore *et al*., 2016).

2.2.7.3 Transmission of maternal antibodies

Immunological competence begins to develop late in the first trimester, by which time the foetus makes all of the components of complement. Immunoglobulins consist almost entirely of maternal immunoglobulin G (IgG), which begins to be transported from mother to foetus at approximately 14 weeks. In this manner, the foetus gains positive immunity against various infectious diseases. Newborns begin to produce their own IgG, but adult levels are not attained until the age of three years(Sadler, 2012; Jabrane-Ferrat and Siewiera, 2014; Moore *et al*., 2016).

2.2.7.4 Hormone production

By the end of the fourth month, the placenta produces progesterone in sufficient amounts to maintain pregnancy if the corpus luteum is removed or fail to function properly. In all probability, all hormones are synthesized in the syncytial trophoblast. In addition to progesterone, the placenta produces increasing amounts of eostrogenic hormones, predominantly eostriol until just before the end of pregnancy, when a maximum level is reached. These high levels of eostrogens stimulate uterine growth and development of the mammary glands (Sadler, 2012; Jabrane-Ferrat and Siewiera, 2014; Moore *et al*., 2016).

During the first two months of pregnancy, the syncytiotrophoblast also produces human chorionic gonadotropin (hCG), which maintains the corpus luteum. This hormone is excreted by the mother in the urine, and in the early stages of gestation, its presence is used as an indicator of pregnancy. Another hormone produced by the placenta is somatomamotropin (formerly placental lactogen). It is a growth-hormone-like substance that gives the foetus priority on maternal blood glucose and makes the mother somewhat diabetogenic. It also promotes breast development for milk production (Sadler, 2012; Jabrane-Ferrat and Siewiera, 2014; Moore *et al*., 2016).

2.2.8 The placenta as an allograft

The placenta can be regarded as an allograft (a graft transplanted between genetically nonidentical individuals) with respect to the mother. The foetal part of the placenta is a derivative of the conceptus, which inherits both paternal and maternal genes. What protects the placenta from rejection by the mother's immune system?

This question remains a major biologic enigma in nature. The syncytiotrophoblast of the chorionic villi, although exposed to maternal immune cells within the blood sinusoids, lacks major histocompatibility (MHC) antigens and thus does not evoke rejection responses. However, extravillous trophoblast (EVT) cells, which invade the uterine decidua and its vasculature (spiral arteries), express class I MHC antigens. These antigens include HLA-G, which, being nonpolymorphic (class Ib), is poorly recognizable by T lymphocytes as an alloantigen, as well as HLA-C, which, being polymorphic (class Ia), is recognizable by T cells. In addition to averting T cells, EVT cells must also shield themselves from potential attack by natural killer (NK) lymphocytes and from injury inflicted by activation of complement. Multiple mechanisms appear to be in place to guard the placenta from immune system rejection (Lala *et al*., 2012; Korf and Rehm, 2013; Jabrane-Ferrat and Siewiera, 2014; Moore *et al*., 2016).

2.2.9 Ultrasound of theplacenta

Despite the fact that placental anatomy, function, and location has far-reaching effects for the parents and the developing offspring, ultrasound examination of the placenta is not usually very interesting to most expectant parents. Examination of the placenta may be considered secondary to the foetal examination by sonographers as well (AIUM, 2013; ACOG, 2014; Reddy *et al*., 2014). Ultrasound professionals must be cognizant of the importance of sonographic examination and documentation of the placenta. Location, size, and shape are easily ascertained with two dimensional techniques. Three-dimensional ultrasound techniques have opened the frontier of placental examination and have set the stage to make placental evaluation as interesting as that of the foetus (Holzman *et al*., 2007; Parra-Saavedra *et al*., 2014; Mone*et al*., 2015).

2.2.9.1 Normal placental ultrasound

2.2.9.1.1Anatomy

The normal placental anatomy is comprised of the umbilical cord, placental membranes and placental parenchyma. The umbilical cord has an average diameter of 0.8 to 2.0 cm and average lengthof 55 cm but may range from 30 to 100 cm. It is composed of oneumbilical vein and two umbilical arteries surrounded by connective tissue that is gelatinous in nature called Wharton's Jelly. The placental membranes are composed of the amnion and chorion. The amnion is first identifiable about the seventh or eighth day of embryonic development and eventually engulfs the growing embryo. As the pregnancy progresses the amnion is brought into contact with the chorion. This occurs at approximately twelve to fifteen weeks gestation. The placentalparenchyma is composed of a stromal compartment that is filled with vascular and lymphatic channels. The stroma eventually becomes slightly elevated with convex areas called lobes which are incompletely separated by grooves. The number of lobes varies from 10 to 38 and the number remains the same throughout gestation (Holzman *et al*., 2007; Sadler *et al*., 2012; Ptacek*et al*., 2014; Moore *et al*., 2016).

2.2.9.1.2Size

The normally developing placenta increases in size and echogenicity as pregnancy progresses.At approximately four menstrual weeks gestation, an intrauterine pregnancy may not be visible. Using transvaginal ultrasound, the gestational sac appears small and is fluid filled with an echogenic rim surrounding it. This represents the chorionic cavity and the implanting chorionic villi. In the early first trimester, the diameter of the gestational sac normally grows 1 mm each day. By five weeks gestation, a small mound of echogenic chorionic villi consistent with the early placenta, a yolk sac and umbilical cord may be visualised (Holzman *et al*., 2007; Sanders and Winter, 2012; Buscarini*et al*., 2013).

In the first trimester, the growth of the placenta is more rapid than the foetus. After the first trimester at approximately 17 weeks, the placental weight increases throughout normal gestation and correlates with birth weight. As a general rule,the placental thickness in mm should approximate the gestational age in weeks plus or minus 10 mm. The extremes of placental size have been associated with abnormal pregnancy outcomes. In pregnancies at 37 weeks gestational age, the placenta should be no greater than 40 mm thick. Placentomegalyhas been classically associated with various disease processes such as hydrops fetalis, maternal heart failure, maternal diabetes, chromosomal abnormalities and congenital viral infections. The ultrasound appearance of a thick heterogeneous placenta hasbeen linked to other adverse pregnancy outcomes and foetaldeath (Holzman *et al*., 2007; Morgan *et al*., 2013; Veerbeek*et al*., 2014).

Small or thin placentas offer an equal disadvantage to the pregnancy outcome. Polyhydramnios may cause the placenta to appear thin because of compression (Holzman *et al*., 2007; Longtine and Nelson, 2011; Ptacek*et al*., 2014).

2.2.9.1.3Grade

Ultrasound can be used to evaluate placental maturity by visualizing the changes in the intervening placental substance. Calcium deposition occurs throughout pregnancy as a normal physiologic process of placental aging. The amount of calcium deposition is known as the placental grade. In the first 2/3rd of gestation, the calcium deposition is microscopic. After 33 weeks more than half of placentas have macroscopic calcifications which then increases until term. Placental calcium deposits are detected sonographically as echogenic foci. The appearance of a grade three placenta in the late third trimester has been associated with pulmonary maturity in nondiabetic pregnancies. The clinical use of this finding is not clinically relevant with the widespread use of more accurate first and second trimesters ultrasound to date pregnancies. The table below demonstrates the description of the placental grading system (Grannum *et al*., 1979; Kazzi*et al*., 1984; Holzman *et al*., 2007; Sanders and Winter, 2012; Barbaux*et al*., 2015).

Table 2.1: Description of ultrasonographic placental grade

Placental grades	Descriptions
Grade 0	• No visible calcifications • Smooth chorionic plate
Grade 1	• Scattered tiny calcifications • Subtle indentations of chorionic plate
Grade 2	• Larger basal and comma like echodensities • Larger indentations of chorionic plate
Grade 3	• Extensive basal echogenicity and circular echodensities fully outlining cotyledons • Complete indentations of chorionic plate

Source: Grannum *et al.*, 1979

2.2.9.1.4Shape

The normal placental shape is a single round disk with a central cord insertion. It has been found that there is a linear increase in placental thickness with gestational age throughout pregnancy. The chorionic plate should be the same size as the basal plate so that the fetal membranes extend all the way to the edge. Circumferential enlargement continues until term (Holzman *et al*., 2007; Lee *et al*., 2012; Menon andVinodha, 2016).

2.2.9.1.5Placental lakes

Placental lakes are part of the normal appearance of the placenta in the second and third trimesters. Placental lakes may be absent, few or numerous and seem to be more prevalent with increasing placental thickness. Lakes are anechoic and contain maternal blood which can be seen swirling and have low velocity venous blood flow within them. Placental lakes have little to no clinical significance. Some authors believe them to be precursors of perivillous fibrin deposition or intervillous thrombosis if venous flow decreases within the lake (Holzman *et al*., 2007; Winder *et al*., 2011; Lee *et al*., 2012).Placental lakes are thought to be of little clinical significance and do not seem to indicate an increase in adverse pregnancy outcome (Bendon*et al*., 2012; Chisholm and Heerema-McKenney, 2015).

2.2.9.1.6Subchorionicfibrin deposition

Subchorionic fibrin deposition (SFD) occurs in 20% of placentas. The SFD appear as complex cystic lesions located on the fetal side of the placenta where fibrin deposits under the chorion and may appear large and dramatic. With gray-scale ultrasound, they can be mistaken for chorioangiomas. Color Doppler flow is not seen within the mass, although low velocity swirling may be seen with realtimeultrasound in the cystic areas. Use of Doppler is critical to distinguish between the two. The SFD has no clinical significance (Holzman *et al*., 2007; Sanders and Winter, 2012; Ptacek*et al*., 2014).

2.2.9.1.7Infarcts

Placental infarcts occur when perfusion to an area of the placenta is reduced enough to cause necrosis of placental tissue. Ifnecrosis causes liquefaction or bleeding, infarcts become visible with ultrasound. If liquefaction does not occur, infarcts may not be seen until pathological examination. Infarcts are usually irregularly shaped and do not contain swirling blood upon direct visualization. Small infarcts are seen in 25% of normal pregnancies (Holzman *et al*., 2007; Bendon*et al*., 2012 Sanders and Winter, 2012).

If placental infarcts are large or extensive, placental function can be compromised. Infarcts may occur as a result of maternal vascular disease, pre-eclampsia, or poor placental implantation (Holzman *et al*., 2007; Roland *et al*., 2012). Perinatal morbidity is associated with infarcts of more than5 percent of the placental mass or greater than 3 cm in diameter. Such a placenta may be described as having a “moth eaten” appearance. Unexplained elevated maternal serum AFP has been associated with extensive placental infarction (Holzman *et al*., 2007; Bendon, 2012; Katzman and Oble, 2013).

2.2.9.2 Abnormal placental ultrasound

2.2.9.2.1Umbilicalcord insertion

If the cord inserts near the edge of the placenta, this is called an eccentric insertion. A Battledore placenta refers to a cord insert on the absolute edge of the placenta, resembling a lollipop. A velamentous or membranous cord insertion refers to vessels inserting into and surrounded only by fetal membranes, with no Wharton's jelly. A velamentous insertion may cause compromise to the integrity of the umbilical vessels because there is little support by the body of the placenta (Holzman *et al*., 2007; Luo and Redline, 2013).

2.2.9.2.2Umbilicalcord vessels and coiling

Single umbilical artery: The normal umbilical cord contains two arteries and one vein. The umbilical arteries branch from the foetal iliac arteries and carry less oxygenated fetal blood from the foetus to the placenta. The umbilical vein carries more oxygenated blood from the placenta to the foetus. The umbilical vein becomes the ductus venosus. After exiting the ductus venosus, blood passes into the inferior vena cava and predominately into the right atrium, foramen ovale, left atrium, left ventricle, and the foetal aorta. A smaller portion of blood from the right atrium passes into the right ventricle, pulmonary artery, ductus arteriosus, and to the foetal aorta. Single umbilical artery (SUA) occurs when one of the umbilical arteries does not form or atrophy during foetaldevelopment (Holzman *et al*., 2007; Georgiadis *et al*., 2014).

In prospective studies, SUA occurs in 1% of all deliveries and in 5% of twin deliveries. The incidence of SUA in autopsy series is twice that in prospective series. There is no evidence of a familial or genetic tendency. The incidence is dependent on race, method of cord examination, and portion of cord examined (Georgiadis *et al*., 2014).The left artery is absent more commonly than the right one (70% vs 30%). The association with additional malformations appears equal for right and left in one series and higher if the left is absent in another series (Holzman *et al*., 2007; Proctor *et al*., 2013).

The number of umbilical arteries can be ultrasonographicallydocumented in several ways. The two arteries may normally fuse at the insertion into the placenta; therefore, the cord is best examined at the foetal insertion or in the midportion (Sanders and Winter, 2012). The number of umbilical arteries can be determined by sagittal and transverse views of the free floating cord. In the sagittal view, two arteries must be visualised running adjacent and parallel to each other to confirm that two arteries are present. In the transverse view, two smaller arteries are visualized next to onevein. This view has the appearance of “Mickey mouse ears” (Holzman *et al*., 2007;Eze*et al*., 2014). Visualisation of free floating cord is easier during andafter the second trimester. Visualisation of the number of arteriescan be achieved after 11 to 12 weeks with colour Doppler examination of the cord as it enters the foetus. In the transverse plane at the level of the foetal bladder, colour Doppler easily maps the separation of the arteries, one on either side of the foetalbladder. Although high resolution ultrasound has more than at 90% sensitivity and near 100% sensitivity for detecting SUA, single artery images should be confirmed with at least two different methods of viewing and on two separate occasions to minimise the false-positive rate. The false-positive rate has been reported to be 8%.The presence of SUA indicates increased pregnancy surveillance and may increase parental anxiety (Eze*et al*., 2014; Khong*et al*., 2016).

The SUA has been associated with other congenital anomalies, intrauterine growth restriction, prematurity, and anincreased perinatal mortality rate when compared to infants with two umbilical arteries. In older prospective series, 20% of infants with SUA had other anomalies (Holzman *et al*., 2007; Proctor *et al*., 2013; Georgiadis *et al*., 2014). A meta-analysis of 37 studies determined that there was a 66% incidence of other congenital anomalies when the diagnosis of SUA was made by examining abortuses, foetal deaths, or autopsies. More recent data support a 30 to 40% risk of another congenital anomaly, once SUA is diagnosed by ultrasound and the newborn and placenta are examined at birth (Hlozman*et al*., 2007; D'Antonio and Bhide, 2014; Khong*et al*., 2016).

Umbilical Cord Coiling: Definitions of under-coiling and over-coiling of the cord have been well described for postnatal examination of the umbilical cord. The umbilical coiling index (UCI) is the number of coilsdivided by the total cord length. Under-coiling is defined as UCI values less than the 10th percentile. Over-coiling is defined as UCI values greater than the 90th percentile (Strong *et al*., 1994; Ernst *et al*., 2013). Postnatally diagnosed coiling abnormalities (under- and over-coiling) have been associated with pregnancy complications. Foetal death, non-reassuring foetal testing, and intrauterine growth restriction occurred in 25% of foetuses with abnormal coiling (deLaat*et al*., 2006;Jessop *et al*., 2014). Other authors have demonstrated different types of complications associated with under- and over-coiling, respectively (Ernst *et al*., 2013; Downey *et al*., 2014).

Coiling indices have also been developed for second trimester antenatal ultrasound assessment of the umbilical cord. The antenatal umbilical coiling index (AUCI) performed in the second trimester is correlated with the postnatal umbilical coiling index (UCI) (Predanic*et al*., 2005; Downey *et al*., 2014). The antenatal umbilical coiling index (AUCI) is the reciprocal of the distance between two coils (AUCI = 1/ distance between two coils in centimeters). The distance between the coils is usually measured from the inner edge of an arterial or venous wall to the outer edge of the next coil along the ipsilateral of the cord. The mean AUCI in the mid trimester is 0.43. The 90^{th} percentile is 0.602. The 10th percentile is 0.204 (Ernst *et al*., 2013; Downey *et al*., 2014).

Abnormal umbilical cord coiling detected by antenatal ultrasound between 18 and 23 weeks has also been associated with perinatal complications when compared to foetuses with normal coiling (small-for-gestational age 15% vs 6% and non-reassuring foetal testing in labour 25% vs 11%). There were nostatistically significant differences with regard to 1 and 5 minutesApgar scores, number of interventional deliveries, and meconium stained amniotic fluid in 294 patients (Ernst *et al*., 2013; Georgiadis *et al*., 2014). Documentation of umbilical cord coiling is not currently a required part ofthe routine ultrasound examination. After more study, it maybecome an important indicator of high-risk pregnancies (AIUM, 2013; ACOG, 2014; Reddy *et al*., 2014).

2.2.9.2.3Circumvallateplacenta

A circumvallate placenta occurs when the chorionic plate is smaller than the basal plate and the fetal membranes are folded into a circular ridge. In other words, a double layer of amnion and chorion, as well as necrotic villi and fibrin, form a white ring around the surface of the placental disk at a variable distance from the umbilical cord insertion site. Circumvallate placentas are more prone to premature separation and are associated with pregnancy complications such as placental abruption, preterm labour, and stillbirth. The accuracy of sonography for diagnosis of circumvallation appears to be limited by high false-positiveand false-negative rates (Sanders and Winter, 2012; Buscarini*et al*., 2013).

2.2.9.2.4Succenturiatelobes

Succenturiate lobes also known as accessory lobes are seen in almost 10% of placentas. Another synonym is a bilobed placenta and refers to a placenta with an additional lobe or lobes of placental tissue located a few centimeters away. The main lobe receives the umbilical cord insertion while placental vessels extend from and within the membrane of the main placental mass to each lobe. The location of these accessory lobes are clinically relevant as the pregnancy is at a higher risk of a vasa praevia if one of the lobes is in the lower uterine segment. If connecting vessels traverse the cervical os, this is a form of vasa praevia. Diagnosis and documentation is critical antenatally because if left undiagnosed rapid foetal hemorrhageand foetal death may occur at the time of ruptured membranes (Sanders and Winter, 2012; Bronsteen*et al*., 2013; Khong*et al*., 2016).

These pregnancies are also at risk for retained placenta if undiagnosed antenatally. Accessory lobes usually spontaneously deliver with the main lobe due to the membranes and vessels connecting them, however, a retained placenta could occur, if accessory lobes were not diagnosed. Care should be taken not to over diagnose succenturiate lobes in placentas that are located laterally and wrap around from the anterior to posterior uterus. Succenturiate placentas are not continuous and demonstrate a significant gap in the placental body (Holzman *et al*., 2007; Sanders and Winter, 2012; Moore *et al*., 2016).

2.2.9.2.5Placentamembranacea

Placenta membranacea occurs when chorionic villi are spread all over the amniotic sac as a result of failure of regression in the first trimester. These very rare placentas are thin and may have abnormal implantation (placenta accreta) resulting in antepartumand postpartum hemorrhage. Antenatal ultrasound would show placenta covering most of the uterine cavity and reports of antenatal ultrasound diagnosis have been published (Sanders and Winter, 2012; Berkley and Abuhamad, 2013). Fourteen out of twenty-six reported cases resulted in a live birth with antepartum and postpartumhaemorrhage causing the highest morbidity followed by abnormal implantation (Berkley and Abuhamad, 2013; Calí*et al*., 2013).

2.2.9.2.6Molarpregnancy

Complete and partial molar pregnancies occur after aberrantfertilisation incites abnormal proliferation of trophoblastic tissue.Normal placental villi are replaced by profuse hydropic villi. The incidence of molar pregnancy in the United States is 1/1000 pregnancies (Sanders and Winter, 2012). A complete mole occurs when an empty ovum is fertilised by a single spermatozoon or two spermatozoa resulting in a 46 XX or 46 XY karyotype, in this case a foetus is not present. A partial mole is characterised by fertilisation of a normal ovum by two spermatozoa resulting in a 69 XXX or 69 XXY karyotype, in this case a foetus is present. The foetus in a partial mole is almost always triploid or aneuploid and usually has multiple congenital anomalies and or growth restriction (Sadler, 2012; D'Antonio and Bhide, 2014).

Ultrasound of a complete molar pregnancy demonstrates echogenic and cystic material filling the endometrium and itclassically resemble a "snowstorm" appearance. High human chorionic gonadotropin (HCG)levels (>100,000) and the presence of theca lutein cysts (enlarged ovaries with multiple small cysts throughout) support the diagnosis of molar pregnancy. The absence of an embryo or foetus and no amniotic fluid are also clues to the diagnosis. Sonographic features suggestive of a partial molar pregnancy include focal anechoic spaces and/or increased echogenicity of chorionic villi (Swiss cheese pattern). A foetus is present, may have cardiac activity, and is usually growth restricted. Oligohydramnios may also be present. Theca lutein cysts are absent (Sanders and Winter, 2012; Salomon *et al*., 2013; Reddy *et al*., 2014; Moore *et al*., 2016).

2.2.9.2.7Chorioangioma

Chorioangiomas are benign vascular (capillary filled) malformations that occur in 1% of placentas. Chorioangiomas range from microscopic lesion(s) that form within the placentalbody to large masses that protrude from the foetal side of theplacenta. Masses greater than 4 to 5 cm in diameter lend anincreased risk for foetal morbidity. Associated complications include output heart failure from arteriovenous shunting, platelet trapping, consumptive coagulopathy, and preterm delivery (Holzman *et al*., 2007; Sanders and Winter, 2012; Ptacek*et al*., 2014).

The ultrasound appearance of a chorioangioma is round, well circumscribed, and mostly hypoechoic. There may be hyperechoic components and solid appearing areas. Generous colour Doppler flow is an important distinguishing finding. Calcifications, cystic areas, and minimal colour flow are more characteristic of a teratoma orsubchorionic fibrin deposition both of which have little to no clinical significance. Frequent ultrasound surveillance is recommended for a chorioangiomas measuring > 5 cm to assist in detection of foetalanaemia and or hydrops (Sanders and Winter, 2012; Buscarini*et al*., 2013).

2.2.9.2.8Placental abruption

Placental abruption occurs in up to 1% of pregnancies and is defined as the premature separation of the placenta from the myometrium usually in the late second and third trimesters. Risk factors include tobacco smoking, hypertension, cocaine use, abdominal trauma, preterm premature rupture of membranes, multifetal gestation and previous abruption (Holzman *et al*., 2007; Fodor *et al*., 2014).

The most common location for placental separation is at the margin (edge) and may extend into a subchorionic collection. Subchorionic bleeds are more commonly described in the first and second trimesters and are usually managed expectantly. It is important to distinguish between subchorionic collections and retroplacental collections because subchorionic collections are not commonly referred to as placental abruptions and do not have the same clinical risk or connotation to obstetricians.Small subchorionic bleeds (< 15 to 60 ml) seen in the first half of pregnancy do not appear to impart adverse pregnancy outcome unlike larger bleeds (Sanders and Winter, 2012; Buscarini*et al*., 2013). Abruptions may be partial, complete, acute or chronic and can occur in any area of the placental bed. Placental abruptions are more commonly a concern in later pregnancy when survival of the neonate becomes possible (after 24 weeks) and intervention could protect the foetus from hypoxiaor death. If > 50% of the placenta appears detached, the risk of adverse pregnancy outcome is significantly increased (Longtineand Nelson, 2011; Sanders and Winter, 2012; Ptacek*et al*., 2014).

The diagnosis of placental abruption is largely clinical. The utility of ultrasound in the diagnosis is poor with 50% sensitivity (Sanders and Winter, 2012) and thus should never be used to “rule out” a placental abruption (Ptacek*et al*., 2014). Clinical correlation and observation are the methods used to correctly diagnose placental abruption. However, if a retroplacental collection is noted on ultrasound, attempts should be made to quantify the amount of retroplacental haemorrhage seen. Retroplacental collections should be distinguished from the normal retroplacental complex that contains decidua, vessels, and myometrium and is usually not more than 1 to 2 cm thick in sagittal plane (Sanders and Winter, 2012; Buscarini*et al*., 2013).

The sonographic appearance of retroplacental hemorrhage is variable. Fresh acute blood will appear hyperechoic. It becomes isoechoic in 3 to 7 days. In one to two weeks it becomes hypoechoic and after two weeks it becomes anechoic (Khong*et al*., 2016).

2.2.9.2.9Placentapraevia

Placenta praevia generally refers to the presence of placentalying over or near the internal cervical os. There are three types of placenta praevia (complete, partial, and marginal). The low lyingplacenta is not technically a praevia because the placental tissue does not cover the osand is usually described as the placental edge within 2 to 3 cm of the internal os (Holzman *et al*., 2007; Bronsteen*et al*., 2013).

A complete placenta praevia is diagnosed when the placenta completely covers the internal cervical os. A subgroup of complete praevia includes central praevias in which the cervix appears in the center of the placenta. Partial placenta praevia is described when the placenta partially covers the internal os, but not completely. Marginal placenta praevia is described as the placenta that only reaches the edge of the internal os (Sanders and Winter, 2012; Bronsteen*et al*., 2013).

Although transabdominal ultrasound is 95% accurate if the placenta appears well away from the lower uterine segment, there is an overall 7% false-positive rate (Sanders and Winter, 2012). Transvaginal sonography is now considered the gold standard for evaluating a suspected placenta praevia with an accuracy of 99% (Bronsteen*et al*., 2013). Transvaginal sonography is performed with an empty bladder by convention which removes the confounder of the full bladder. A full bladder commonly gives the false appearance of an anterior praevia during an abdominal examination. Transvaginal sonography also reduces the shadowing resulting from an engaged foetal presenting part during the third trimester and is better at evaluating the cervical involvement of a lateral or wrap around placenta. Translabial imaging is also an effective alternative. Gentle transvaginal sonography is the preferred method of detecting placenta praevia. It does not appear to incite placental bleeding in the setting of placenta praevia and is not comparable to a digital examination with regard to risk (Sanders and Winter, 2012; Bronsteen*et al*., 2013; D'Antonio and Bhide, 2014).

2.2.9.2.10Placentaaccreta

Placenta accreta complicates 5 to 10 percent of pregnancies with placenta praevia (Abuhamad, 2013). Placenta accreta is abnormal placental implantation in which the anchoring chorionic villi attach to the myometrium, rather than being contained by decidua. The normal decidua basalis and fibrinoid layer (Nitabuch's layer) are defective and as a result the placental villi adhere to the myometrial layer and may penetrate through it to reach other structures (Sanders and Winter, 2012; Calí*et al*., 2013). There are three levels of invasive placentas. The first is accreta where the placenta adheres to the fetal surface of the myometrium. The second is increta where the placenta invades into the myometrium. The third is placenta percretawhere the placenta invades all the way through the myometrium and often into the bladder wall and or into the bladder cavity itself if the placenta is anterior (D'Antonio*et al*., 2013; Comstock and Bronsteen, 2014). Abnormal placentation may also occur posteriorly which is not as common and more difficult to diagnose by ultrasound. All forms of placenta accreta are associated with significant antenatal and/or intrapartum haemorrhage at the time of placental separation/removal (Esakoff*et al*., 2011; Bronsteen*et al*., 2013).

Ultrasound is 85% sensitive for the detection of placenta accreta in high-risk women (Sanders and Winter, 2012; Rac*et al*., 2015). The normal hypoechoic placental myometrial interface is obscured and the placenta appears continuous with the myometrium. Colour Doppler is also sensitive (82%) and specific (97%) for the diagnosis of placenta praevia/ accreta when four criteria are used (Mone*et al*., 2015). The criteria are diffuse and focal intraparenchymal placental lacunar flow, hypervascularity of the bladder and uterine serosa, prominent subplacentalvenous complex and loss of subplacental Doppler vascular signals (Berkley and Abuhamad, 2013; Saraví*et al*., 2014; Mone*et al*., 2015).

A high index of suspicion by the sonographer could be lifesaving for women with risk factors. Risk factors for placenta accreta include prior uterine surgery, placenta praevia, maternal smoking, and advanced maternal age (Fodor *et al*., 2014; Moore *et al*., 2016). The incidence of placenta accreta among women with one, two and four or more cesarean sections and a concomitant placenta praevia is 25, 47, and 67%, respectively (Sanders and Winter, 2012; Abuhamad, 2013; Rac*et al*., 2015).

2.2.9.2.11Multiplepregnancy placentation

One of the most important reasons for performing ultrasound for multiple pregnancies is to determine the number of amnions and the number of chorions (placentas). Amnionicity and chorionicity are related to pregnancy outcome and will determine obstetrical management. Diamniotic dichorionic twin pregnancies have the lowest mortality rate among twins (9%) (Sanders and Winter, 2012; Yakasai and Rabiu, 2013).

In Nigeria and most parts of the world, about 35% (one third) of twins are identified as monozygotic and 75% (two third) are fraternal or dizygotic (two ova fertilised by two sperms) (Obiechina*et al*., 2011; Yakasai and Rabiu, 2013; Martin*et al*., 2017). Dizygotic pregnancies are always diamniotic dichorionic. On very rare occasions, post-zygotic mutations can cause genetic discordance among monozygotic pairs. All monochorionic twin pregnancies are monozygotic, but not all monozygotic pregnancies are monochorionic (Sadler, 2012; Moore *et al*., 2016). For monozygotic pregnancies (one ovum fertilized by one sperm), the timing of embryonic splitting determines the number of amnions and chorions. Once the chorion, amnion, or embryo differentiates, itcannot split. The chorion differentiates first (day 4 to 8) followed by the amnion (day 8 to 13) (Sadler, 2012; Moore *et al*., 2016).

Patients with twins during ultrasound often ask, “are my babies identical?” The answer is based on one of three scenarios. If monochorionicity is documented, then the answer is “yes with very rare exception”. If dichorionicity is present and the genders are different then the answer is “no”. If dichorionicity is present and the genders are the same the answer is “possibly”. There is an 8% chance that same gender dichorionic gestations will be identical (Holzman *et al*., 2007; Sanders and Winter, 2012). In the third scenario, newborn zygosity testing (HLA matching or DNA polymorphism analysis) is the only way to prove identical twins. Zygosity testing is rarely clinically indicated. Ultrasound examination is most helpful for determining chorionicity, not zygosity (Sanders and Winter, 2012; Reddy *et al*., 2014).

The presence or absence of the dividing membrane determines amnionicity. Chorionicity can be ultrasonographicallydistinguished in several ways. Simply documenting the presence or absence of a dividing membrane is insufficient information. Sonographers should make an effort to determine number of chorions as well as the number of amnions (Salomon *et al*., 2013). Discordant gender (male and female) is diagnostic for dichorionicity. A thick dividing membrane, triangular membranes at the placental insertion (lambda sign or twin peak sign), visualization of four membrane layers, and separate placentas also indicate dichorionicity(Sanders and Winter, 2012).

The first trimester is the optimal time to document chorionicity with ultrasound. The presence of a single yolk sac and two embryos is also diagnostic for monochorionicity. Thefirst trimester dichorionic membrane appears at it is thickestand is clearly visualized. The placental membrane insertion (lambda sign) is more prominent in the first trimester and may become less prominent as pregnancy progresses. Visualization of the lambda sign is nearly 100% accurate for prediction of dichorionicity. At 10 to 14 weeks, twin pregnancies with the lambda sign can be classified as dichorionic. Pregnancies with absent lambda sign can be classified as monochorionic. At 10 to 14 weeks the lambda sign is seen in 100% of dichorionic gestations with fused placentas and 90% of dichorionic gestations with separate placentas. At 16 to 20 weeks, the lambda sign is seen less often in dichorionic pregnancies (75% with separate placentas and 93% with fused placentas). The absence of the lambda sign does not exclude dichorionicity during the second trimester (Sanders and Winter, 2012, Reddy *et al*., 2014). The presence of separate placentas alone is not diagnostic of dichorionicity. Separate placental masses may occur in 3% of monochorionic gestations (Sadler, 2012; Moore *et al*., 2016). To reduce diagnostic error, documentation of multiple markers of chorionicity is recommended. In prospective studies using first and second trimester ultrasounds, multiple markers of chorionicity have an overall accuracy of 95 to 99%.

First trimester ultrasounds that incorporate multiple markers have accuracy closer to 99% (Sanders and Winter, 2012; Salomon *et al*., 2013; ACOG, 2014).

Multiple ultrasound markers of chorionicity should also be applied to higher order multiples. Membranes, membrane insertions, and placentas should be documented for all of the sacs. High order multiples can have any combination of chorionicity particularly if conceived with assisted reproductive techniques (Sadler, 2012; Moore *et al*., 2016). Any combination is possible with early foetal demise and embryo splitting. Documentation of chorionicity is extremely important before considering multifoetal reduction. Multifoetalreduction is contraindicated in multiple pairs that appear monochorionic, unless the desired effect is the reduction of both foetuses in that pair (Holzman*et al*., 2007; Sanders and Winter, 2012).

2.2.9.3 Placental 3D Doppler ultrasound

Uteroplacental development is dependent on invasion of the spiral arteries by trophoblast to create a low resistance system.Normally, villi become incorporated into the vessel wall. This invasion occurs in a stepwise fashion starting with plugging of the distal ends of the arteries followed by migration into the decidual segments, and finally, into the myometrium. Establishment of the uteroplacental circulation in the second trimester is not a random phenomenon, but rather a consequence of events in the first trimester (Sadler, 2012; Moore *et al*., 2016). The visualisation and evaluation of placental vascularity may be improved with the use of 3D Doppler ultrasound. The distal ends of the fetal placental blood vessels (secondary and tertiary stem vessels) are better visualized with 3D power Doppler when compared to 2D (Saraví*et al*., 2014; Mone*et al*., 2015).

One of the major weaknesses of more traditional 2D Doppler studies is the variable reproducibility of results. The benefits of 3D Doppler examination include minimization of operator error and variability and examination in real and remote time. Reproducibility of 3D Doppler parameters of the placental vascular tree is good in normal pregnancies (Sanders and Winter, 2012; Buscarini*et al*., 2013).

The Virtual Organ Computer-aided Analysis (VOCAL) imaging program is used to assess different patterns of blood flow by using three different calculations, the vascularisation index (VI), flow index (FI) and vascularisationflow index (VFI). The vascularisation index gives information inpercentages about the amount of colour values (vessels) in theplacenta. The flow index is a dimensionless index (0 to 100) with information about the intensity of blood flow. It is calculated as a ratio of weighted colour values (amplitudes) to the number of colour values. The vascularisation flow index is the combinedinformation of vascularisation and mean blood flow intensity. It is also a dimensionless index (1 to 100) calculated by dividing weighted colour values (amplitudes) by the total voxels minus background voxels. Placental and spiral artery volumes and vascular indices have been studied in normal pregnancies andappear to increase slowly and steadily as pregnancy advances (Abuhamad, 2014; Lobmaier*et al*., 2014; Parra-Saavedra *et al*., 2014).

2.3 A Short History of Zaria Local Government Area, Kaduna State

Zaria lies between latitude 90 to 120 North, and longitude 70 to 90 East. According to tradition, it is one of the original seven Hausa states known as the Hausa Bakwai (Walker and Gaddafi, 2015). The name Zaria is mainly associated with the capital city of the emirate of Zazzau. Zaria is a cosmopolitan city in Kaduna State, in Northern Nigeria, as well as being a Local Government Area. Formerly known as Zazzau, it was one of the original seven Hausa city-states. The 2006 Census population estimated Zaria's population as 408,198, the town is home to Zazzau Emirate (Thomas, 1984; Maiwada and Renne, 2007; Walker and Gaddafi, 2015).

Historically, Zazzau was the name of a sword that served as a symbol of unity among the different people living in the area known today as Zaria. The formation of Zaria could be best tied-up with the desiccation of the Sahara which forced people out in search of more favourable settlements (Abbas, 2010; Walker and Gaddafi, 2015).

The first settlers were said to be immigrants from Borno who first settled at a place now known as Kofar Kona. The twenty second ruler of the community was a woman called BakwaTurunku, who gave birth to two daughters; Amina and Zaria. The two daughters were to become Queens in their own right and the latter even gave her name to the city (Ibrahim, 2008; Walker and Gaddafi, 2015).

Zaria is among the twenty local government areas (LGA) of Kaduna state. The LGA has thirteen wards and is a land of many ethnic groups. The old part of the city, known as BirninZazzau or Zaria-City, was originally surrounded by walls and fortress, which now have been mostly removed (Thomas, 1984). The Emir's palace is located in the old city. In the old city and the adjacent Tudun Wada neighborhood people typically reside in traditional adobe compounds. These two neighborhoods are predominantly occupied by the indigenous Hausa (Thomas, 1984).

The neighbourhoods of Samaru and Sabon Gari are predominantly occupied by Nigerians of southern origin, such as the Igbo and Yoruba (Thomas, 1984). The largest marketplace is in Sabon Gari (Thomas, 1984). Other more recent neighborhoods include: Danmagaji/Wusasa, PZ, Kongo, GRA-Zaria, Hanwa, Bassawa, LowcostKofan-Gayan and Shika (Thomas, 1984; Maiwada and Renne, 2007; Ibrahim, 2008; Walker and Gaddafi, 2015).

Zaria's economy is primarily based on agriculture. Staples are guinea corn and millet, and cash crops include cotton, groundnuts and tobacco (Maiwada and Renne, 2007). Zaria is also the center of a textile industry that for over 200 years has made elaborately hand-embroidered robes that are worn by men throughout Nigeria and West Africa (Thomas, 1984; Maiwada and Renne, 2007; Abbas, 2010).

Zaria is home to Ahmadu Bello University, Nigerian College of Aviation Technology, National Research Institute for Chemical Technology, Nigerian Institute of Transport Technology and Barewa College among many other institutions. Shika on the other hand, housed the Ahmadu Bello University Teaching Hospital and the National Animal Production Research Institute (Ibrahim, 2008; Abbas, 2010; Walker and Gaddafi, 2015).

3.0 MATERIALS AND METHODS

3.1 Materials

i. KaixinKX200Gportable full digital B mode human ultrasound scanner (B Mode, 2.5 MHz – 9.0 MHz Convex Probe, Xuzhou Kaixin electronic instrument co., ltd., China) was the ultrasound machine used for this study. Generation of research data is part of routine sonographic prenatal examination procedure and was done in strict compliance with the International Diagnostic Ultrasound Practice Protocol (AIUM, 2013; ACOG, 2014). See Appendix IIIfor research questionnaire.

Figure 3.1: Kaixin KX2000GHuman Portable ultrasound scanner. *www.kaixin-ultrasound.com.*

ii. SulosonicUltrasound Transmission Gel (Okene,KogiState, Nigeria.), was used as a coupling agent (gel).

Figure 3.2: Sulosnicultrasound Gel. *Sulosonic Global World Enterprises*

iii Stadiometer; electronic weighing scale with anthropometer (Radwag Balances and Scales, model WPT 60/150 OW, Torunska, Poland), was used to get maternal weight and height.

Figure 3.3: WPT 60/150 OW personal scale.

iv Electronic digital caliper (Model No. cn045, Conic Industrial Co., Ltd., Fuzhou, Fujian, China); used to measure maternal parameters such as length of digitsof the hands, hand length and breadth, foot length and leg breadth.

Figure 3.4: Electronic digital caliper.

3.2 Sample Population

From the formula: $n = \frac{(Z_\alpha + Z_\beta)^2 - \sigma^2}{d^2}$ (Gogtay, 2010)

Z_α= 1.96 (from Z tables) at type I error of 5%

Z_β = 0.842 (from Z tables) at 80% power

σ = 6.35 SD from a previous study

d = 1 (I deem a change of 1cm for placenta thickness to be clinically significant).

Computing into the above formula, it implies sample size = 316 patients needed to be studied.

Participants recruited for the purpose of this study were expectant mothers in their second and third trimesters who presentedfor routine ultrasound scanning.

3.3 Data CollectionTechniques/Methodology

3.3.1 Ultrasonographic parameters

Ultrasonographic parameters obtained include the following:

3.3.1.1 Placenta thickness (PT)

The thickness of the placenta was measured according to the method of Hoddick (Hoddick*et al*., 1985). A standardised method for measurement of placental thickness in which the thickness was measured perpendicular to the uterine wall (excluding the myometrium and subplacental veins) and through the placenta at the site of umbilical cord insertion. The location of the placenta was recorded, either as anterior or posterior depending on whether it implants on the anterior or posterior wall of the uterus.

3.3.1.2 Femoral length (FL)

A standardised method according to Hadlock *et al* (1985), was applied in measuring the FL which is to measure the longest length of the femoral shaft showing the cartilaginous femoral head and the femoral condyles.

3.3.1.3 Bi-parietal diameter (BPD)

The standard method for measuring BPD was that developed by Hadlock *et al* (1985), which is to obtain an image of the foetal head whose shape should correspond to that of a rugby football. The widest diameter between the fetal skull was measured from inner surface of the distal to the outer surface of the proximal skull bone.

3.3.1.4 Head circumference (HC)

This was measured from the same view as that used for the BPD. The first onscreen cursor was placed on the outer table of the skull at the occiput while the second cursor was then placed on the outer table of the skull at the synciput. Using the appropriate control, a ready-formed ellipse of dots is moved out from between the two cursors until it matched the outline of the fetal skull. This complies with the method of Hadlock and his colleagues (Hadlock *et al*., 1985).

3.3.1.5 Occipitofrontal diameter (OFD)

This was measured from the same view as that used for the BPD and HC. The first onscreen cursor was placed on the outer table of the skull at the occiput while the second cursor was then placed on the outer table of the skull at the synciput. This measurement was taken as the OFD and conforms with the method developed by Hadlock and his colleagues (Hadlock *et al*., 1985).

3.3.1.6 Abdominal circumference (AC)

Complying with the method developed by Hadlock and his colleagues (Hadlock *et al*., 1985), AC was measured from a transverse section of the foetal abdomen which included the following structures; a short rib on both sides, a vertebra, short length of umbilical vein and the foetal stomach. A measurement of the circumference of this image was taken as the AC.

3.3.1.7 Gestational age (GA)

The machine's software automatically calculated the GA from the FL, BPD and AC obtained as above which agrees with the method developed by Hadlock and his colleagues (Hadlock *et al*., 1985).

3.3.1.8 Foetalweight (FW)

The estimation of the FW was according to the method of Hadlock (Hadlock *et al*., 1985) whereby combining the FL, BPD and AC by the machine's software automatically generated the FW.

For consistency, all sonographic parameters were taken by the lead researcher and each of the above parameter was calculated by taking the average of three best measurements for each variable.

3.3.2 Maternal parameters

Maternal parameters obtained included the following:

3.3.2.1 Weight and height

A machine was used that simultaneously measured the maternal weight and height which was recorded. In measuring the maternal height, the method of DeVader*et al*(2007).

3.3.2.2 Digit lengths of the hands, hand length, hand breadth, foot length and footbreadth

Digit length (DL) was measured on the ventral surface of the hand from the basal crease of the digit to the tip.

*Hand length (HL)*was measured as the projected distance between the midpoint of a line joining the styloid process of radius and ulna bones of forearm and the tip of the third finger.

Hand breadth (HB) was measured as the distance between the most prominent point on the lateral aspect of head of second metacarpal and the most prominent point on the medial aspect of the head of fifth metacarpal.

Foot length (FL) was measured as the distance from the most prominent part of the heel to the most distal part of the longest toe (great or second toe).

Foot breadth (FB) was measured as the distance between the most prominent point on the medial aspect of head of first metatarsal and the most prominent point on the lateral aspect of the head of fifth metatarsal.

All measurements were made using vernier caliper measuring to 0.05 mm. This method is shown to have a high degree of repeatability (Manning, 1995; Scutt and Manning, 1996).

3.3.3 Inclusion and exclusion criteria

The sonographic component of the inclusion and exclusion criteria was confirmed for each patient by a preliminary scan whichtook about 2 minutes to conclude. While for the non-sonographic component, their medical history was used since the study group was for pregnant women referred for routine ante natal care (ANC) ultrasound.

3.3.3.1 Inclusion criteria

The followings were the inclusion criteria:

i. pregnant Nigerian women

ii. singleton pregnancies in 2nd and 3rd trimesters of gestation

iii. presence of adequate amniotic fluid

iv. patients with no medical diseases such as gestational diabetes mellitus, pregnancy induced hypertension, hydrops fetalis and other congenital malformations

v. placentas with clear point of cord insertion visualization

vi. placentas showing no morphological variations

vii. placentas with no variations in the insertions of the cord.

viii. placentas with no variations in uterine implantation.

3.3.3.2 Exclusion criteria

The followingswere excluded from the study:

i. pregnant women that were not Nigerians

ii. multiple gestation

iii. oligohydramnios and polyhydramnios

iv. patients with medical diseases such as gestational diabetes mellitus, pregnancy induced hypertension, hydrops fetalis and other congenital malformations

v. placentas with poor visualization of site of cord insertion

vi. placentas showing morphological variations such as succenturiate placenta, lobed placenta, membranous placenta.

vii. placentas with variations in the insertions of the cord like marginal placenta and velamentous cord insertions.

viii. placentas with variations in uterine implantation like praevia and creta.

3.3.4 Study location

The study was carried out at FirstScan Zaria in Sabon GariLocal Government Area of Kaduna state.

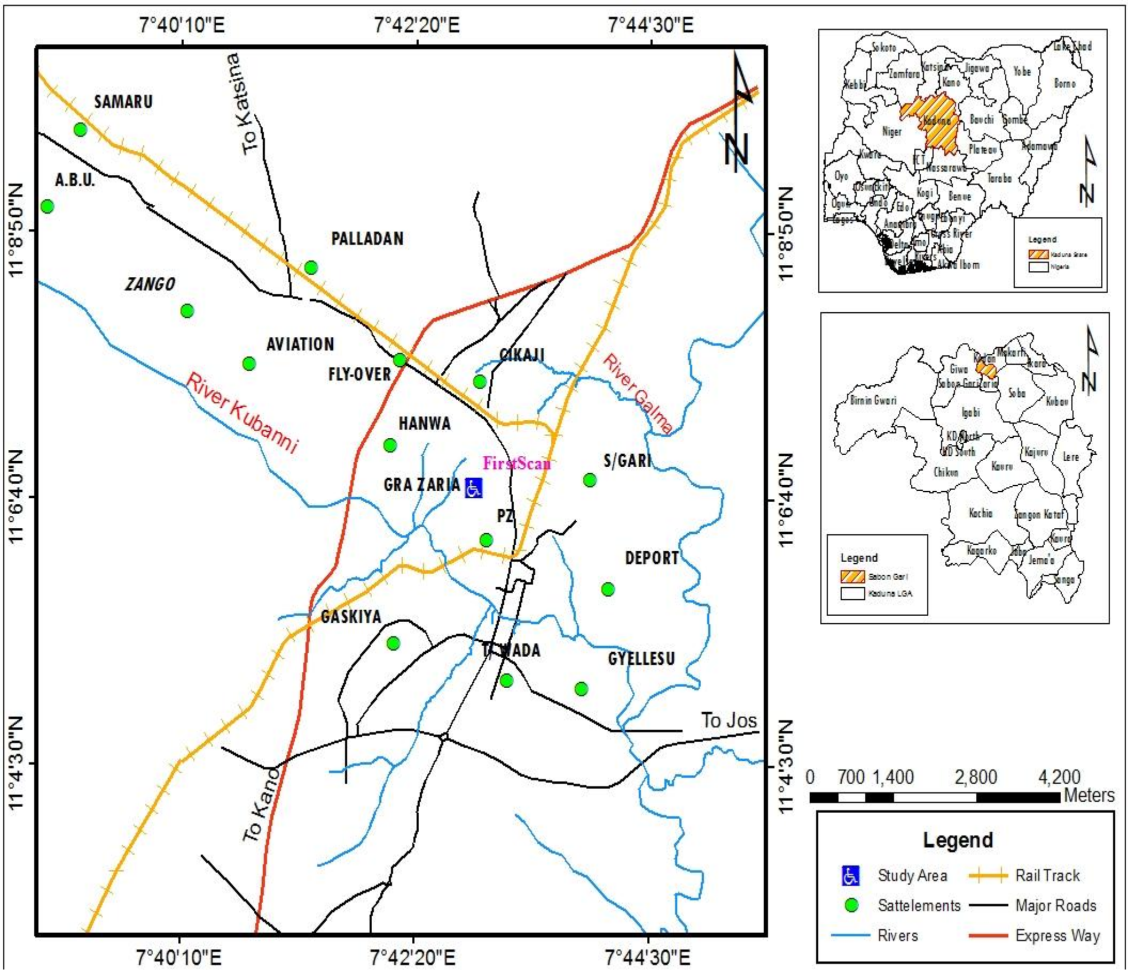

Figure 3.5.Map of Kaduna state, its local governments and study area.

Zaria, Quick Bird Image 2016.

3.4 Ethical Consideration

The proposal was submitted to Ahmadu Bello University Committee for Use of Human Subjects for Research (ABUCUHSR) for consideration and approval. Informed consent was obtained from all the volunteers using standard consent form (see Appendix II).

3.5 Statistical Analyses

Data were expressed as mean ± standard deviation (SD). Student's t-test was used to compare placental thickness, FW, AC, FL, BPD, HC, OFD and FHR in male and female foetusesand alsocompare inter-trimester foetal growth parameters and maternal anthropometric parameters. Pearson correlation was applied to test the relationship between PT, FW, AC, FL, BPD, HC and OFD. ANOVA was used to test for significant difference in FL, BPD, HC, OFD, AC, FW, PT and FHR according to maternal parity, level of education and ethnic group. Pearson correlation was also used to test the relationship between maternal anthropometric parameters and foetal growth parameters. Linear regression and multiple regression was used to predict FW and gestational age from PT. Statistical significance difference was deemed acceptable at $P < 0.05$. SPSS version 23 (IBM Corp., New York) was used for the statistical analyses and MS Excel 2016 was used to plot bar charts with error bars and correlation graphs.

4.0RESULTS

4.1 Analyses of Study Population

Pregnant motherswho presented for routine ante natal care (ANC) scan (n = 921) in their secondand thirdtrimesters of gestation participated in this study.Four hundred and sixtyeight were in their secondtrimester of gestation while the remaining four hundred and fifty three were in their third trimester.

Of the total nine hundred and twenty one pregnant mothers, six hundred and four belonged to the Hausa ethnic group, one hundred and twenty six were Fulani and the remaining one hundred and ninety one belonged to diverse ethnic groups including Ebira, Yoruba, Gurei, Jabba, Gwari, Mangu, Munguda, Idoma, Boju, Igala, Ibo, Nupe,Ogoja, Shala, Tiv and Jarawa who were grouped as Others for easier statistical analyses.

While grouping according to educational level, one hundred and ninety eight were of the group that either never went to school or had primary education, four hundred and sixteen were either in secondary school or have completed theirs and were currently not enrolled in any higher institution, while the rest three hundred and seven were either enrolled in a higher institution or have already acquired an advanced degree.

Parity grouping among the pregnant mothers was done according to the number of births. Group1 have 0 – 4 children, group 2 have 5 – 8 children and group 3 have 9 – 13 children. For group 1 we have seven hundred and forty eight mothers, group 2 have one hundred and forty four mothers while for group 3 there were twenty nine mothers.

4.2 Anthropometric Variables and Foetal Parameters

Data was collected from pregnant mothers who presented for routine ante natal care (ANC) scan in their second and third trimester of gestation using a pre-designed questionnaire. Descriptive statistics of the entire sample population of pregnant mothersand foetal growth parameters are shown on Table 4.1. From Table 4.1, the mean age and mean menarcheal age of all the pregnant mothers is (25.18 ± 5.69) years and (12.86 ± 0.73) yearsrespectively. Also from the Table, there is a significant difference between maternal weight and foetal growth parameters between pregnant mothers in their third trimester of gestation and those in their second trimester of gestation. The average maternal weight of pregnant mothers in their second trimester of gestation and those in third trimester of gestation were 58.89 ± 8.75 and 61.66 ± 10.63 kg respectively, indicating that increased foetal weight in the third trimester caused a higher maternal weight, ($t = -4.10$, $p < 0.001$). The results also revealed that all foetal growth parameters in the second trimester were different from those of the third trimester, with statistically significant difference ($p <0.001$).

Looking at Table 4.2 and 4.3, there was no statistically significant difference betweenhand and foot parameters of pregnant mothers in the second and trimesters of gestation in both the right and left hands, and the right and left feet.

Table 4.4 shows the ratio of the second to fourth digit ratio of the right and left hands of pregnant mothers according to foetal sex and period of gestation. There was no statistically significant difference in either the right or left hands when the digit ratios are grouped according to period of gestation but mothers carrying male foetuseshad higher values.

Plate 4.1: Measurement of maternal height and weight.

Plate 4.2: Measurement of maternal digit lengths of both hands (1DL: first digit length, 2DL: second digit length, 3DL: third digit length, 4DL: fourth digit length, 5DL: fifth digit length).

Plate 4.3: Measurement of maternal hand dimensions (RHB: right hand breadth, RHL: right hand length, LHB: left hand breadth, LHL: left hand length).

Plate 4.4: Measurement of maternal foot parameters (RFB: right foot breadth, RFL: right foot length, LFB: left foot breadth, LFL: left foot length).

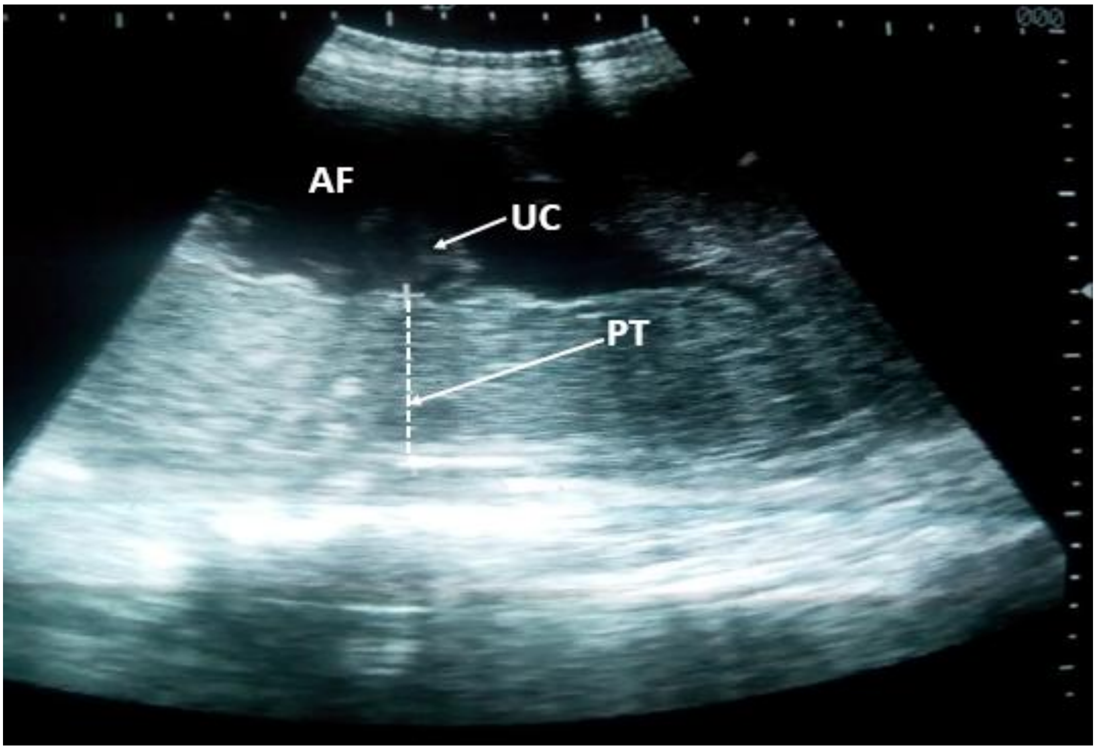

Plate 4.5: Correct level for obtaining placenta thickness and measurement (AF: amniotic fluid, UC: umbilical cord, PT: placenta thickness).

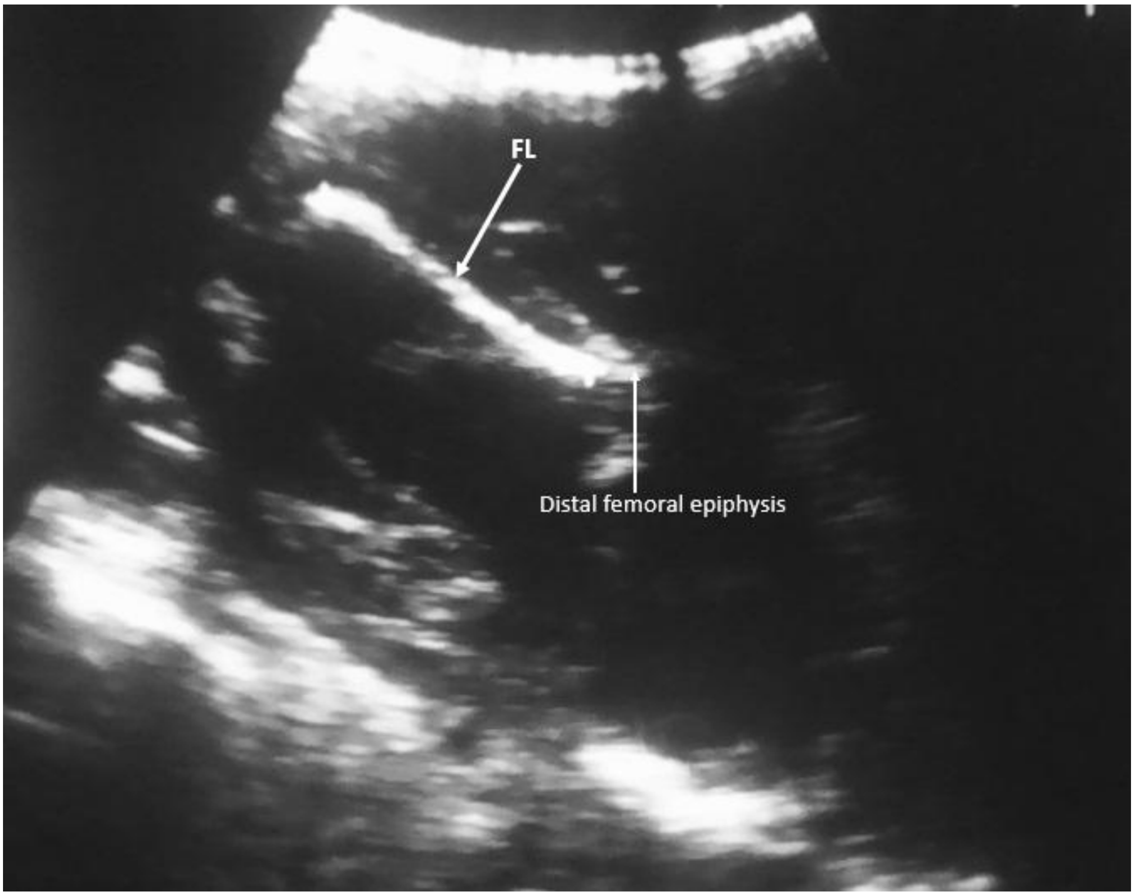

Plate 4.6: Optimal imaging of femur for length measurement. (FL: femoral length).

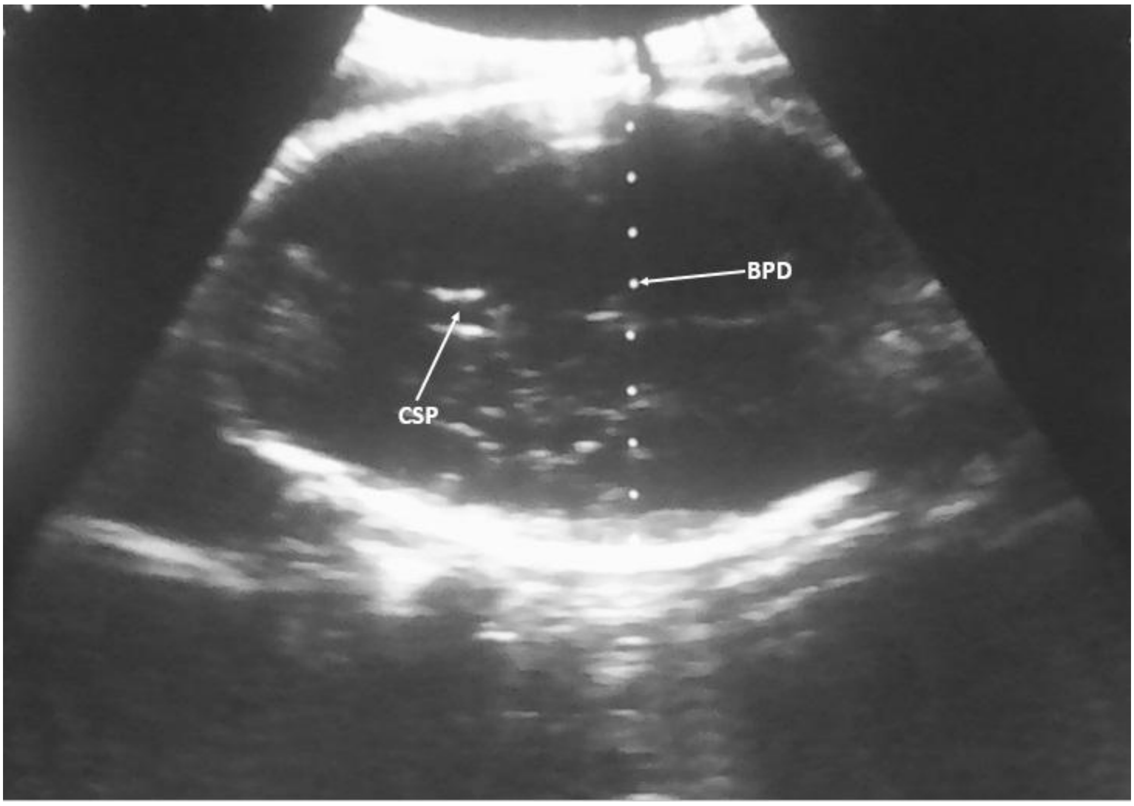

Plate 4.7: Transverse plane of the foetal head at the biparietal diameter (BPD) level. (CSP: cavum septum pellucidum).

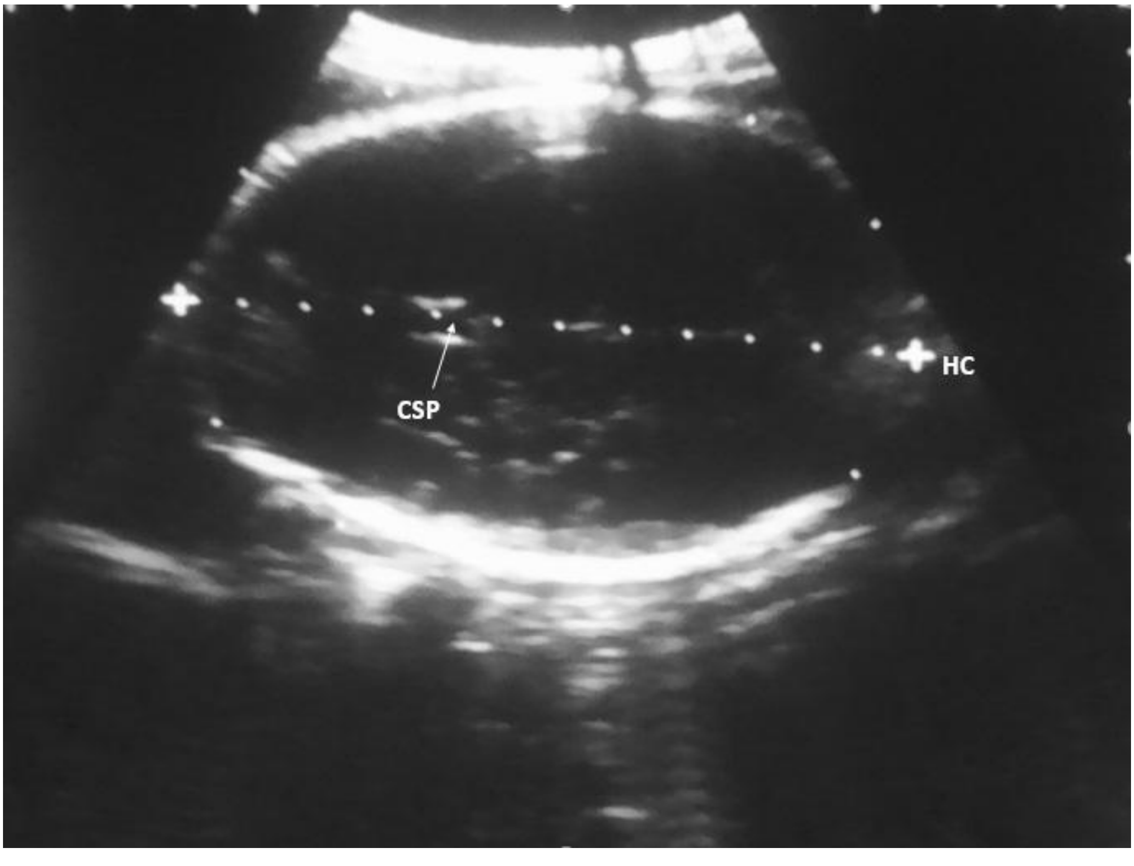

Plate 4.8: Transverse plane of the foetal head at the biparietal diameter level measuring head circumference (HC). The HC is measured by the ellipse method.(CSP: cavum septum pellucidum).

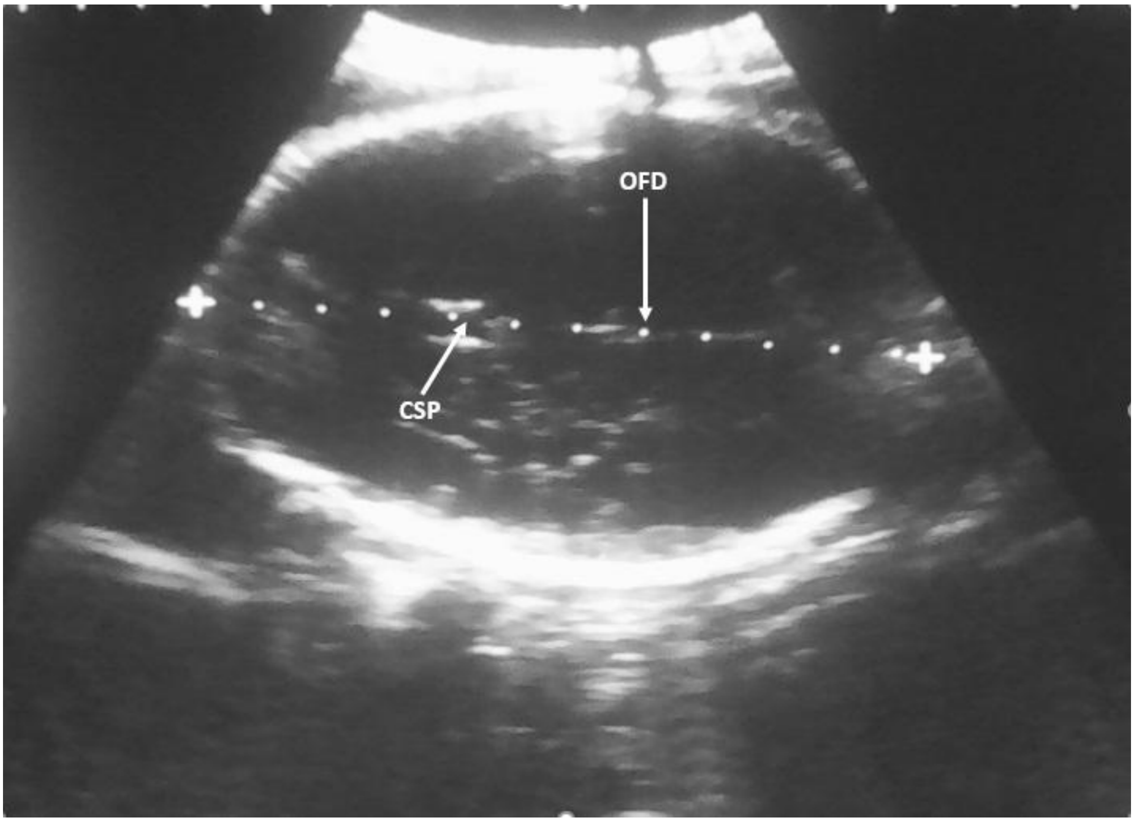

Plate 4.9: Transverse plane of the foetal head at the biparietal diameter level measuring occipitofrontal diameter(OFD). (CSP: cavum septum pellucidum).

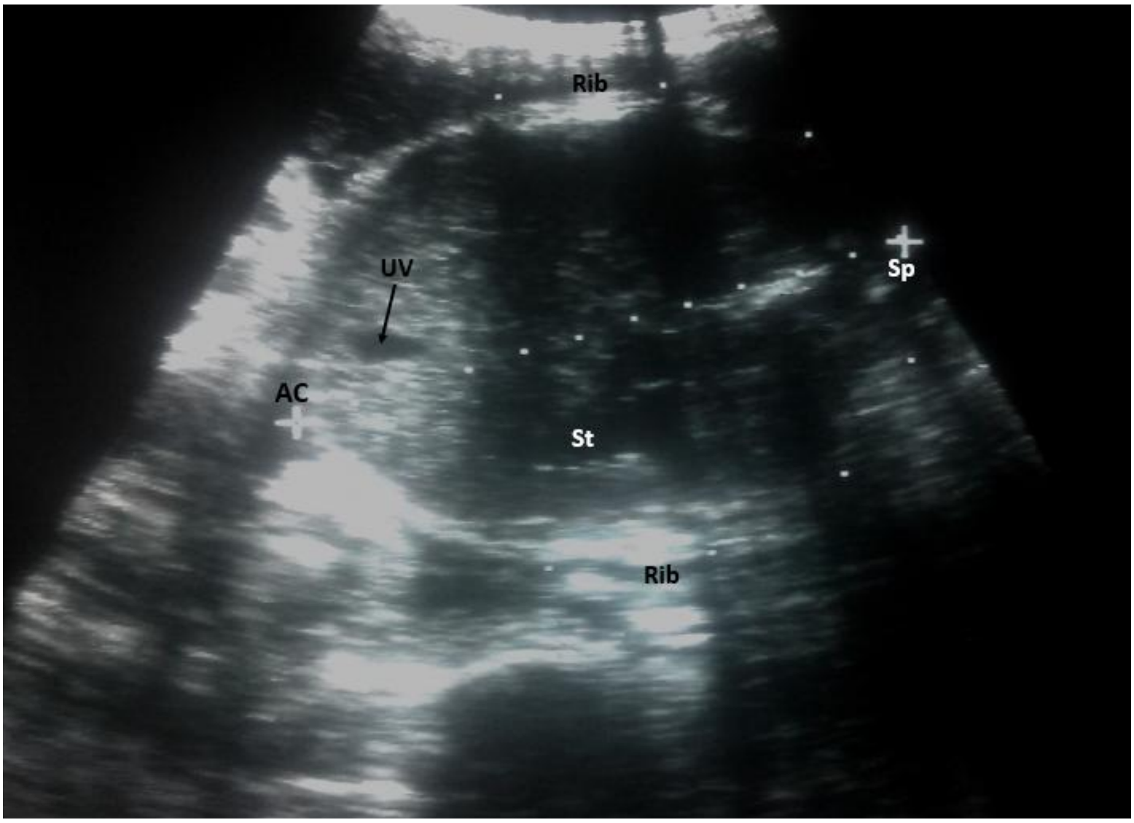

Plate 4.10: Transverse plane of the foetal abdomen at the anatomic level of the abdominal circumference (AC). (UV: Umbilical vein, St: Stomach bubble, Sp: Spine at 2’oclock position).

Table 4.1 Maternal anthropometric parameters and foetal growth parameters for all trimesters of gestation (n=906)and for subjects according to period of gestation.

Parameters	(All subjects n= 921) Mean ± SD	Min – Max	(2nd trimester n=468) Mean ± SD	Min - Max	(3rd trimester n=453) Mean ± SD	Min - Max	t	p
Age (years)	25.18 ± 5.69	16.00 - 44.00	24.72 ± 5.36	14.00 - 18.00	25.66 ± 5.99	16.00 – 44.00	-2.64	0.009
MA (years)	12.86 ± 0.73	10.00 - 14.00	12.89 ± 0.63	11.00 – 14.00	12.82 ± 0.82	10.00 – 14.00	1.43	0.153
HT (cm)	160.75 ± 5.64	144.00-174.00	160.83 ± 5.37	145.00-174.00	160.67 ± 5.89	144.00 – 173.00	0.53	0.598
WT (kg)	60.26 ± 9.82	40.00 - 98.00	58.89 ± 8.75	43.00 – 98.00	61.66 ± 10.63	40.00 – 98.00	-4.10	0.001
FL (cm)	5.19 ± 1.22	2.90 - 7.60	4.14 ± 0.53	2.90 – 5.10	6.29 ± 0.63	5.10 – 7.60	-55.00	0.001
BPD (cm)	6.98 ± 1.33	4.50 - 9.70	5.85 ± 0.66	4.50 – 7.80	8.15 ± 0.65	6.50 – 9.70	-53.13	0.001
HC (cm)	25.51 ± 4.85	16.20 - 34.90	21.32 ± 2.37	16.20 – 30.00	29.84 ± 2.27	24.30 – 34.90	-55.53	0.001
OFD(cm)	9.44 ± 1.70	5.70 - 18.10	8.03 ± 0.97	5.70 – 18.10	10.92 ± 0.82	9.00 – 12.80	-47.50	0.001
AC (cm)	24.12 ± 5.55	14.40 – 37.10	19.39 ± 2.24	14.40 – 25.40	29.01 ± 3.23	19.80 – 37.10	-52.56	0.001

FW (kg)	1.43 ± 0.88	0.30 – 3.83	0.69 ± 0.23	0.30 – 1.32	2.19 ± 0.62	1.03 – 3.83	-48.11	0.001
FHR (bpm)	140.95 ± 5.79	128.00–157.00	136.89 ± 3.22	130.00-143.00	145.14 ± 4.79	128.00 – 157.00	-31.69	0.001
PT (cm)	4.02 ± 0.59	2.80–5.80	3.61 ± 0.34	2.80– 4.50	4.45 ± 0.47	3.00 – 5.80	-31.34	0.001

MA: Menarcheal age, HT: height, WT: weight, FL: femoral length, BPD: biparietal diameter, HC: head circumference, OFD: occipitofrontal diameter, AC: abdominal circumference, FW: foetal weight, FHR: foetal heart rate, PT: placenta thickness

Table 4.2Maternal right hand and right footparameters for all trimesters of gestation (n=675) and for subjects according to period of gestation.

Parameters	(All subjects n= 675) Mean ± SD	Min – Max	(2nd trimester n=222) Mean ± SD	Min - Max	(3rd trimester n=453) Mean ± SD	Min - Max	t	p
1st digit (cm)	6.28± 0.39	5.08- 8.81	6.29± 0.37	5.36 - 7.31	6.28 ± 0.40	5.08 – 8.81	-0.21	0.829
2nd digit (cm)	6.94 ± 0.44	5.83 - 8.39	5.83 ± 0.44	5.83 – 8.39	6.94 ± 0.44	5.85 – 8.39	-0.09	0.927
3rd digit (cm)	6.54 ± 0.42	6.54 - 9.19	7.77 ± 0.41	6.77 - 9.19	7.77 ± 0.42	6.54 – 8.99	-0.45	0.656
4th digit (cm)	7.23 ± 0.46	5.99 - 9.44	7.24 ± 0.44	5.99 – 8.35	7.22 ± 0.47	6.02 – 9.44	-0.33	0.739
5th digit (cm)	5.69 ± 0.38	4.58 - 7.04	5.68 ± 0.39	4.58 – 7.04	5.69 ± 0.37	4.59 – 6.91	-0.50	0.614
Hand length (cm)	18.15 ± 0.85	16.12 - 20.73	18.14 ± 0.80	16.65 – 20.62	18.16 ± 0.86	16.12 – 20.73	-1.02	0.305
Hand breadth (cm)	7.96 ± 0.45	6.47 - 9.97	7.99 ± 0.43	6.52 – 9.18	7.95 ± 0.46	6.47 – 9.97	0.62	0.532
Foot length (cm)	23.88 ± 1.08	21.00 - 27.30	23.86 ± 1.14	21.40 – 27.30	23.89 ± 1.06	21.00 – 26.70	0.41	0.676

Foot breadth (cm)	9.56 ± 0.55	7.57 – 11.03	9.55 ± 0.55	7.57 – 11.01	9.57 ± 0.55	8.07 – 11.03	-0.68	0.493
2:4 hand digit ratio	0.96 ± 0.04	0.74 – 1.16	0.96 ± 0.04	0.85 – 1.16	0.96 ± 0.04	0.74 – 1.06	0.21	0.834

Table 4.3Maternal left hand and left footparameters for all trimesters of gestation (n=675) and for subjects according to period of gestation.

Parameters	(All subjects n= 675) Mean ± SD	Min – Max	(2^{nd} trimester n=222) Mean ± SD	Min - Max	(3^{rd} trimester n=453) Mean ± SD	Min - Max	t	p
1st digit (cm)	6.35 ± 0.36	4.75 - 7.42	6.34± 0.33	4.97 - 7.36	6.35 ± 0.36	4.75 – 7.42	-0.57	0.565
2nd digit (cm)	6.94 ± 0.44	5.84 - 8.42	6.94 ± 0.45	5.95 – 8.32	6.94 ± 0.44	5.84 – 8.42	-0.62	0.533
3rd digit (cm)	7.79 ± 0.41	5.59-8.93	7.80 ± 0.43	5.59 - 8.92	7.79 ± 0.40	6.51 – 8.93	-0.56	0.576
4th digit (cm)	7.17 ± 0.43	6.07 - 8.49	7.17 ± 0.42	6.28 – 8.35	7.17 ± 0.43	6.07 – 8.49	-0.46	0.644
5th digit (cm)	5.69 ± 0.42	4.19 - 7.07	5.69 ± 0.43	4.71 – 7.07	5.69 ± 0.42	4.19 – 7.01	-0.33	0.741
Hand length (cm)	18.18 ± 0.79	16.07 - 20.34	5.85 ± 0.66	18.19 – 0.76	18.17 ± 0.79	16.07 – 20.27	-0.69	0.488
Hand breadth (cm)	7.86 ± 0.46	6.59 - 9.34	7.88 ± 0.45	6.79 – 9.23	7.85 ± 0.46	6.59 – 9.34	-0.12	0.990
Foot length (cm)	23.59 ± 1.11	20.90 - 26.90	23.55 ± 1.16	20.90 – 26.90	23.62 ± 1.08	20.90 – 26.90	-0.72	0.942
Foot breadth (cm)	9.54 ± 0.59	7.64 – 11.37	9.53 ± 0.59	7.64 – 10.94	9.54 ± 0.59	8.08 – 11.37	-0.69	0.489

2 to 4 hand digit ratio	0.97 ± 0.05	0.87 – 1.08	0.97 ± 0.04	0.87 – 1.08	0.97 ± 0.06	0.86 – 1.05	-0.34	0.727

Table 4.4: 2D:4D ratios in right and left hands of study subjects according tofoetal sex and trimester of gestation

	Parameter	Mean ±SD	Min – Max	t	p
	All subjects				
	R2D:4D	1.01 ± 0.04	0.74 – 1.16	-2.79	0.005
	L2D:4D	0.97 ± 0.05	0.87 – 1.08		
	Second trimester				
R2D:4D	M	0.97 ± 0.04	0.85 – 1.16	0.000	1.000
R2D:4D	F	0.96 ± 0.04	0.88 – 1.07		
L2D:4D	M	0.97 ± 0.04	0.87 – 1.06	0.137	0.891
L2D:4D	F	0.97 ± 0.04	0.87 – 1.08		
	Third trimester				
R2D:4D	M	0.97 ± 0.04	0.74 – 1.06	1.429	0.155
R2D:4D	F	0.96 ± 0.05	0.85 – 1.06		
L2D:4D	M	0.97 ± 0.04	0.86 – 1.04	2.150	0.033
L2D:4D	F	0.96 ± 0.05	0.82 – 1.05		

R2D:4D: Right hand 2nd to 4th digit ratio, L2D:4D: Left hand 2nd to 4th digit ratio, M: male, F: female

4.3 Foetal Ultrasonographic Parameters

Foetal sonographic parameters collected included femoral length (FL), biparietal diameter (BPD), head circumference (HC), occipitofrontal diameter (OFD), abdominal circumference (AC), gestational age (GA), foetal weight (FW), foetal heart rate (FHR), placenta thickness (PT), placenta location, sex of foetus and foetal lie/presentation. A total of nine hundred and twenty one pregnant mothers were scanned and data divided into second(n = 468) and third(n = 453) trimester according to gestational age of the foetus. As stated above, the pregnant women were also grouped according to ethnic group, level of education and parity. The most populous ethnic group was Hausa, while for level of education, most of the pregnant mothers went to (or are in) secondary schools and the most parity among them was 0-4 number of children.

For the foetal presentation/lie, the grouping was into three viz; cephalic longitudinal presentation which is for those foetus whose presenting part (close to the cervix) is head first and the fetal spine is in orientation to the maternal spine, breech longitudinal for thosefoetus whose presenting part is the buttocks while the foetal spine is in orientation to the maternal spine, while others grouping was for those foetus whose lie differ from longitudinal. A total of six hundred and ninetythreefoetuswere in the cephalic/longitudinal presentation, one hundred and fifty five in the breech/longitudinal presentation and seventy three were in a lie different from longitudinal.

There were more female foetuses identified with a total number of four hundred and seventy seven while four hundred and forty four foetuses were male.

As for the placental location, a total of four hundred and sixty two were anterior while four hundred and fifty eight were posterior.

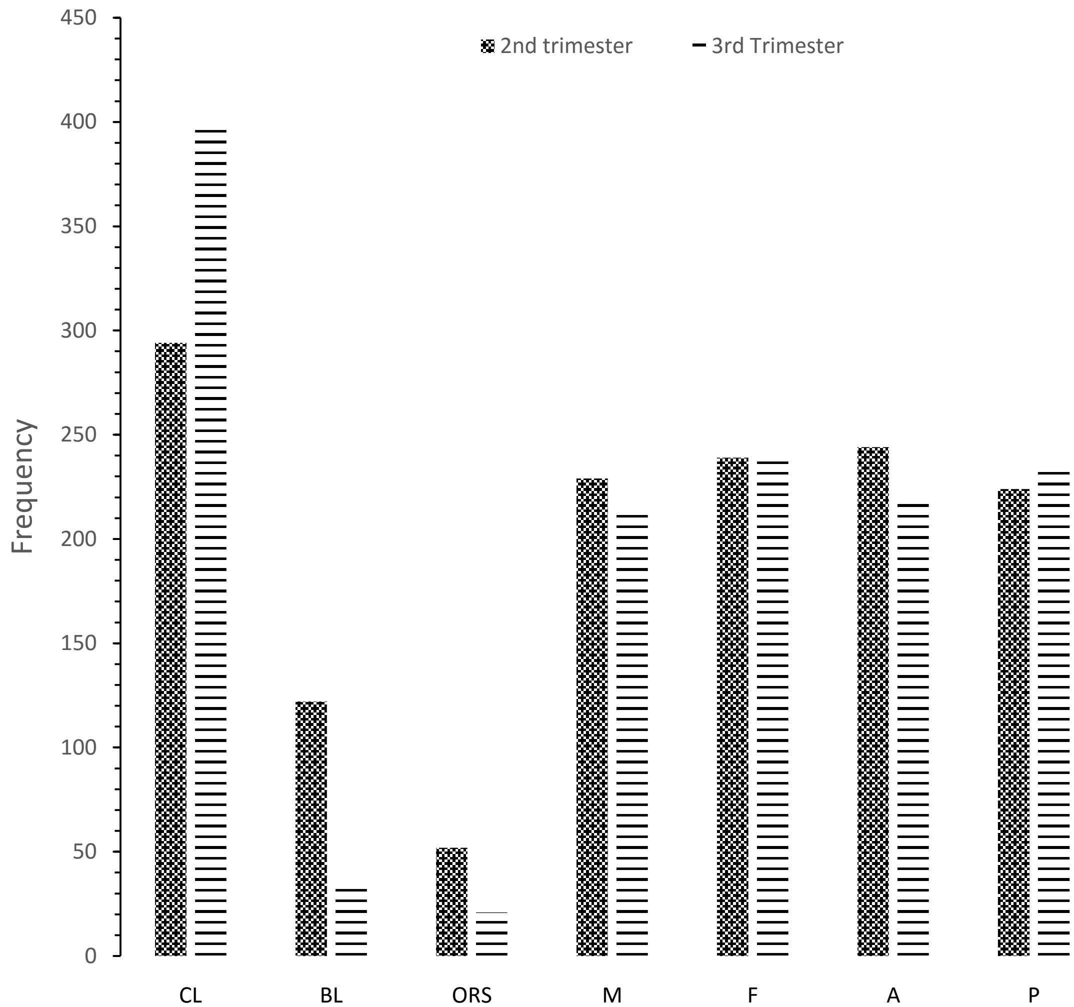

Figure 4.1: Frequency of foetal parameters in the second and third trimesters of gestation. CL = Cephalic longitudinal, BL = Breech longitudinal, ORS = Others, M = Male, F = Female, A = Anterior, P = Posterior.

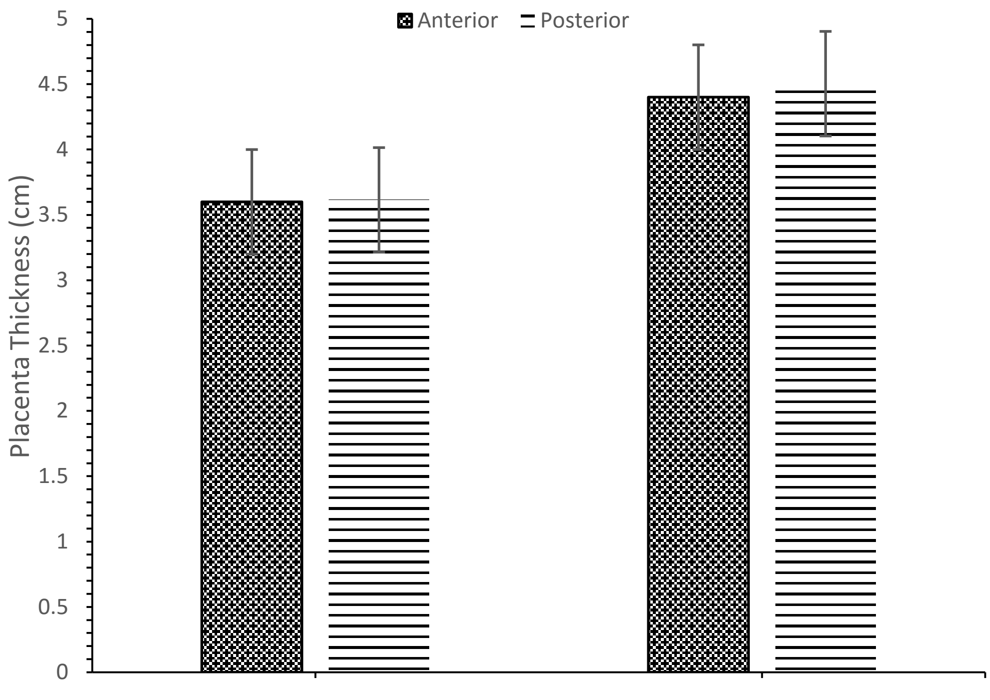

Figure 4.2: Placenta thickness according to location. Student t-test indicates no significant difference in thickness between anterior and posterior placenta in the 2nd and 3rd trimester gestation.

4.4 Foetal Growth Parameters According to Ethnic Group, Mothers Level of Education, Parity and Sex of Foetus

Figures 4.3 to 4.10 shows foetal growth parameters according to the mother's ethnic group in the second and third trimester of gestation. The Fulani ethnic group showed consistently lower values for foetal growth parameters measured except for placenta thickness (PT) of which it had the highest value in the second trimester than other groups. In the third trimester, the other ethnic group had the highest value of abdominal circumference (AC) and foetal weight (FW).There was statistically significant difference for PT when compared with other ethnic groups in the second trimester and alsofor AC and FW in the third trimester. But for all the other foetal parameters, there was no statistically significant difference amongst the ethnic groups.

Mother's level of education had influence on the placenta thickness in the second trimester but not any other foetal growth parameter across the trimesters. The highest value was from those in the tertiary level of education group followed by the primary group and the least was from the secondary group; this can be seen from Figure4.18.But all the other foetal parameters both in second and third trimester gestation showed no statistically significant difference when grouped according to maternal level of education(Figures 4.11 to 4.18).

The foetal parameters were grouped according to parity, those mothers having 9 to 13 children had foetuses exhibiting higher foetal heart rate followed by those with 0 to 4 children while the least is for mothers with 5 to 8 children in the third trimester of pregnancy.Except for the foetal heart rate, all other foetal parameters showed no statistically significant difference when grouped according to parity(Figures 4.19 to 4.26).

The foetuses show no statistically significant difference in parameters when grouped according to sex in both second and third trimester of gestation (Figures 4.27 to 4.32).

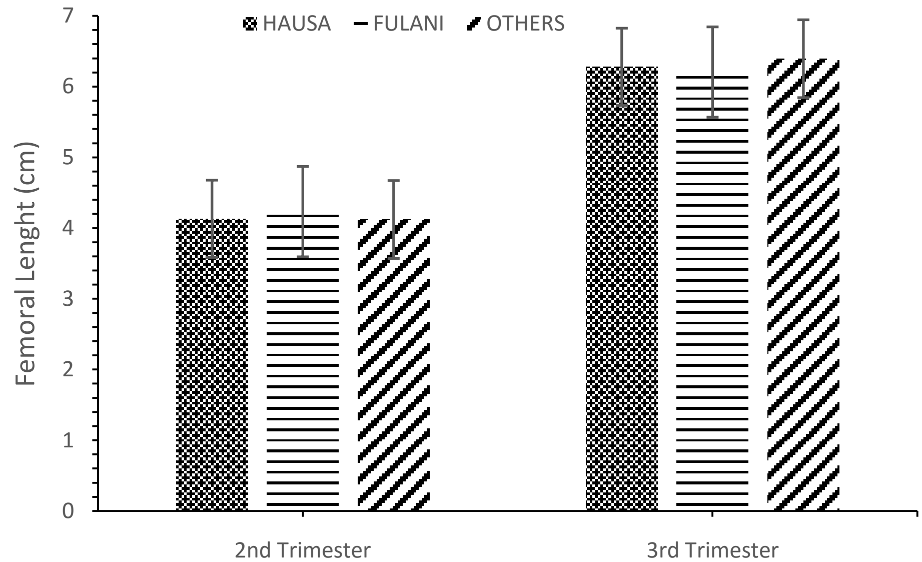

Figure 4.3: Femoral length according to trimester and ethnic group. ANOVA indicates no significant difference between the ethnic groups in 2nd and 3rd trimester gestation.

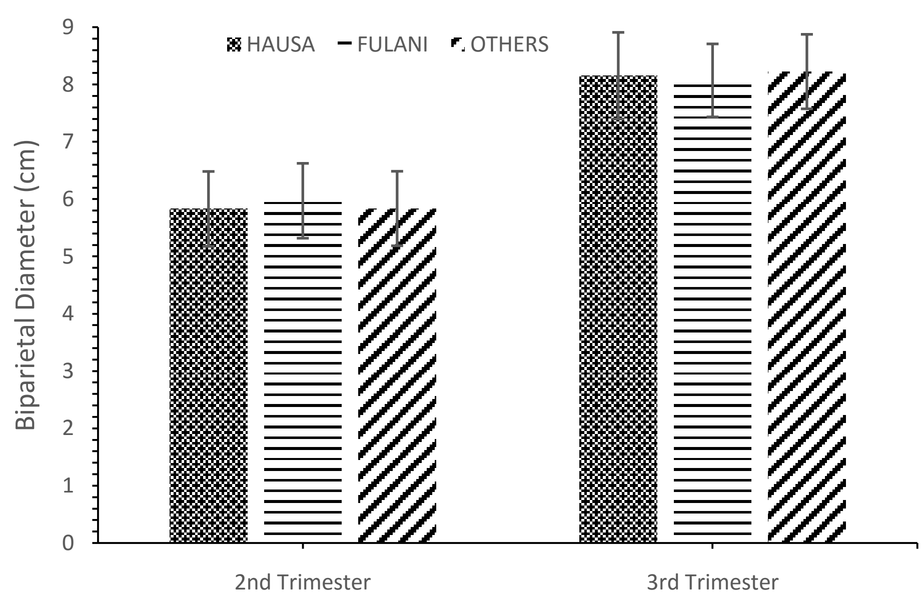

Figure 4.4: Biparietal diameter according to trimester and ethnic group. ANOVA indicates no significant difference between the ethnic groups in 2^{nd} and 3^{rd} trimester gestation.

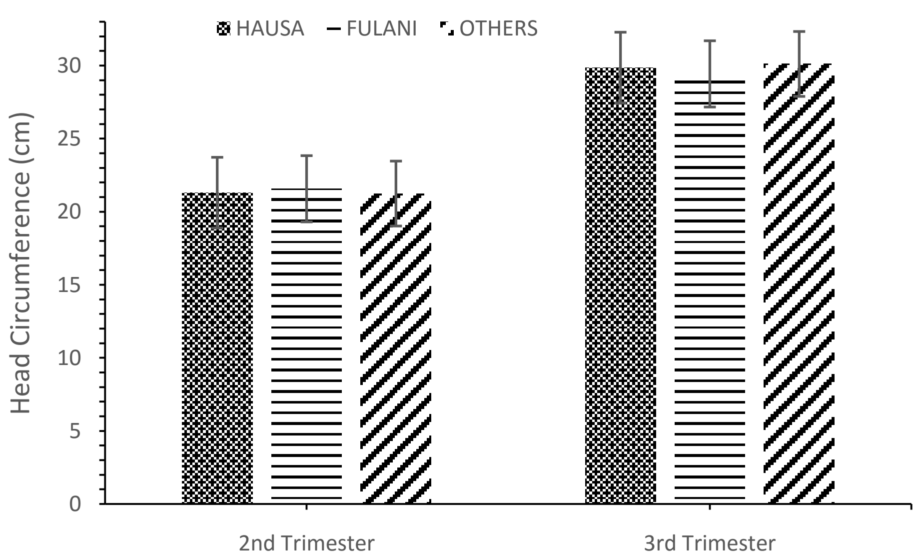

Figure 4.5: Head circumference according to trimester and ethnic group. ANOVA indicates no significant difference between the ethnic groups in 2nd and 3rd trimester gestation.

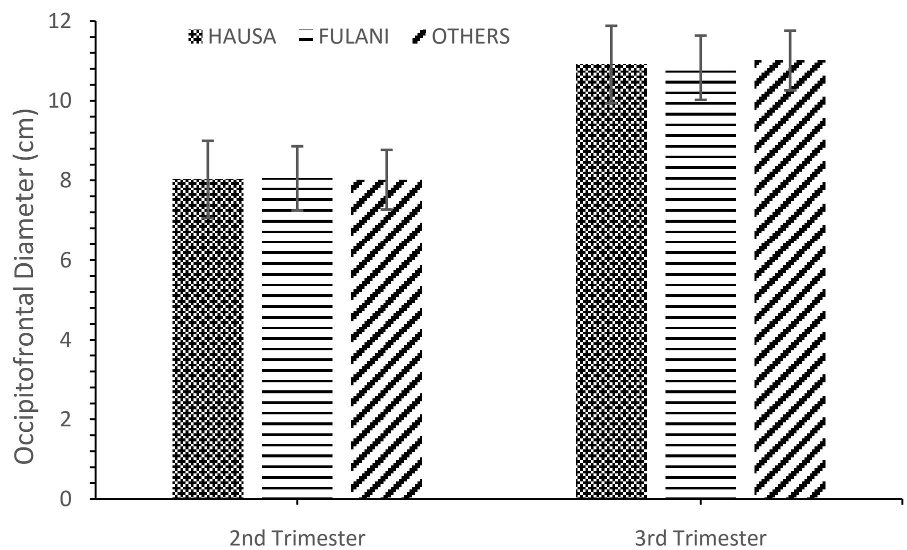

Figure 4.6: Occipitofrontal diameter according to trimester and ethnic group. ANOVA indicates no significant difference between the ethnic groups in 2nd and 3rd trimester gestation.

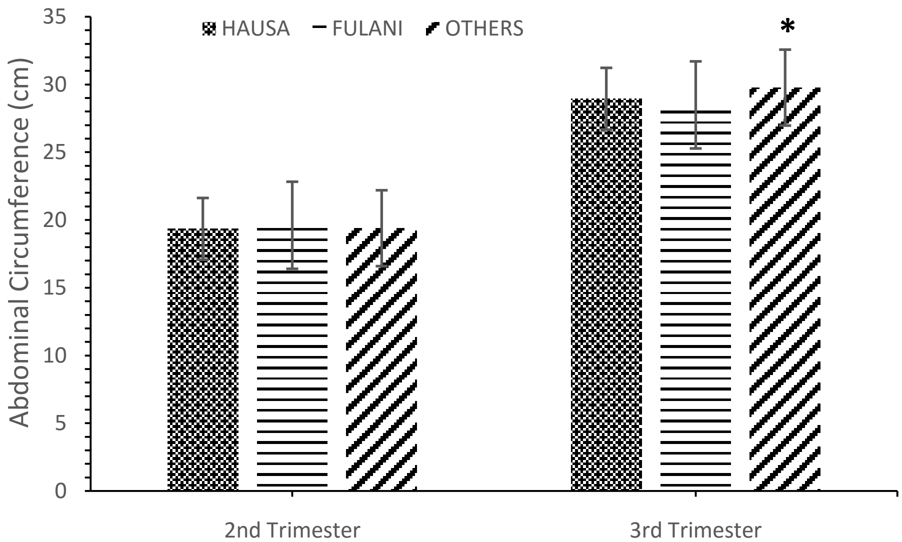

Figure 4.7: Abdominal circumference according to trimester and ethnic group. ***** = ANOVA indicatessignificant difference between the ethnic groups for abdominal circumference in 3rd trimester gestation, $p < 0.05$.

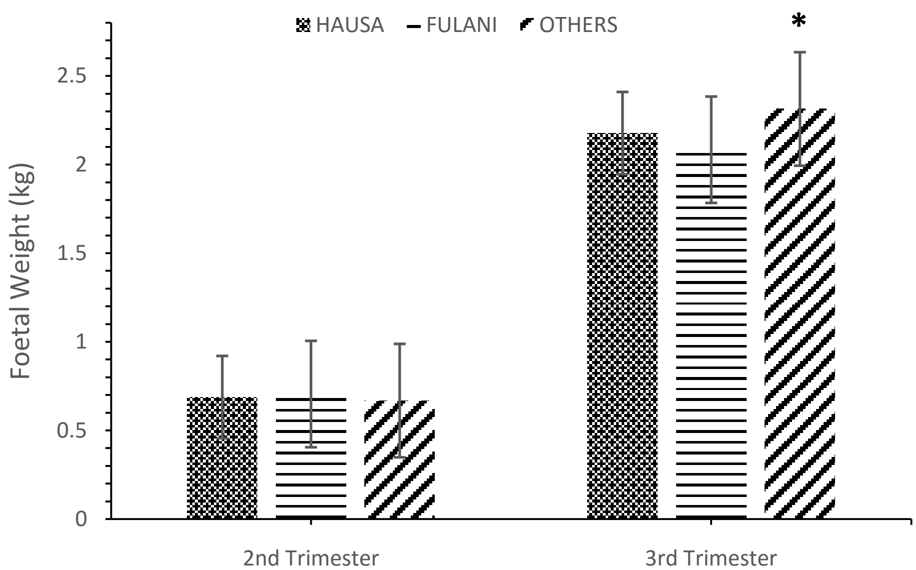
HAUSA
FULANI
OTHERS
*
Foetal Weight (kg)
0
0.5
1
1.5
2
2.5
2nd Trimester
3rd Trimester

Figure 4.8: Foetal weight according to trimester and ethnic group. ***** = ANOVA indicates significant difference between the ethnic groups for foetal weight in 3rd trimester gestation, $p < 0.05$.

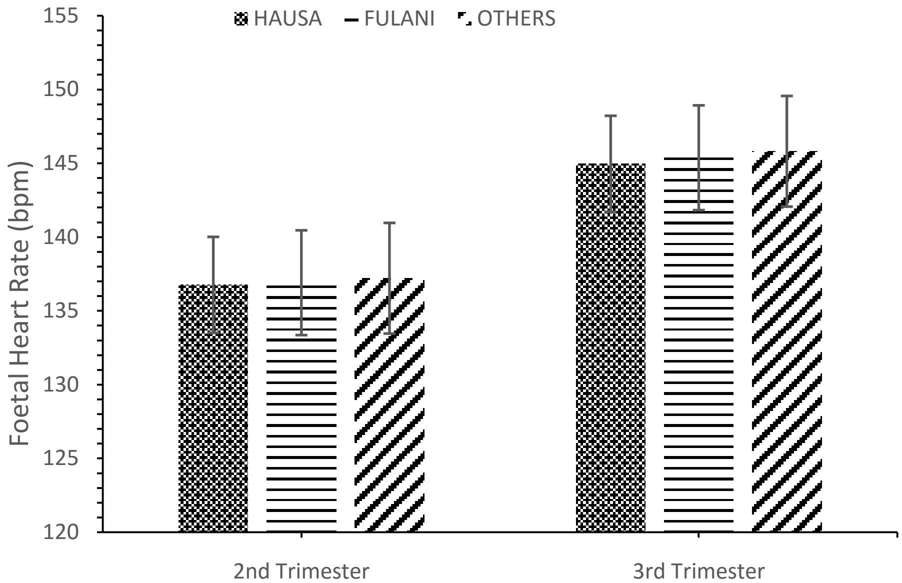

Figure 4.9: Foetal heart rate according to trimester and ethnic group. ANOVA indicates no significant difference between the ethnic groups in 2nd and 3rd trimester gestation.

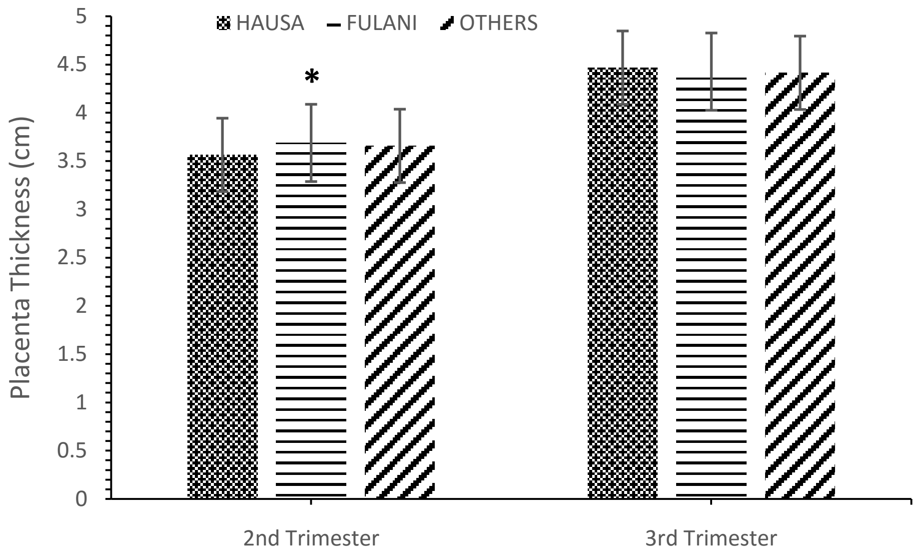

Figure 4.10: Placenta thickness according to trimester and ethnic group. * = ANOVA indicates significant difference between the ethnic groups for placenta thickness in 2nd trimester gestation, $p < 0.05$.

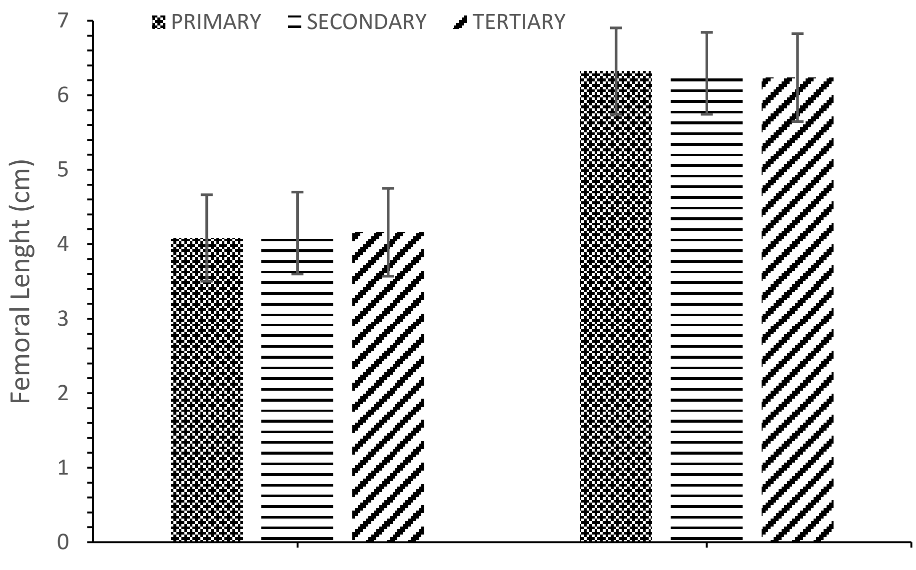

Figure 4.11: Femoral length according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

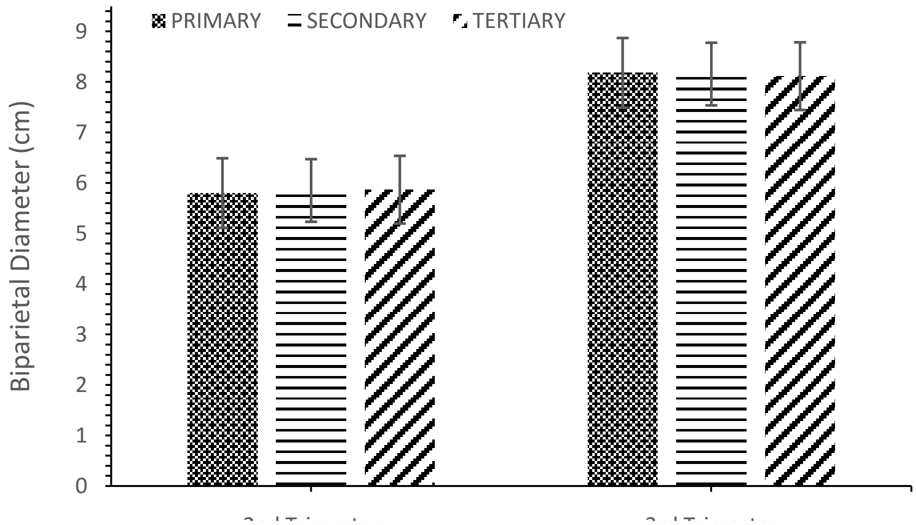

Figure 4.12: Biparietal diameter according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

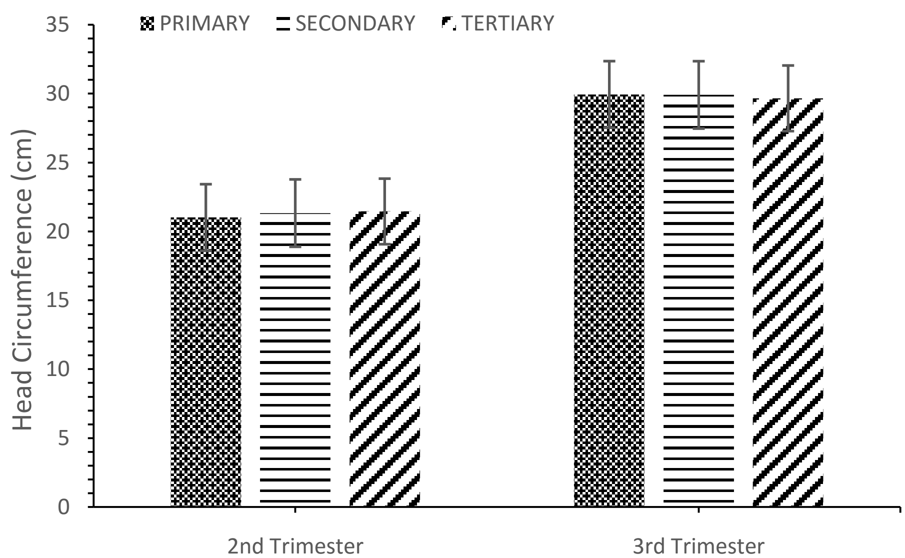

Figure 4.13: Head circumference according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

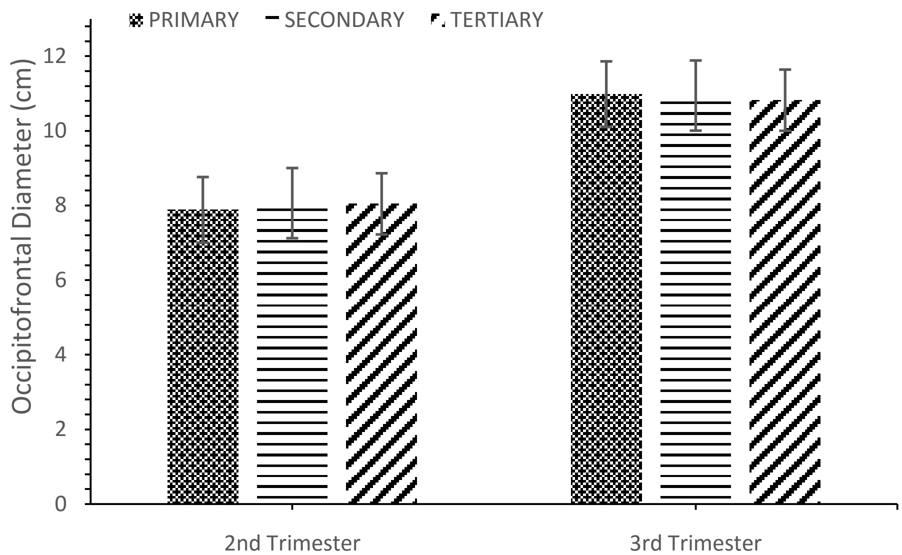

Figure 4.14: Occipitofrontal diameter according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

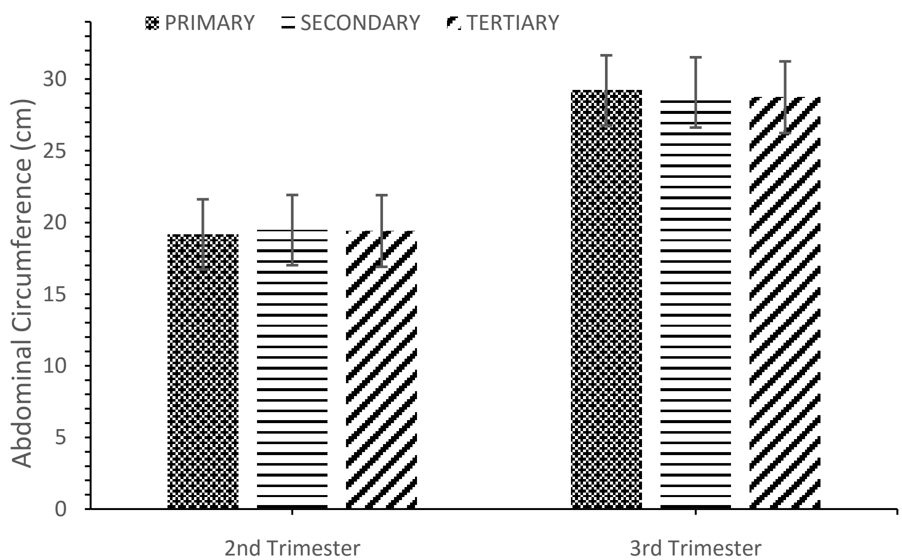

Figure 4.15: Abdominal circumference according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

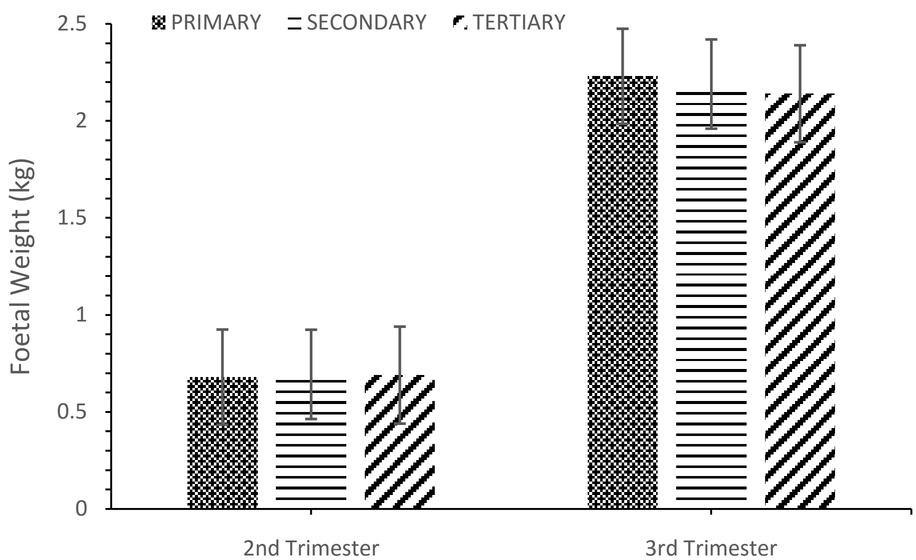

Figure 4.16: Foetal weight according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

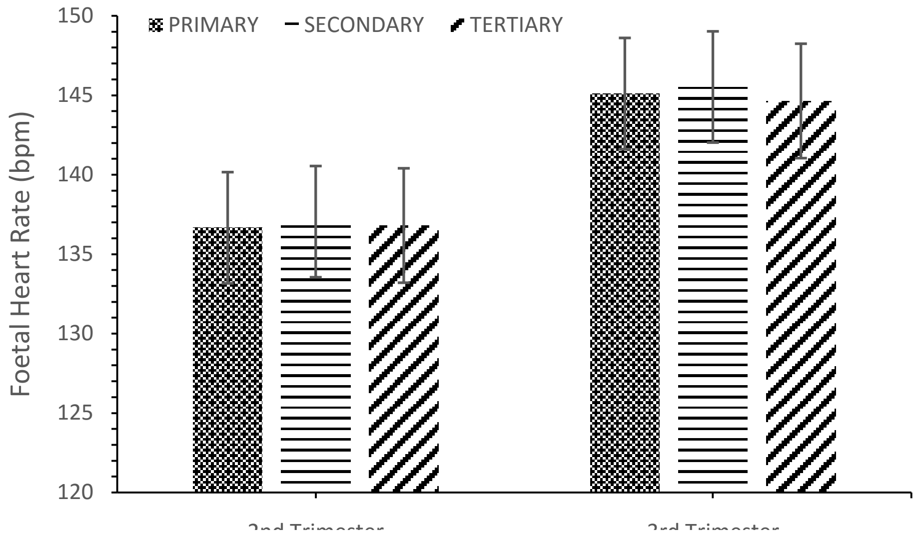

Figure 4.17: Foetal heart rate according to trimester and level of education. ANOVA indicates no significant difference between level of education in 2nd and 3rd trimester gestation.

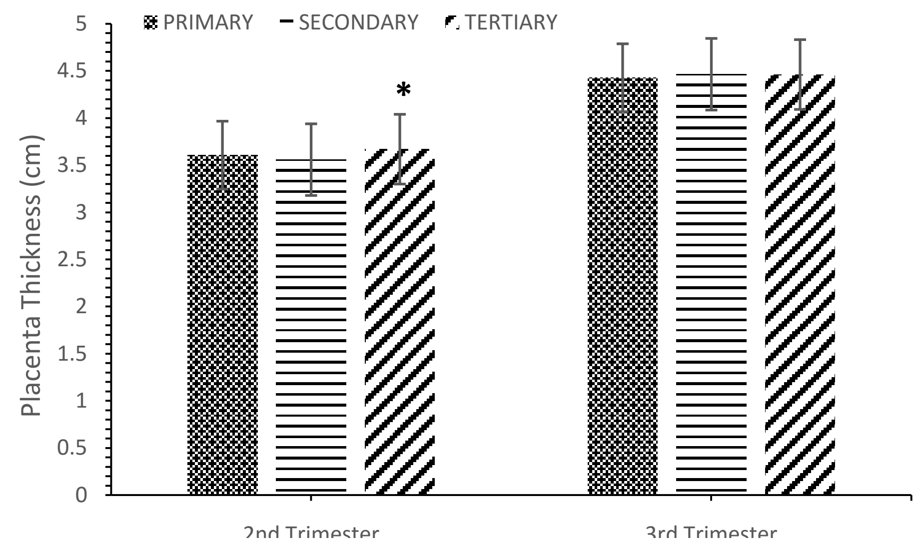

Figure 4.18: Placenta thickness according to trimester and level of education. ***** = ANOVA indicates significant difference between the groups for placenta thickness in 2nd trimester gestation, $p < 0.05$.

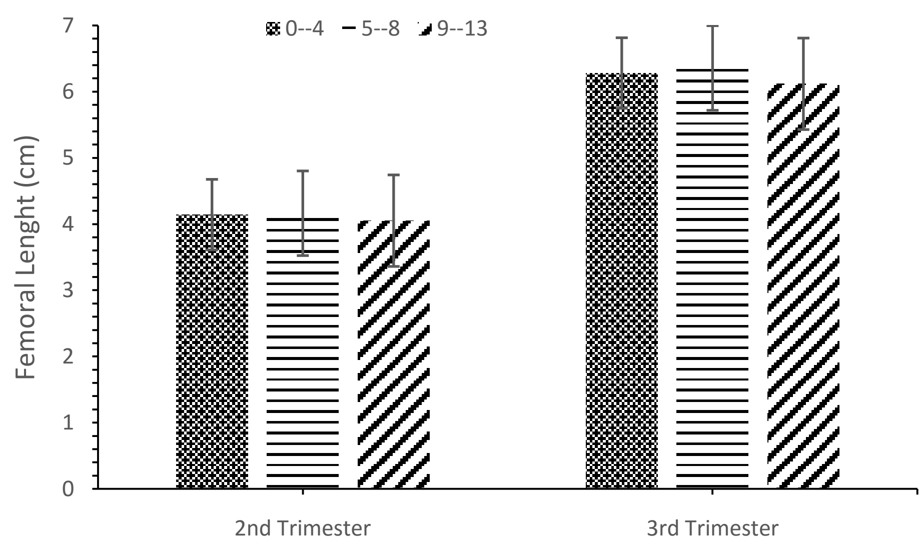

Figure 4.19: Femoral length according to trimester and parity. ANOVA indicates no significant difference between parity in 2nd and 3rd trimester gestation.

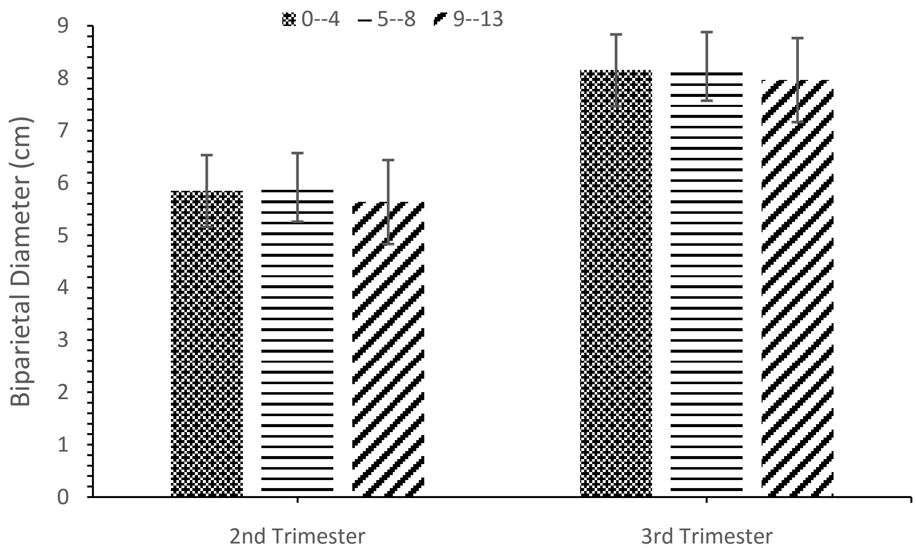

Figure 4.20: Biparietal diameter according to trimester and parity. ANOVA indicates no significant difference between parity in 2nd and 3rd trimester gestation.

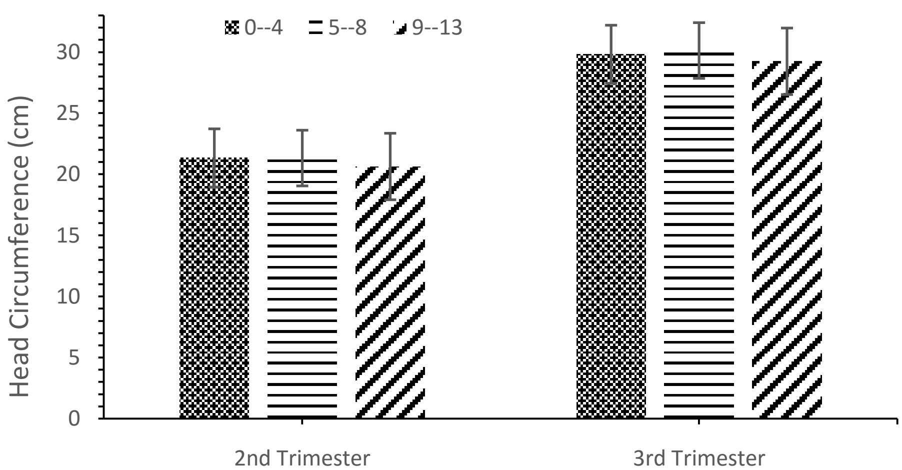

Figure 4.21: Head circumference according to trimester and parity. ANOVA indicates no significant difference between parity in 2^{nd} and 3^{rd} trimester gestation.

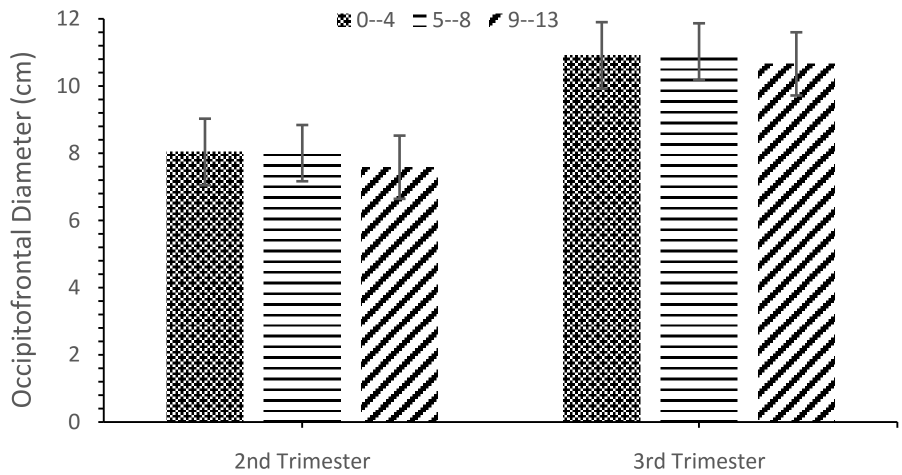

Figure 4.22: Occipitofrontal diameter according to trimester and parity. ANOVA indicates no significant difference between parity in 2nd and 3rd trimester gestation.

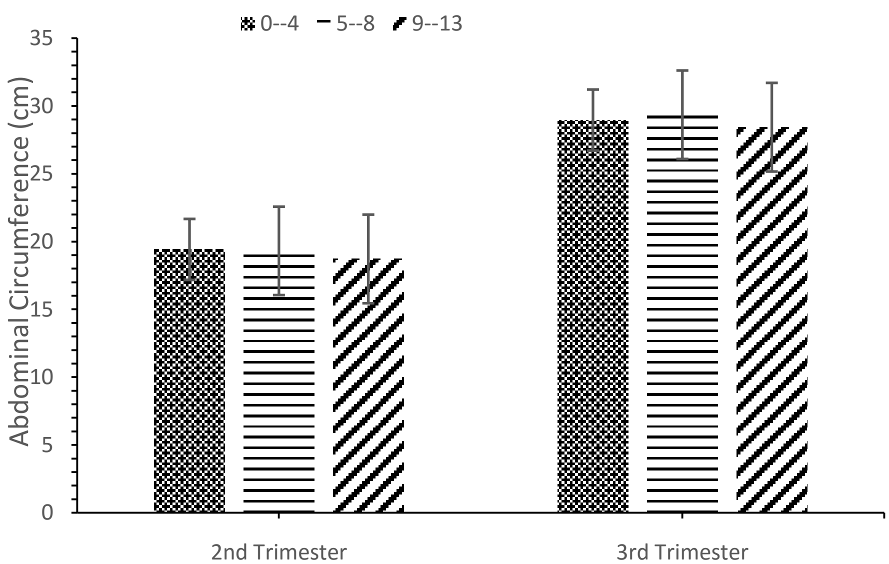

Figure 4.23: Abdominal circumference according to trimester and parity. ANOVA indicates no significant difference between parity in 2nd and 3rd trimester gestation.

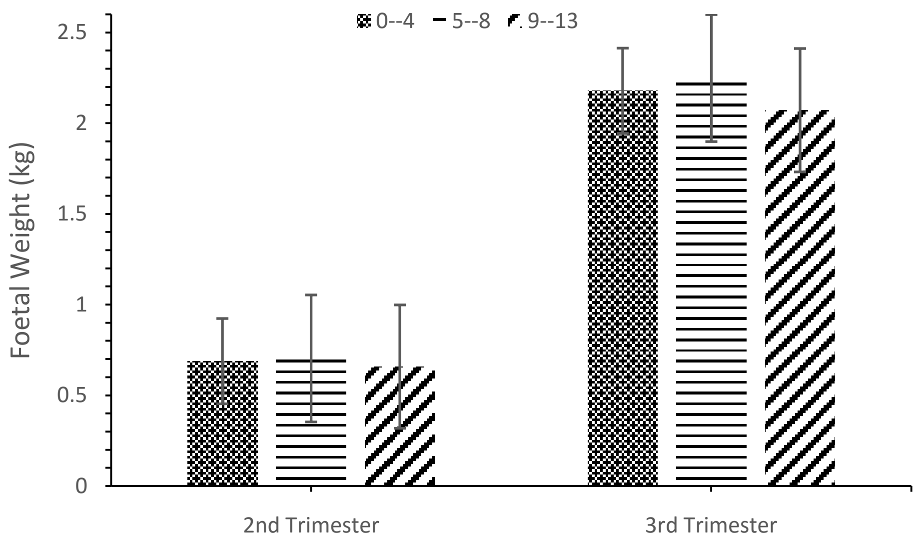

Figure 4.24: Foetal weight according to trimester and parity. ANOVA indicates no significant difference between parity in 2nd and 3rd trimester gestation.

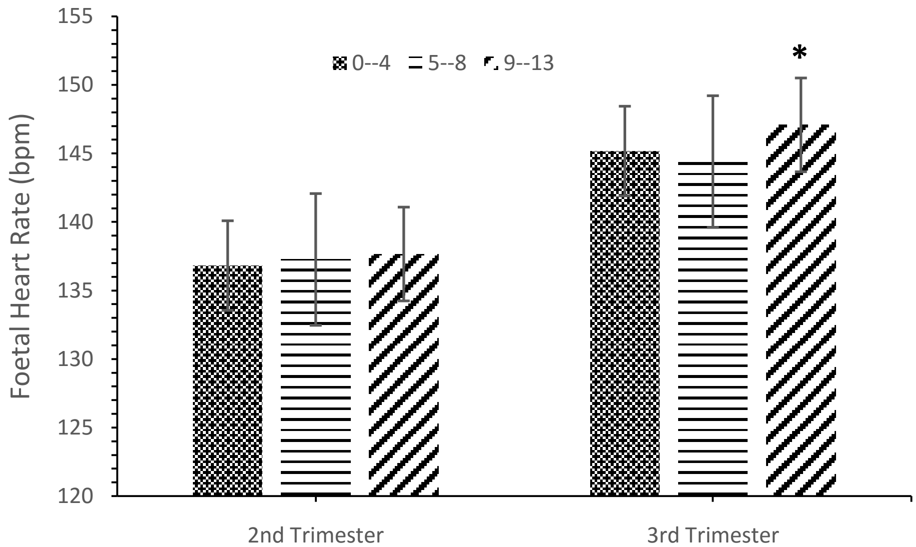

Figure 4.25: Foetal heart rate according to trimester and parity. ***** = ANOVA indicates significant difference between the groups for foetal heart rate in 3rd trimester gestation, $p < 0.05$.

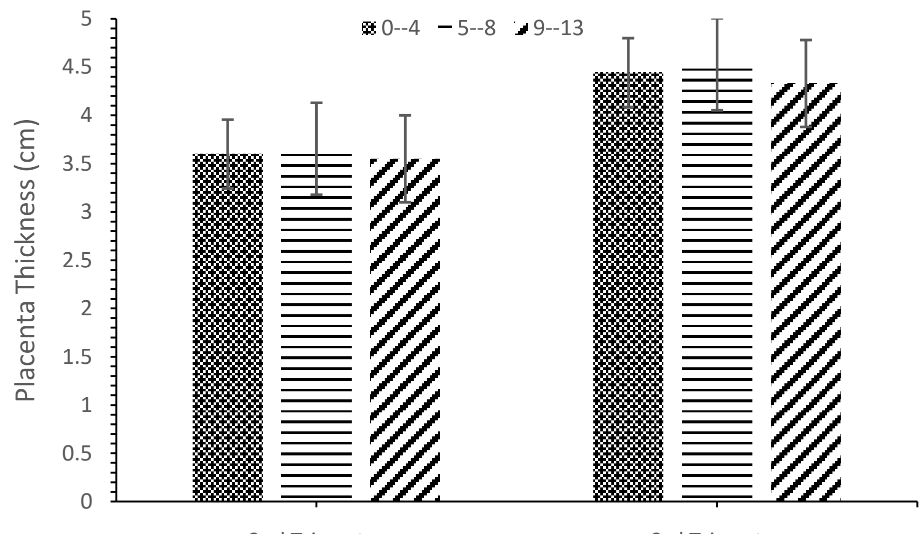

Figure 4.26: Placenta thickness according to trimester and parity. ANOVA indicates no significant difference between parity in 2nd and 3rd trimester gestation.

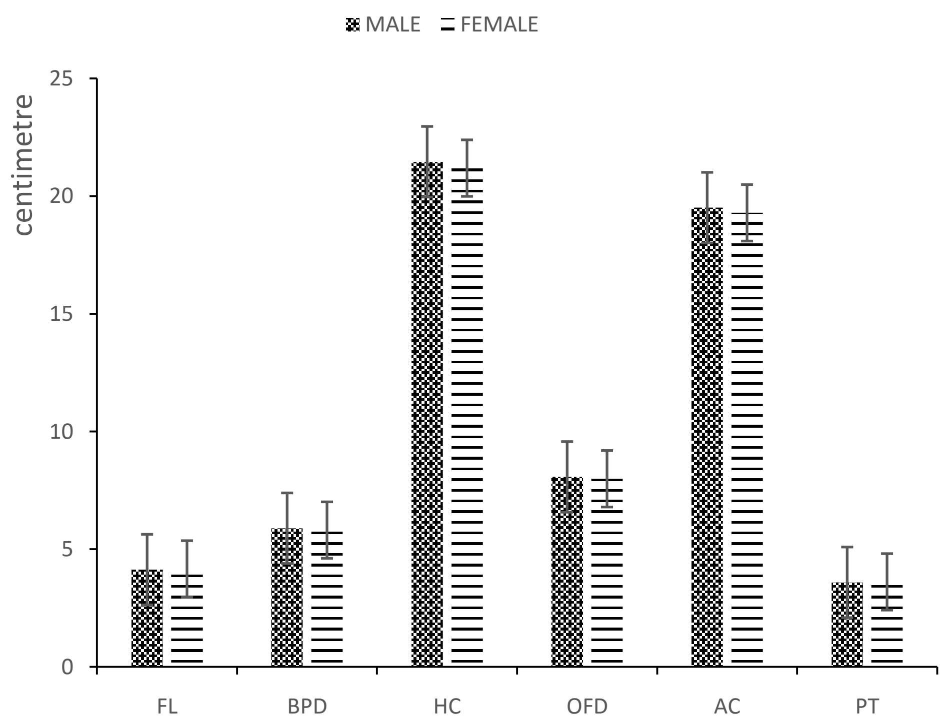

Figure 4.27: Foetal growth parameters in the 2ndtrimester of gestation according to sex of foetus. Student t-test indicates nosignificant difference between foetal parameters and sex of foetus. FL: femoral length, BPD: biparietal diameter, HC: head

circumference, OFD: occipitofrontal diameter, AC: abdominal circumference, PT: placenta thickness.

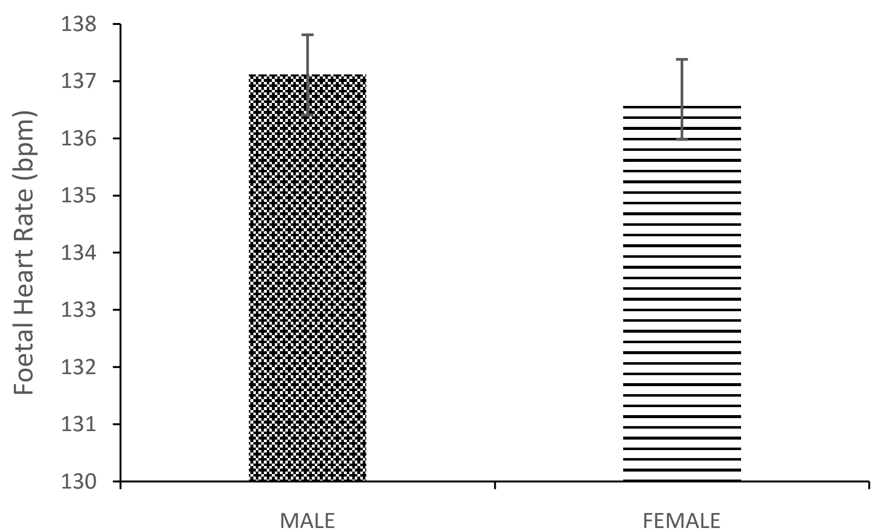

Figure 4.28: Foetal heart rate in the 2ndtrimester of gestation according to sex of foetus. Student t-test indicates no significant difference between foetal heart rate and sex of foetus.

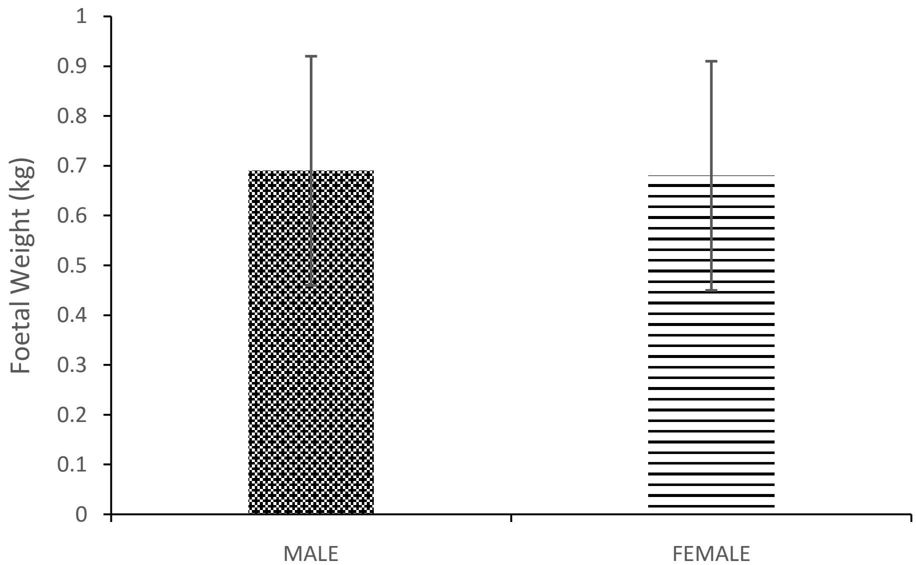

Figure 4.29: Foetalweight in the 2nd trimester of gestation according to sex offoetus. Student t-test indicates no significant difference between foetalweight and sex of foet
us.

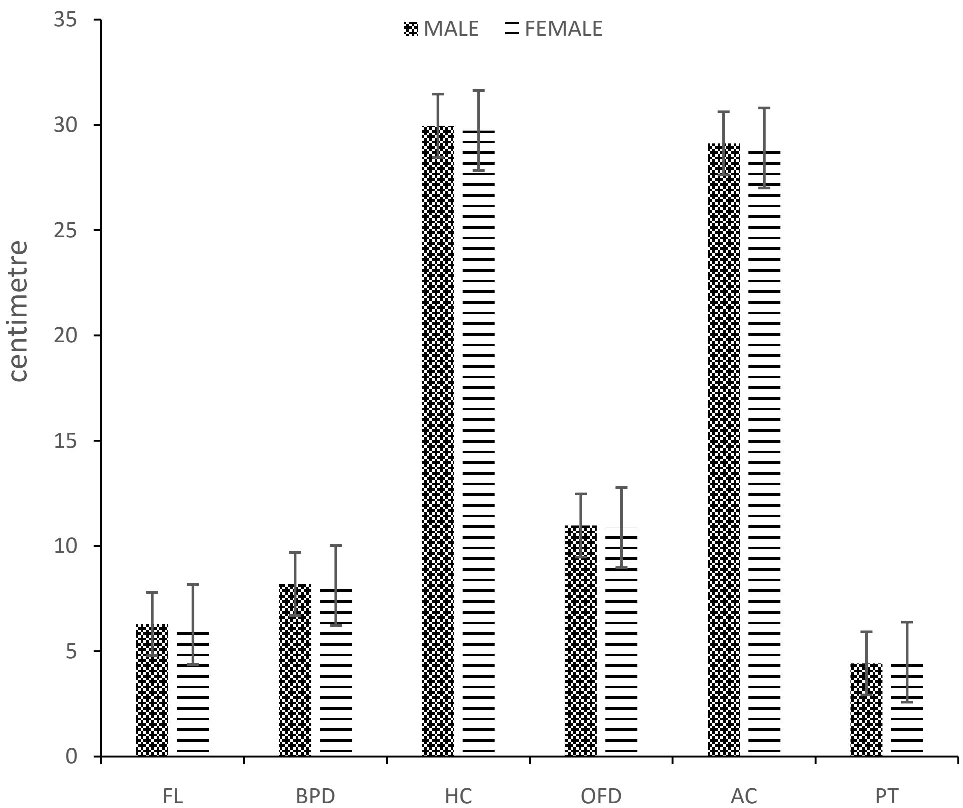

Figure 4.30: Foetal growth parameters in the 3^{rd}trimester of gestation according to sex of foetus. Student t-test indicates no significant difference between foetal parameters and sex of foetus. FL: femoral length, BPD: biparietal diameter, HC: head circumference, OFD: occipitofrontal diameter, AC: abdominal circumference, PT: placenta thickness.

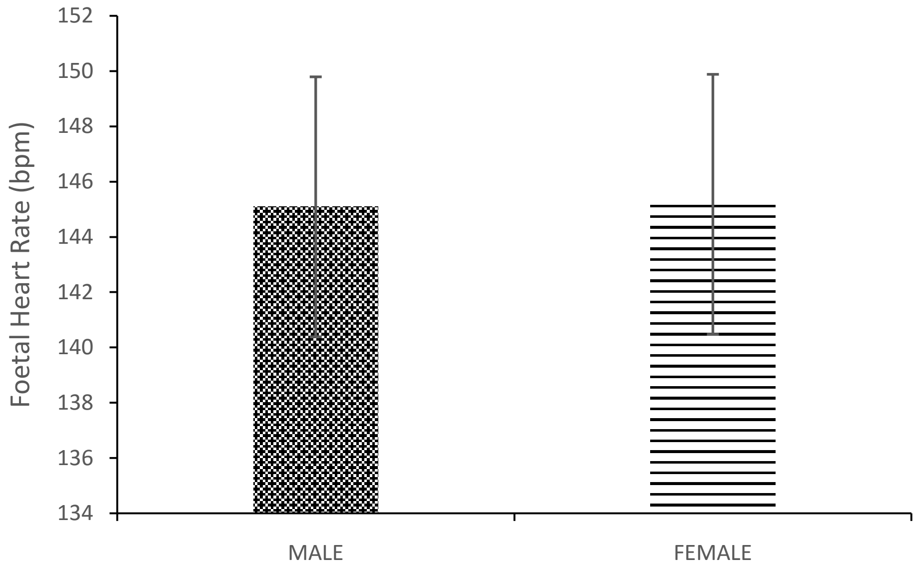

Figure 4.31: Foetal heart rate in the 3rd trimester of gestation according to sex of foetus. Student t-test indicates no significant difference between foetal heart rate and sex of foetus.

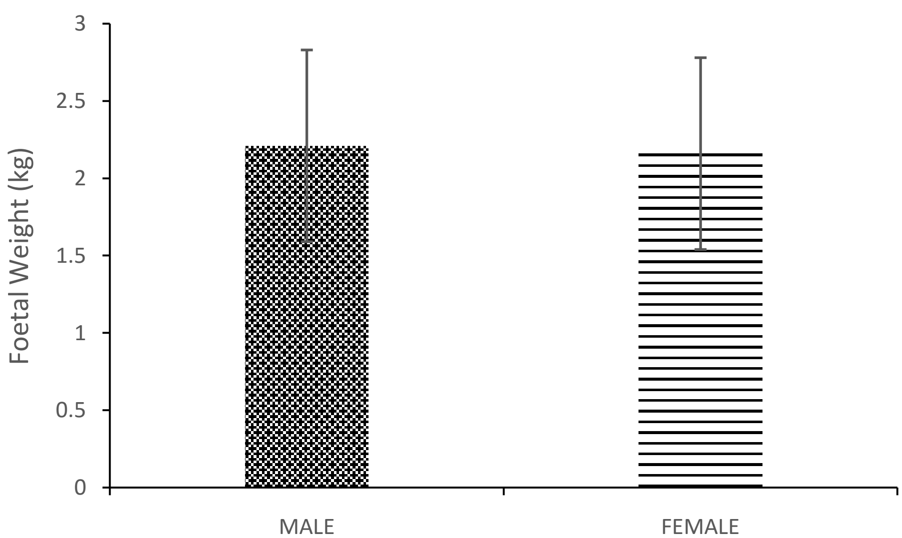

Figure 4.32: Foetal weight in the 3rd trimester of gestation according to sex offoetus. Student t-test indicates no significant difference between foetal weight and sex of foetus.

4.5Correlation Between Maternal Anthropometryand Foetal Sonographic Parameters

Table 4.5 showed the correlation matrix of some maternal anthropometric characteristics and foetal ultrasonographic parameters in the second trimester of gestation. Pearson's correlation coefficient was used to test the relationship between maternal anthropometric characteristics andfoetal sonographic parameters. From Table 4.5, there is a weak relationship between maternal weight, height and age, while the maternal weight shows significant strong positive relationshipwithfoetal sonographic parameters. There is also a strong relationship between foetal sonographic parameters $p < 0.05$. The placenta thickness shows strong relationship with maternal weight and other foetal sonographic parameters $p < 0.01$.

Looking at Table 4.6, there is a stronger relationship between the maternal anthropometric characteristics and foetal sonographic parameters in the third trimester than in the second trimester of gestation$p < 0.01$.Placenta thickness strongly correlates with all foetal growth parameters in both second and third trimesters of gestation$p < 0.01$.

Table 4.7 is a correlation matrix for maternal hand digits and foetal growth sonographic parameters in the second trimester. There was generally a negative relationship between maternal hand digit lengths and foetal sonographic growth parameters in the second trimester of gestation.

Table 4.8 shows correlation between some maternal hand and leg dimensions with foetal growth parameters. There was significant correlation between foot length and breadth with placenta thickness in second trimester gestation.

Correlation was carried out between maternal digit lengths and foetal growth parameters in the third trimester as shown in Table 4.9. Only one significant positive relationship was observed which is between maternal first digit (thumb) length of the right and left hand and placenta thickness.

Table 4.10 shows correlation between some maternal hands and foot parameters with foetal growth parameters in the third trimester gestation. There was a significant relationship between the right footbreadth and placenta thickness. While a relationship was also seen between left foot and foetal heart rate.

Correlation was carried out between second to fourth digit ratio (2D:4D) and foetal growth parameters both for the right and left hands. Table 4.11 shows no significant relationship between 2D:4D and foetal growth parameters in the second trimester of gestation. While in the third trimester there was significant positive relationship between 2D:4D of the right hand with OFD and AC but it was negative with FL, BPD and FW. The left 2D:4D showed no significant relationship with foetal growth parameters in the third trimester of gestation.

Table 4.5: Correlation matrix of maternal anthropometric parameters and foetal growth parameters in second trimester of gestation.

	AGE	HT	WT	MA	FL	BPD	HC	OFD	AC	FW	FHR	PT
AGE	-											
HT	.289[a]	-										
WT	.408[a]	.661[a]	-									
MA	-.008	-.013	-.017	-								
FL	-.001	.006	.029	-.095[b]	-							
BPD	.018	.014	.020	-.032	.901[a]	-						
HC	.001	.032	.029	-.069	.916[a]	.949[a]	-					
OFD	-.003	.001	-.017	-.012	.766[a]	.807[a]	.845[a]	-				
AC	-.011	-.027	-.005	-.038	.881[a]	.874[a]	.886[a]	.762[a]	-			
FW	.007	.000	.024	-.081	.916[a]	.900[a]	.916[a]	.765[a]	.908[a]	-		
FHR	.067	.017	.027	-.058	.042	.054	.067	.025	.054	.070	-	
PT	.052	.080	.132[a]	.133[a]	.224[a]	.254[a]	.241[a]	.217[a]	.247[a]	.240[a]	.078	-

HT = Height (cm), WT = Weight (kg), MA = Menarcheal age (yrs), FL = Femoral length (cm), BPD = Biparietal diameter (cm), HC = Head circumference (cm), OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm). a = $p < 0.05$ *b =* $p < 0.01$

Table 4.6: Correlation matrix of maternal anthropometric parameters and foetal growth parameters in third trimester of gestation.

	AGE	HT	WT	MA	FL	BPD	HC	OFD	AC	FW	FHR	PT
AGE	-											
HT	.269[a]	-										
WT	.336[a]	.531[a]	-									
MA	.108[b]	-.060	-.009	-								
FL	.033	.056	.117[b]	.008	-							
BPD	.019	.052	.112[b]	.020	.931[a]	-						
HC	.041	.103[b]	.134[a]	.025	.901[a]	.938[a]	-					
OFD	.023	.106[b]	.105[b]	.003	.863[a]	.866[a]	.957[a]	-				
AC	.049	.050	.106[b]	.024	.932[a]	.905[a]	.894[a]	.855[a]	-			
FW	.040	.047	.123[a]	.025	.965[a]	.950[a]	.915[a]	.861[a]	.976[a]	-		
FHR	.011	-.046	.043	.209[a]	.225[a]	.217[a]	.183[a]	.161[a]	.235[a]	.252[a]	-	

PT	.051	.079	.210[a]	-.049	.401[a]	.372[a]	.391[a]	.358[a]	.410[a]	.398[a]	.120[b]	-

HT = Height (cm), WT = Weight (kg), MA = Menarcheal age (yrs), FL = Femoral length (cm), BPD = Biparietal diameter (cm), HC = Head circumference (cm), OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm). a = $p < 0.05$ b = $p < 0.01$

Table 4.7: Correlation matrix of maternalright hand digits (up) and left hand digits (down) parameters and foetal growth parameters in second trimester of gestation.

	1DL	2DL	3DL	4DL	5DL	FL	BPD	HC	OFD	AC	FW	FHR	PT
1DL	-	.626[a]	.541[a]	.533[a]	.549[a]	.116	.159[b]	.120	.089	.084	.116	.022	.097
2DL	.417[a]	-	.821[a]	-.759[a]	.658[a]	.020	.004	-.010	.029	-.020	-.006	.005	.002
3DL	.385[a]	.740[a]	-	.845[a]	.693[a]	-.010	-.024	-.024	.025	-.031	-.030	-.031	.044
4DL	.418[a]	.772[a]	.820[a]	-	.718[a]	-.020	-.034	-.042	-.045	-.034	-.026	-.065	.045
5DL	.428[a]	.748[a]	.671[a]	.747[a]	-	.014	.021	.008	.021	.022	.033	-.061	.085
FL	.000	.013	.046	.030	-.021	-	.901[a]	.916[a]	.766[a]	.881[a]	.916[a]	.042	.224[a]
BPD	.051	-.005	.002	.014	-.028	.901[a]	-	.949[a]	.807[a]	.874[a]	.900[a]	.054	.254[a]
HC	.019	-.018	.002	.012	-.046	.0916[a]	.949[a]	-	.845[a]	.886[a]	.916[a]	.067	.241[a]
OFD	.011	.017	.015	.019	-.042	.766[a]	.807[a]	.845[a]	-	.762[a]	.765[a]	.025	.217[a]
AC	-.004	-.032	-.004	.002	-.036	.881[a]	.874[a]	.886[a]	.762[a]	-	.908[a]	.054	.247[a]
FW	.003	-.010	.008	.012	-.021	.916[a]	.900[a]	.916[a]	.765[a]	.908[a]	-	.070	.240[a]

FHR	.054	.005	-.067	-.010	-.046	.042	.054	.067	.025	.054	.070	-	.078
PT	.066	.006	.023	.093	.048	.224[a]	.254[a]	.241[a]	.217[a]	.247[a]	.240[a]	.078	-

1DL = First digit length (cm), 2DL = Second digit length (cm), 3DL = Third digit length (cm), 4DL = Fourth digit length (cm), 5DL = Fifth digit length (cm), FL= Femoral length (cm), BPD = Biparietal diameter, HC = Head circumference (cm), OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm). a = $p < 0.05$ b = $p < 0.01$

Table 4.8: Correlation matrix of maternal right hand and foot (up) and left hand and foot (down) parameters with foetal growth parameters in the second trimester of gestation.

	HL	HB	FTL	FB	FL	BPD	HC	OFD	AC	FW	FHR	PT
HL	-	.630[a]	.567[a]	.380[a]	-.032	-.030	-.028	.035	-.053	-.037	-.004	.096
HB	.630[a]	-	.405[a]	.548[a]	.073	.087	.073	.039	.035	.061	.122	.114
FTL	.594[a]	.432[a]	-	.363[a]	.049	.069	.075	.092	.033	.048	-.061	.094
FB	.391[a]	.373[a]	.559[a]	-	.083	.112	.077	.104	.058	.082	.174[a]	.147[b]
FL	-.006	.006	.076	.114	-	.901[a]	.916[a]	.766[a]	.881[a]	.916[a]	.042	.224[a]
BPD	-.015	.021	.085	.169[b]	.901[a]	-	.949[a]	.807[a]	.874[a]	.900[a]	.054	.254[a]
HC	-.010	.034	.056	.123	.916[a]	.949[a]	-	.845[a]	.886[a]	.916[a]	.067	.241[a]
OFD	.029	.063	.054	.150[b]	.766[a]	.807[a]	.845[a]	-	.762[a]	.765[a]	.025	.217[a]
AC	-.029	-.021	.045	.117	.881[a]	.874[a]	.886[a]	.762[a]	-	.908[a]	.054	.247[a]
FW	-.014	-.002	.064	.131	.916[a]	.900[a]	.916[a]	.765[a]	.908[a]	-	.070	.240[a]
FHR	-.006	-.098	.131	.128	.042	.054	.067	.025	.054	.070	-	.078

PT	.096	.053	.164[b]	.236[a]	.224[a]	.254[a]	.241[a]	.217[a]	.247[a]	.240[a]	.078	-

HL = Hand length (cm), HB = Hand breadth (cm), FTL = Foot length (cm), FB = Footbreadth (cm), FL = Femoral length (cm), BPD = Biparietal diameter (cm), HC = Head circumference (cm), OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm). a = $p < 0.05$ b = $p < 0.01$

Table 4.9: Correlation matrix of maternalright hand digits (up) and left hand digits (down) parameters and foetal growth parameters in the third trimester of gestation.

	1DL	2DL	3DL	4DL	5DL	FL	BPD	HC	OFD	AC	FW	FHR	PT
1DL	-	.621[a]	.579[a]	.566[a]	.508[a]	-.005	.020	.036	.012	.011	.017	-.043	.126[a]
2DL	.455[a]	-	.814[a]	.730[a]	.720[a]	-.013	-.011	-.002	-.018	-.034	-.010	-.054	.001
3DL	.473[a]	.824[a]	-	.851[a]	.728[a]	.046	.040	.060	.035	.036	.048	-.039	.056
4DL	.049	.140[a]	.143[a]	-	.755[a]	.054	.053	.071	.045	.067	.073	-.061	.052
5DL	.006	-.020	.027	.005	-	.001	.025	.037	-.001	-.004	.018	-.063	.005
FL	-.083	.010	.012	-.053	-.051	-	.931[a]	.901[a]	.863[a]	.932[a]	.965[a]	.225[a]	.401[a]
BPD	-.074	.012	.008	-.043	-.054	.931[a]	-	.938[a]	.866[a]	.905[a]	.950[a]	.217[a]	.372[a]
HC	-.036	.022	.024	-.024	-.050	.901[a]	.938[a]	-	.957[a]	.894[a]	.915[a]	.183[a]	.391[a]
OFD	-.035	.000	.008	-.015	-.018	.863[a]	.866[a]	.957[a]	-	.855[a]	.861[a]	.161[a]	.358[a]
AC	-.049	-.006	.001	-.054	-.066	.932[a]	.905[a]	.894[a]	.855[a]	-	.976[a]	.235[a]	.410[a]
FW	-.066	.015	.016	-.047	-.056	.965[a]	.950[a]	.915[a]	.861[a]	.976[a]	-	.252[a]	.398[a]

FHR	-.032	-.048	-.051	-.026	-.062	.225^a	.217^a	.183^a	.161^a	.235^a	.252^a	-	.120^b
PT	.132^a	.035	.026	-.044	-.005	.401^a	.372^a	.391^a	.358^a	.410^a	.398^a	.120^b	-

1DL = First digit length (cm), 2DL = Second digit length (cm), 3DL = Third digit length (cm), 4DL = Fourth digit length (cm), 5DL = Fifth digit length (cm), FL= Femoral length (cm), BPD = Biparietal diameter, HC = Head circumference (cm), OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm). a = $p < 0.05$ b = $p < 0.01$

Table 4.10: Correlation matrix of maternal right hand and foot (up) and left hand and foot (down) parameters with foetal growth parameters in the third trimester of gestation.

	HL	HB	FTL	FB	FL	BPD	HC	OFD	AC	FW	FHR	PT
HL	-	.131[a]	.660[a]	.466[a]	.039	.032	.055	.034	.040	.044	-.024	.062
HB	.679[a]	-	.103[b]	.110[b]	.003	-.008	.011	.022	-.001	-.005	.030	-.007
FTL	.676[a]	.524[a]	-	.613[a]	.044	.044	.061	.036	.016	.030	-.102[b]	.072
FB	.005	-.003	-.029	-	-.005	.009	.033	.013	-.022	-.026	-.083	.120[b]
FL	.031	.050	.023	-.036	-	.931[a]	.901[a]	.863[a]	.932[a]	.965[a]	.225[a]	.401[a]
BPD	.032	.054	.039	-.039	.931[a]	-	.938[a]	.866[a]	.905[a]	.950[a]	.217[a]	.372[a]
HC	.066	.067	.051	-.023	.901[a]	.938[a]	-	.957[a]	.894[a]	.915[a]	.183[a]	.391[a]
OFD	.050	.069	.016	-.012	.863[a]	.866[a]	.957[a]	-	.855[a]	.861[a]	.161[a]	.358[a]
AC	.023	.036	-.012	-.042	.932[a]	.905[a]	.894[a]	.855[a]	-	.976[a]	.235[a]	.410[a]
FW	.031	.042	.011	-.039	.965[a]	.950[a]	.915[a]	.861[a]	.976[a]	-	.252[a]	.398[a]
FHR	-.043	-.063	-.061	.017	.225[a]	.217[a]	.183[a]	.161[a]	.235[a]	.252[a]	-	.120[b]

PT	.069	.063	.091	-.033	.401[a]	.372[a]	.391[a]	.358[a]	.410[a]	.398[a]	.120[b]	-

HL = Hand length (cm), HB = Hand breadth (cm), FTL = Foot length (cm), FB = Footbreadth (cm), FL = Femoral length (cm), BPD = Biparietal diameter (cm), HC = Head circumference (cm), OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm). a = $p < 0.05$ b = $p < 0.01$

Table 4.11: Correlation matrix of maternal2D:4D ratios in right (up) and left (down) hands with foetal growth parameters in the second trimester of gestation.

	FL	BPD	HC	OFD	AC	FW	FHR	PT	2D:4D
FL	-	.901[a]	.916[a]	.766[a]	.881[a]	.916[a]	.042	.224[a]	.060
BPD	.901[a]	-	.949[a]	.807[a]	.874[a]	.900[a]	.054	.254[a]	.055
HC	.916[a]	.949[a]	-	.845[a]	.886[a]	.916[a]	.067	.241[a]	.046
OFD	.766[a]	.807[a]	.845[a]	-	.762[a]	.765[a]	.025	.217[a]	.107
AC	.881[a]	.874[a]	.886[a]	.762[a]	-	.908[a]	.054	.247[a]	.021
FW	.916[a]	.900[a]	.916[a]	.765[a]	.908[a]	-	.070	.240[a]	.031
FHR	.042	.054	.067	.025	.054	.070	-	.078	.099
PT	.224[a]	.096	.053	.164[b]	.236[a]	.224[a]	.254[a]	-	-.057
2D:4D	-.023	-.029	-.042	.001	-.053	-.027	-.032	.017	-

FL = Femoral length (cm), BPD = Biparietal diameter (cm), HC = Head circumference (cm),

OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg),

FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm), 2D:4D: Second to fourth digit ratio.

a = $p < 0.05$ b = $p < 0.01$

Table 4.12: Correlation matrix of maternal2D:4D ratios in right (up) and left (down) hands with foetal growth parameters in the third trimester of gestation.

	FL	BPD	HC	OFD	AC	FW	FHR	PT	2D:4D
FL	-	.931[a]	.901[a]	.863[a]	.932[a]	.965[a]	.225[a]	.401[a]	-.095[b]
BPD	.931[a]	-	.938[a]	.866[a]	.905[a]	.950[a]	.217[a]	.372[a]	-.095[b]
HC	.901[a]	.938[a]	-	.845[a]	.886[a]	.916[a]	.067	.241[a]	.046
OFD	.863[a]	.866[a]	.957[a]	-	.957[a]	.894[a]	.915[a]	.183[a]	.391[a]
AC	.932[a]	.905[a]	.894[a]	.855[a]	-	.855[a]	.861[a]	.161[a]	.358[a]
FW	.965[a]	.950[a]	.915[a]	.861[a]	.976[a]	-	.252[a]	.398[a]	-.117[b]
FHR	.225[a]	.217[a]	.183[a]	.161[a]	.235[a]	.252[a]	-	.120[b]	.012
PT	.401[a]	.372[a]	.391[a]	.358[a]	.410[a]	.398[a]	.120[b]	-	-.078
2D:4D	-.034	-.013	-.017	-.026	-.053	-.041	-.018	.039	-

FL = Femoral length (cm), BPD = Biparietal diameter (cm), HC = Head circumference (cm),

OFD = Occipitofrontal diameter (cm), AC = Abdominal circumference (cm), FW = Foetal weight (kg), FHR = Foetal heart rate (bpm), PT = Placenta thickness (cm),2D:4D: Second to fourth digit ratio.

a = $p < 0.05$ b = $p < 0.01$

4.6PredictiveEquations of Placenta Thickness for Gestational Age and Foetal Weight

Figures 4.33 and 4.34 are the regression graphs showing the relationship between placenta thickness and foetal weight in the second and third trimester of gestation respectively. There is a strong relationship in both which is more pronounced in the third trimester of gestation. The R^2 value for second trimester was 0.0574 while that of third trimester is 0.1584. While the predictive equations are $y = 0.1648x + 0.0958$ and $y = 0.5218x - 0.1381$ for second and third trimester gestation respectively.

Figures 4.35 and 4.36 show the relationship between placenta thickness and foetal weight in the second trimester of gestation for male and female foetuses respectively. Female foetuses had R^2 value of 0.1089 which was higher than males of 0.0008. The predictive equation for female foetuses was $y = 0.2255x - 0.1334$ while that of male was $y = -0.0192x + 0.7674$.

The third trimester relationship between placenta thickness and foetal weight according to sex from Figures 4.37 and 4.38, shows male foetuses having a higher R^2 of 0.1199 than 0.0146 for females. The predictive equations are $y = 0.496x + 0.0179$ for male foetuses and $y = 0.1484x +1.4968$ for females in the third trimester gestation.

Figures 4.39 and 4.40 shows the relationship between gestational age and placenta thickness in second and third trimester of gestation respectively. In both trimesters, there was increase in placenta thickness as gestational age increases. With a regression equation of $y = 1.3507x + 18.514$ and R^2 value of 0.0449 for second trimester, and $y = 2.6151x + 20.981$ and R^2 value of 0.1651 for third trimester gestation, the model shows a predictive value of placenta thickness for gestational age.

In Figures 4.41 and 4.42, regression plots are made to generate regression equations in the second trimester according to male and female foetuses respectively. The predictive equation for gestational age according to placenta thickness for male foetuses in the second trimester is $y = 0.814x + 20.459$ with R^2 value of 0.0215 while that of female foetuses is $y = 1.6481x + 17.513$ with an R^2 value of 0.0871.

Similarly, Figures 4.43 and 4.44 shows the relationship between gestational age and placenta thickness according to sex in the third trimester. While the predictive equation and R^2 value for third trimester female foetuses is $y = 2.6407x + 20.757$ and 0.1833 respectively, predictive equation for male foetuses in the same trimester is $y = 2.6167x + 21.095$ with an R2 value of 0.1299.

Generally, the prediction model shows greater promise when used according to trimester of gestation than when it is related to foetal sex. In all cases where regression was carried out for the predictive value of placenta thickness for foetal weight and gestational age in both second and third trimester of pregnancy, P value was less than 0.05 ($p < 0.01$) showing the model's power for predicting foetal weight and gestational age from placenta thickness.

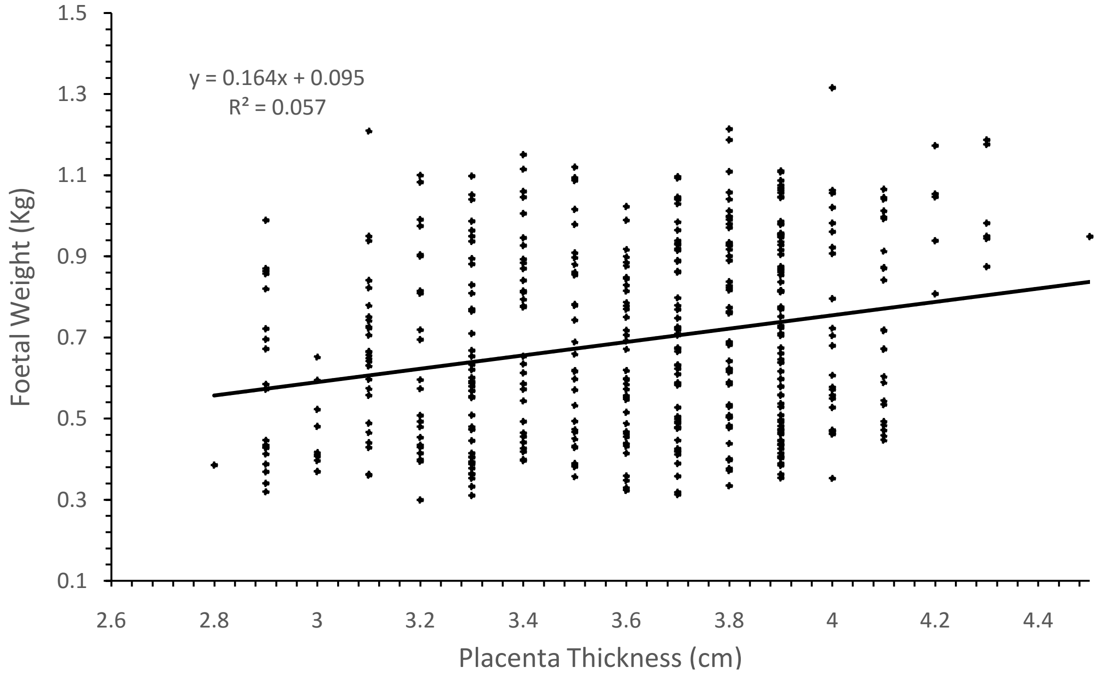

Figure 4.33: Scatter plot of the relationship between placenta thickness and foetal weight in the second trimester of gestation and the predictive equation for foetal weight. x = placenta thickness, y = foetal weight, R^2 = Regression coefficient.

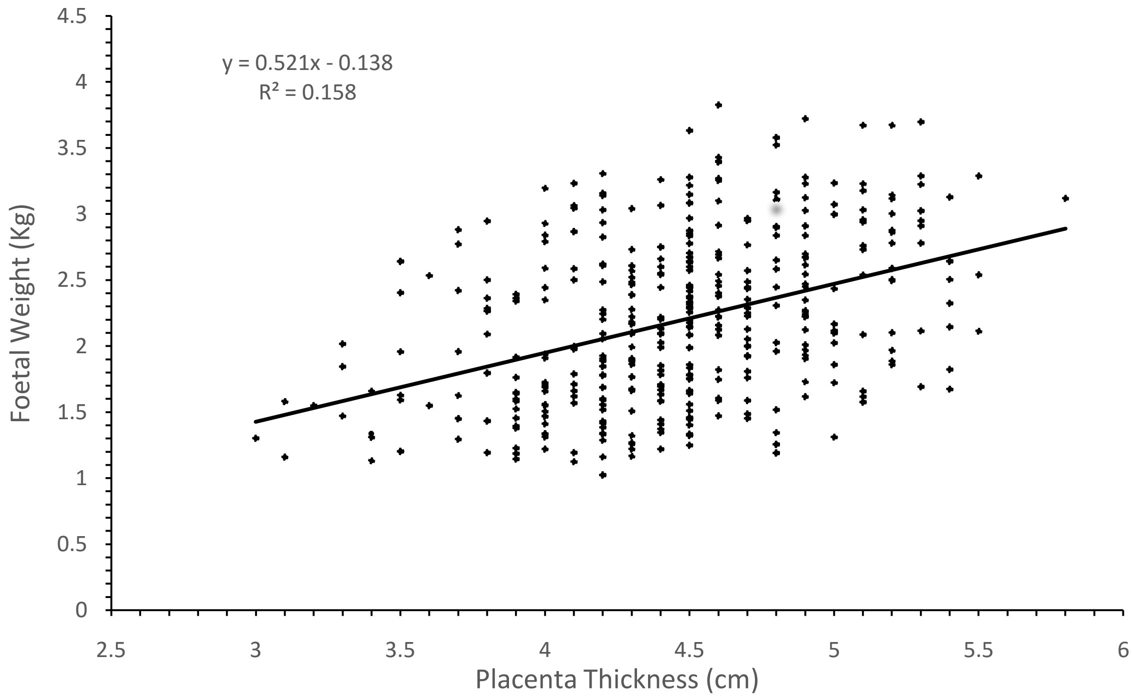

Figure 4.34: Scatter plot of the relationship between placenta thickness and foetal weight in the third trimester of gestation and the predictive equation for foetal weight. x = placenta thickness, y = foetal weight, R^2 = Regression coefficient.

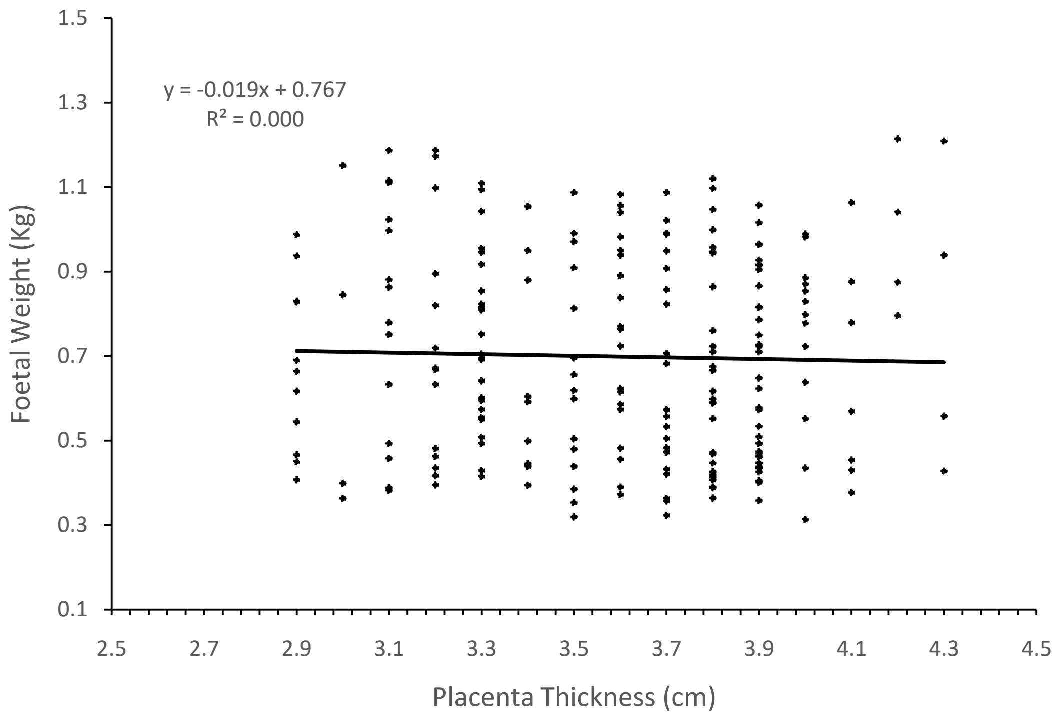

Figure 4.35: Scatter plot of the relationship between placenta thickness and foetal weight in the second trimester of gestation and the predictive equation for foetal weight in a male foetus. x = placenta thickness, y = foetal weight, R^2 = Regression coefficient.

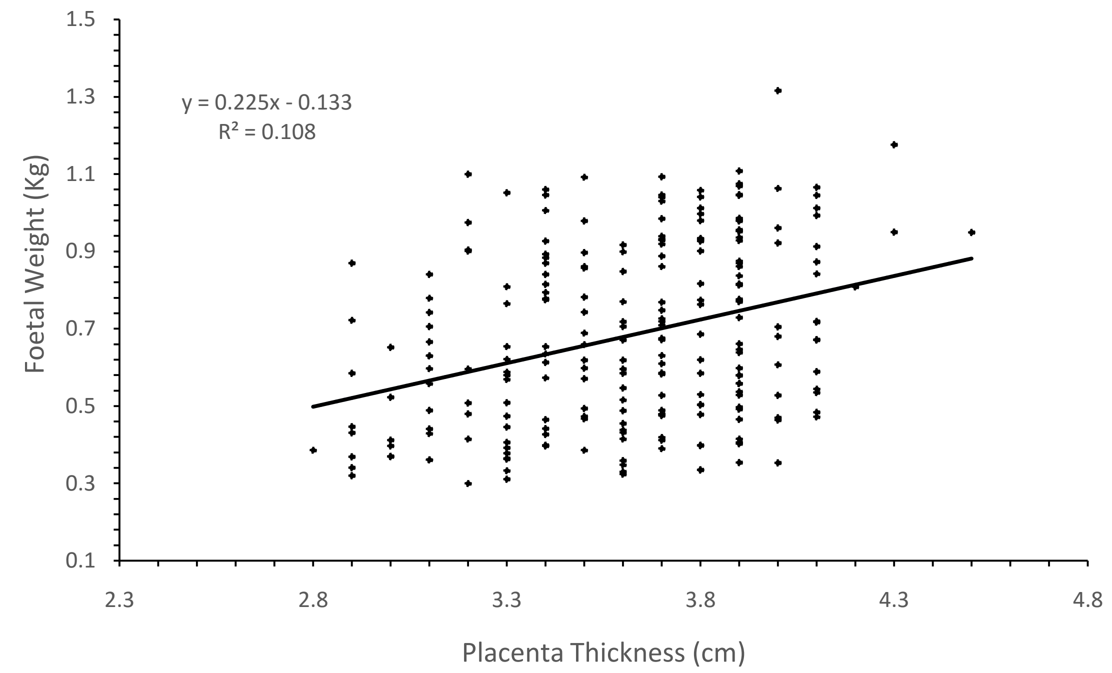

Figure 4.36: Scatter plot of the relationship between placenta thickness and foetal weight in the second trimester of gestation and the predictive equation for foetal weight in a female foetus. x = placenta thickness, y = foetal weight, R^2 = Regression coefficient.

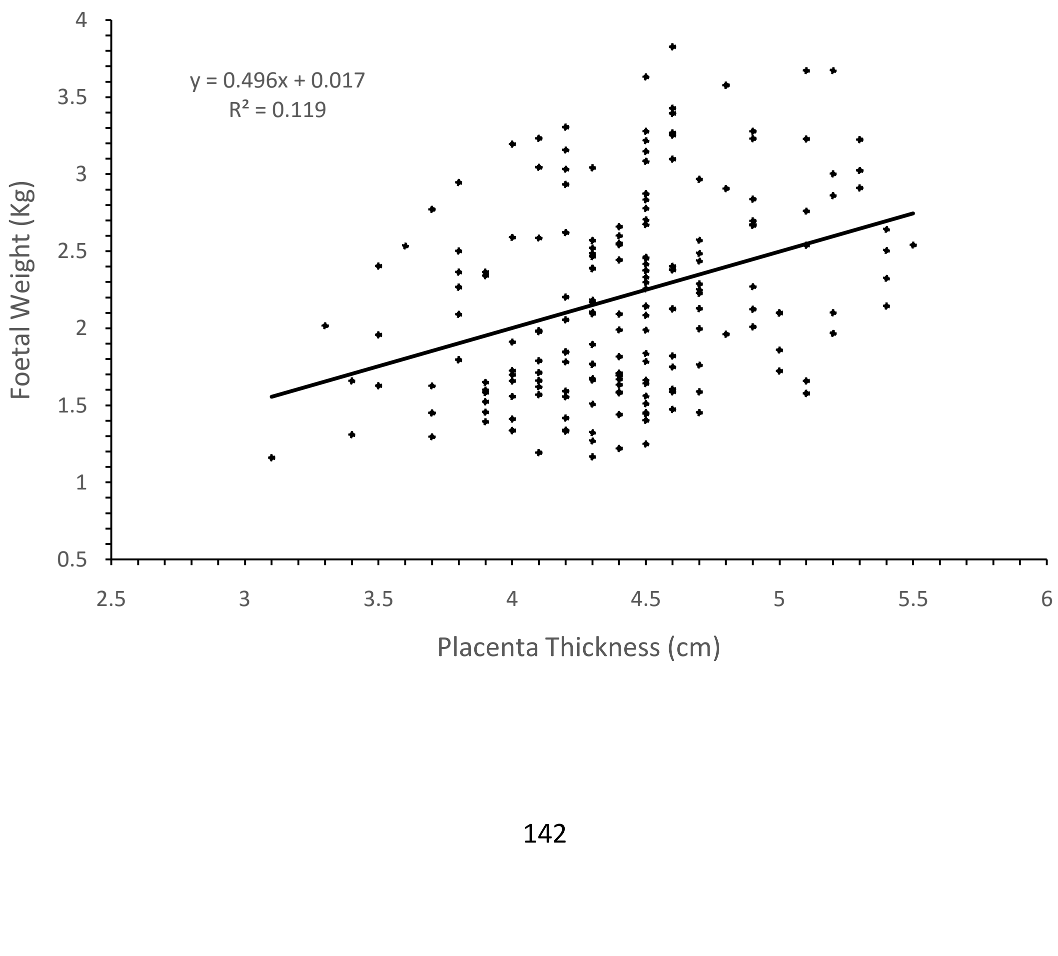

Figure 4.37: Scatter plot of the relationship between placenta thickness and foetal weight in the third trimester of gestation and the predictive equation for foetal weight in a male foetus. x = placenta thickness, y = foetal weight, R^2 = Regression coefficient.

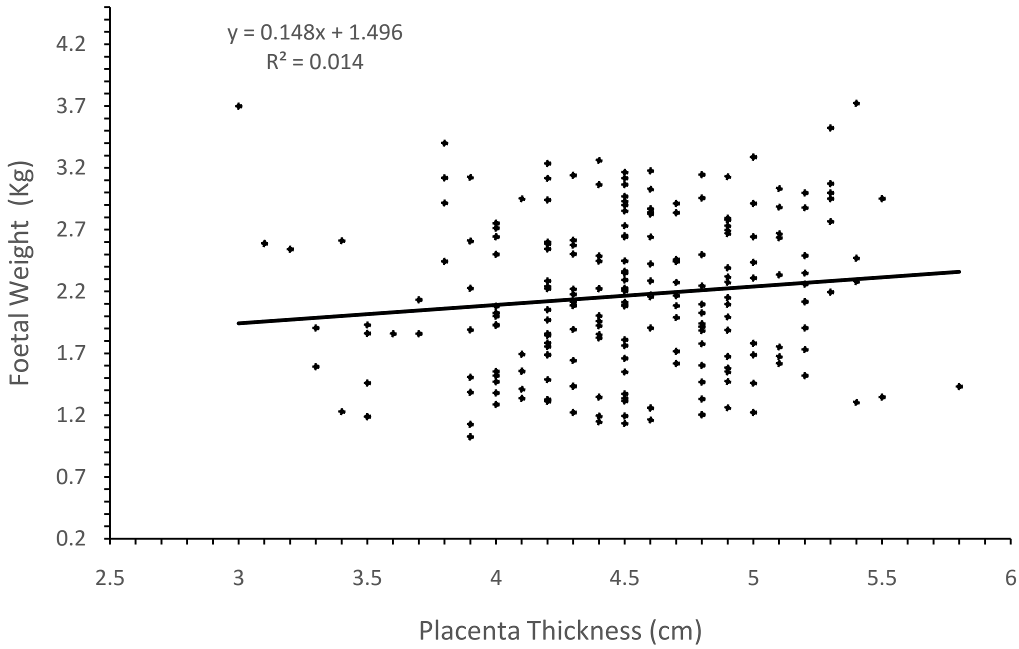

Fig. 4.38: Scatter plot of the relationship between placenta thickness and foetal weight in the third trimester of gestation and the predictive equation for foetal weight in a female foetus.x = placenta thickness, y = foetal weight, R^2 = Regression coefficient.

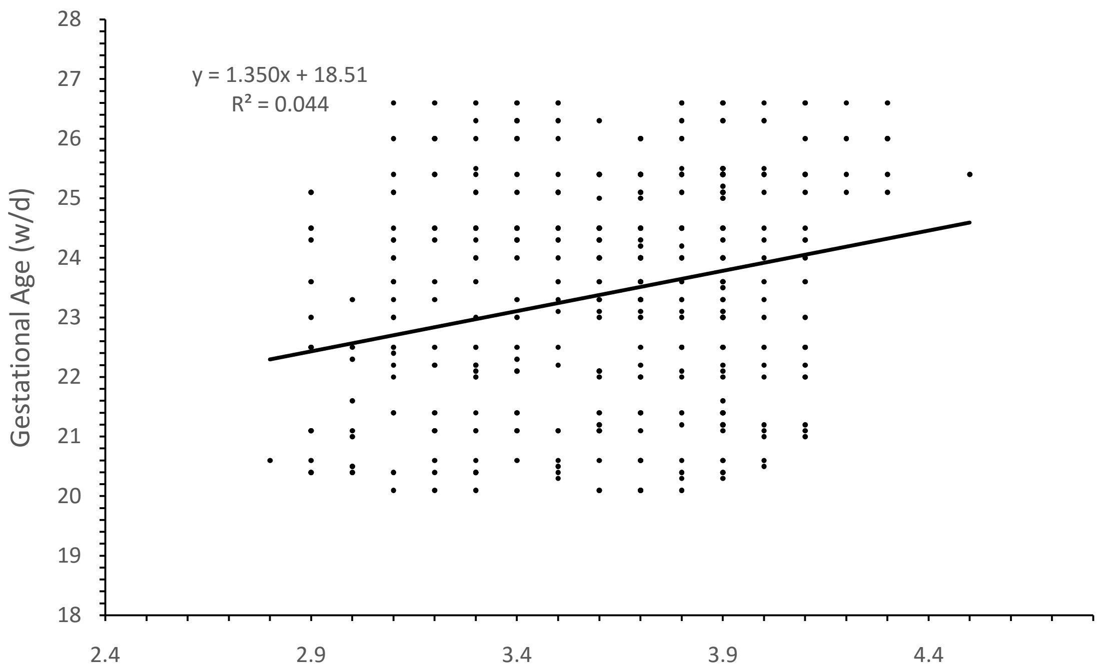

Fig. 4.39: Scatter plot of the relationship between placenta thickness and gestational age in the second trimester of gestation and the predictive equation for gestational age.x = placenta thickness, y = Gestational Age, R^2 = Regression coefficient.

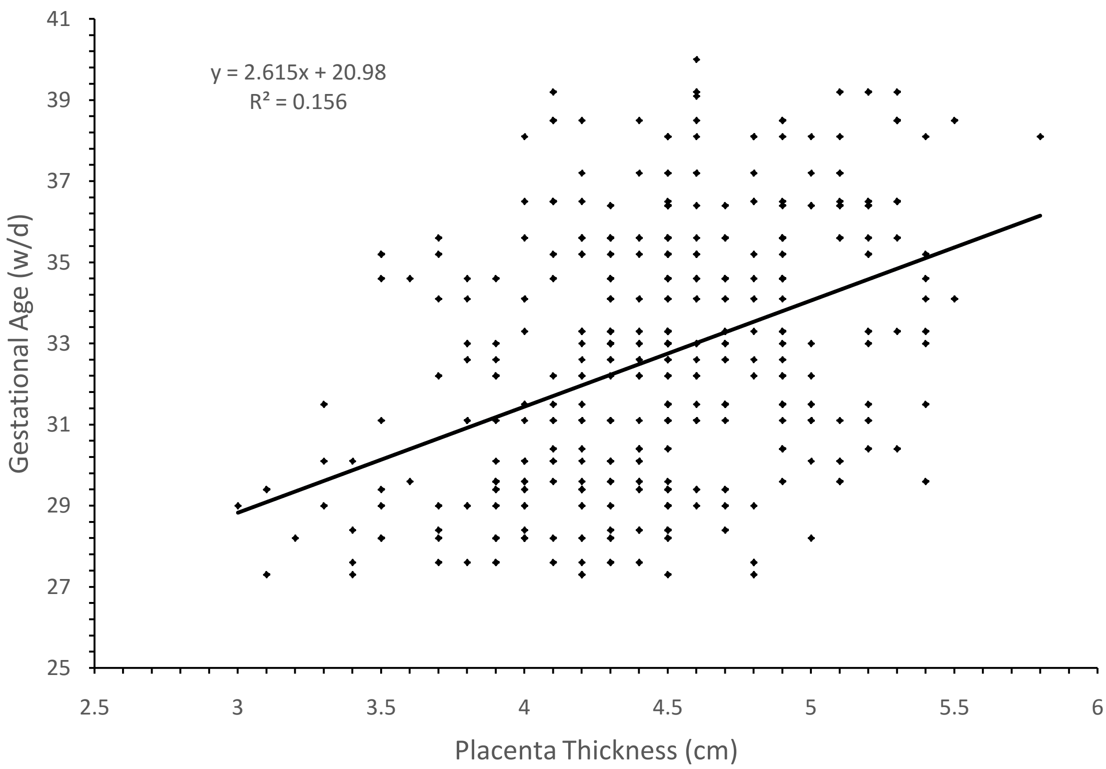

Fig. 4.40: Scatter plot of the relationship between placenta thickness and gestational age in the third trimester of gestation and the predictive equation for gestational age.x = placenta thickness, y = Gestational Age, R^2 = Regression coefficient.

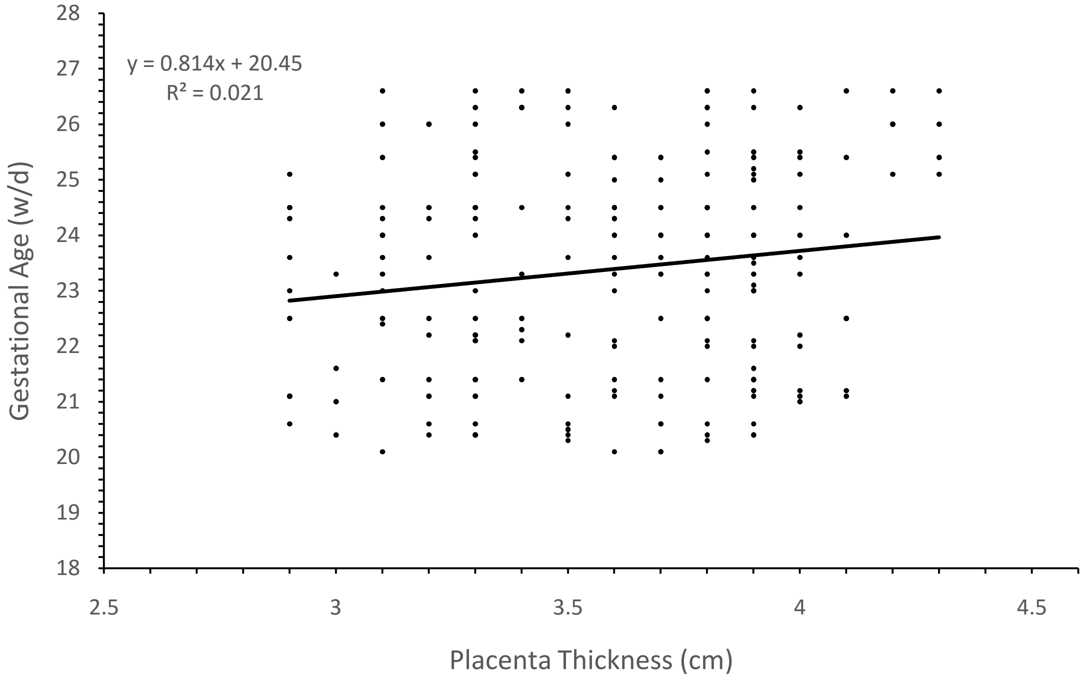

Fig. 4.41: Scatter plot of the relationship between placenta thickness and gestational age in the second trimester of gestation and the predictive equation for gestational age in a male foetus.x = placenta thickness, y = Gestational Age, R^2 = Regression coefficient.

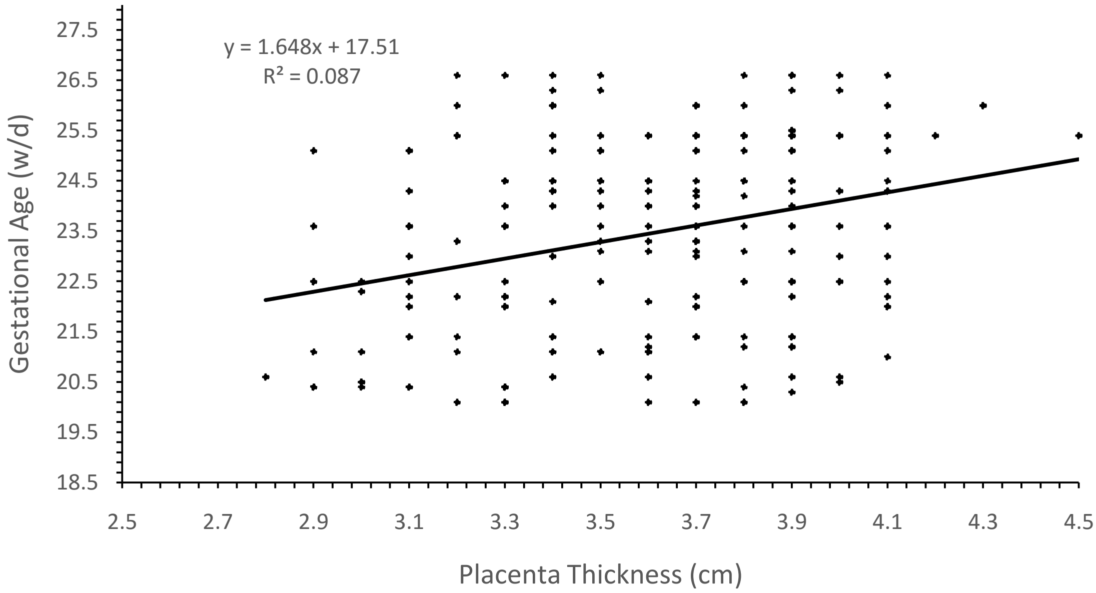

Fig. 4.42: Scatter plot of the relationship between placenta thickness and gestational age in the second trimester of gestation and the predictive equation for gestational age in a female foetus.x = placenta thickness, y = Gestational Age, R^2 = Regression coefficient.

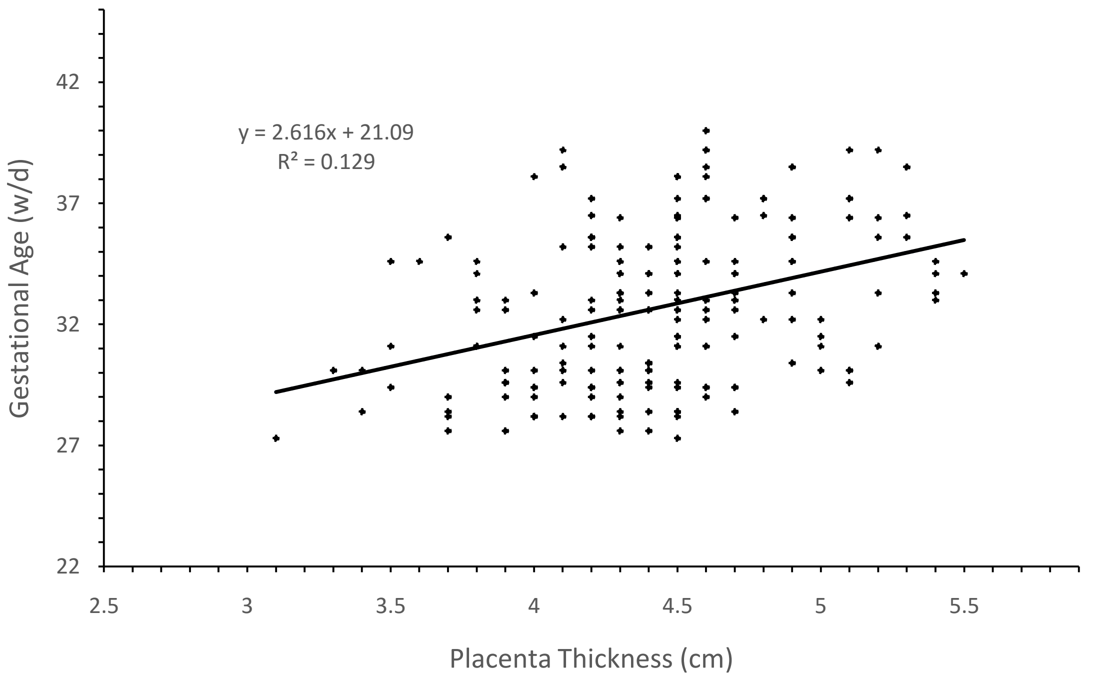

Fig. 4.43: Scatter plot of the relationship between placenta thickness and gestational age in the third trimester of gestation and the predictive equation for gestational age in a male foetus.x = placenta thickness, y = Gestational Age, R^2 = Regression coefficient.

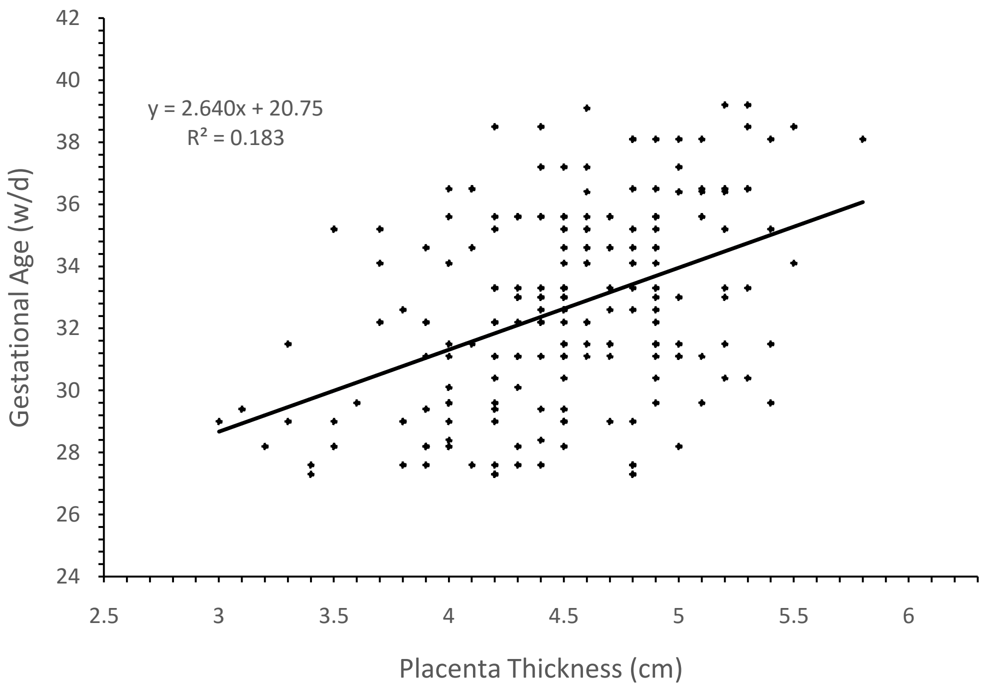

Fig. 4.44: Scatter plot of the relationship between placenta thickness and gestational age in the third trimester of gestation and the predictive equation for gestational age in a female foetus.x = placenta thickness, y = Gestational Age, R^2 = Regression coefficient.

5.0 DISCUSSION

This research was carried out with the aim of determining placental thickness according to sex and its relationship to other foetal characteristics in second and third trimesters using ultrasonography. The study also assessed if maternal factors such as ethnic group, parity, level of education could influence foetal characteristics. Finally, correlation of maternal anthropometry and foetal growth parameters were also investigated.

The role of obstetric ultrasonography has proven invaluable, inaccurate pregnancy dating and detection of foetal anomalies (Campbell, 2013; Alfadhli*et al.*, 2015).Normal placental function and structure is a necessary factor forthe formation of a healthy foetus and consequently normal birthweight (Singhal and Potdar, 2016). Several authors have reported a linear increase in placenta thickness with gestational age as do other foetal parameters and maternal weight (Afrakhteh*et al*., 2012; Balla*et al*., 2014; Yee and Grobman, 2016).

The results show that foetal growth parameters differ in their relationships to maternal anthropometry. There was significant correlation between maternal weight and foetal growth parameters in the second and third trimester gestation. This agrees with work done by numerous researchers which indicates that there is gradual and significant maternal weight gain across different ethnic groups in pregnancy up to the time of delivery(Catalano, 2007;Denison *et al*., 2008; Ota *et al*., 2011; Sharmila*et al*., 2011; Alfadhli*et al*., 2015; Coffey, 2015).

Weight gain of between 12.5kg to 18.0kg, has been recommended as optimal for any pregnancy by United States National Academyof Sciences Institute of Medicine (IOM) (Ota *et al*., 2011; Alfadhli*et al*., 2015). In this study, the mean weight of second trimester pregnant mothers as compared to third trimester was statistically significantly different.But without knowing the prepregnancy weight, a specific weight gain in pregnancy couldnot be quoted for this work.Although a previous report showed that pregnant women gainan average of 250 g per week throughout the period ofpregnancy in Nigeria(Aisenand Olarewaju, 2003).

The difference in maternal weight between the second and third trimester in this study is largely attributed to increase fluid and fat accumulation in the mother, growth of foetus and other accompanying structures such as placental weight and amniotic fluid. This agrees with previous works where there is significant difference between second and third trimester maternal weight (Lubchenco *et al*., 1963; Thame*et al*., 2004; Lampl*et al*., 2010).

However, for maternal anthropometry that involves measurement of lengths i.e. maternal height, hands and feet parameters, no significant relationship was observed except for leg length and breadth which correlated with foetal heart rate, biparietal diameter, occipitofrontal diameter and placenta thickness. Also, maternal first digit (thumb) of the right hand was found to correlate with placenta thickness in the third trimester. There was also a relationship between maternal right hand 2D:4D and femoral length, biparietal diameter, abdominal circumference and foetal weight. Nowhere in the literature to the knowledge of the researchers has this been observed sonographically, but work done by Danborno*et al*(2010) showed a significant relationship between 2D:4D and birth weight among Nigerians. The lack of significant relationship between maternalheight, foetal weight and foetal growth parameters is at variance with some reports which showed that maternal height is a strong predictorof birth weight (Nahar *et al*., 2007;Ota *etal*., 2011). However, the finding of this studyis not surprising and agrees with the works of (Lampl*et al*., 2010; Onubogu*etal*., 2017) because maternal heightneither reflectscurrent nutritional status nor response to nutritionalinterventions. Although bipedal oedema(which is more frequent in pregnancy) could account for correlation seen between maternal leg length and breadth with some foetal parameterseven though interaction between growth hormone and placental growth hormone cannot be ruled out.

Although more pregnant mothers in their second trimester were included in this study in a higher number than those in third trimester, there were more foetuses that were presenting in the cephalic longitudinal lie in the third trimester than in the second. About 88.08% of the foetuses in the third trimester were in the cephalic presentation as compared to 7.28% in the breech longitudinal lie and 4.64% in the breech transverse lie. While in the second trimester,62.82% of foetuseswere in cephalic presentation, 26.07% in the breech longitudinal lie and 11.11% exhibited breech transverse lie. Several authors believe that as high as 96% of foetuses in the third trimester of gestation are in the cephalic presentation (Chudleigh and Thilaganathan, 2004; Yee and Grobman, 2016).

In this study group, there were more anteriorly placed placenta in the second than third trimester while the reverse was the case for third trimester placentas.Placental migration in pregnancy might have accounted for the differences as it has been observed that a normal placenta is not fixed permanently to a part of the uterus throughout the period of gestation. Abnormal placental fixation often results from inability of the placenta to migrate and could be a significant factor in the causation of praevia and creta (Chudleigh and Thilaganathan, 2004).Anterior placentas were thinner in this study when compared to posterior ones. This agrees with the works of Durnwald and Mercer (2004) and Lee *et al*(2012), even though forHoddick*et al*(1985), the placental location is irrelevant to its size. Although no reason has been advanced for the differences in thickness in relation to placental location anywhere in the literature to the best of our knowledge, we postulate that the variation might due to the pressure exerted by the transducerwhen placed on the maternal abdomen due to its close proximity to an anteriorly placed placenta.

Ethnic differences of pregnant mothers, socio economic status, parity and sex of foetushave been observed to influence foetal parameters during intrauterine life and after delivery(Freeman*et al*., 1970; Zhan, 1989; Sivarao*et al*., 2002; Gomes *et al*., 2005; Coffey, 2015). Statistically significant difference was observed for abdominal circumference (AC), foetal weight (FW) in the third trimester and placenta thickness in the second trimester when foetal parameters were classified according to the mother's ethnic group. Also, foetal weight which is a growth determinant was found to be lowest among the Fulani ethnic group followed by the Hausas and highest was seen in the other ethnic groups apart from these two.Works done in Nigeria for birth weights and twinning found the Hausa and Fulani ethnic groups to be among those with low birth weights (Akinboro*et al*., 2008; Obiechina*et al*., 2011; Yakasai and Rabiu, 2013). Level of education which influences socio economic status was also found to be a significant determinant of placenta thickness for second trimester gestation in this study as those mothers with tertiary education had the highest values which was significant.

It was noted that the Fulaniethnic group had the highest placental thickness. Although nowhere in the literature to the best our knowledge has inter-ethnic comparison of placental thickness been made sonographically, gross placenta examination after birth indicates that indigenous populations tend to have heavier placenta, larger surface of insertion, with a higher volumeoccupied by villi, trophoblast and syncytiotrophoblast,greater villous surface and thicker trophoblast layer (Zhan, 1989; Sivarao*et al*., 2002; Gomes *et al*., 2005).Based on the location of this study, the indigenous populations consist more of the Hausa and Fulani ethnic groups. However, Jackson *et al*(1987)found no differences in therelative volumes of the placenta structures belonging toIndigenous and non-Indigenous of Bolivia. Differences in placenta thickness is mostly attributed to ethnic and biological factors which includes increased volumes of villi, trophoblast andsyncytiotrophoblast (Gomes *et al*., 2005).

Intrauterine growth retardation (IUGR) is considered when foetal weight is below 10^{th} percentile of the normal growth curve for a given gestational age and is usually caused by placental insufficiency in maternal diseases (Reddy *et al*., 2014; Singhaland Potdar, 2016).The term foetalmacrsomia implies foetal obesity and has been traditionally defined by a foetal weight greater than 4000 or 4500 grams irrespective of gestational age(ACOG, 2014). Maternal factors such as pregestational diabetes, gestational diabetes and maternal obesity predisposes a foetus to macrsomia (Denison *et al*., 2008;Alfadhli*et al*., 2015). High socioeconomic status has been associated with optimal foetal and birth weight with those having a higher educational qualification more likely to have a more improved quality of life (Malin*et al*., 2014; Veerbek*et al*., 2014; Martin*et al*., 2017). In this study group, those participants with secondary level of education had more of the high value foetal parameters in the second trimester, while those who only finished primary school had the highest value foetal parameters except forfoetal weight and placenta thickness which the secondary group had the highest. Our observation in this study is that those in the primary school category tend to go for routine antenatal scan when it is late in the pregnancy and as such could also explain the reason why they had higher foetal parameters. Also, in both second and third trimester gestation, most pregnant mothers were seen to have been enrolled in a secondary school or have a secondary certificate as their highest level of education.

Those pregnant mothers with a parity of 9–13 number of children had the lowest parameters including foetal weight and placenta thickness.These are women usually between the ages of≥36 years of age, at which time the intrauterine conditions for a foetusare less than optimal (Obiechina*et al*., 2011; Ouyang *et al*., 2013) and could account for the low foetal weight and placenta thickness seen in this group. Pregnant mothers with a parity of 5 – 8 number of children had the highest foetal parameters followed by those with a parity 0 – 4. These were mothers between the ages of 17 to 32 years of age. At this age group, maternal diseases such as pregestational diabetes, gestational diabetes, maternal obesity are less common unlike for those mothers above 36 years (Kaimaland Kuppermann, 2012; Malin*et al*., 2014; Coffey, 2015).

Sexual dimorphism in anatomical, physiological, andlabouronset and parturition characteristics, have been observed in foetusesand adults for a long time with males having higher values than females not only in humans but other animals as well (Bekedam*et al*., 2002; Bermejo-Álvarez *et al*., 2008; Danborno*et al*., 2007;Lampl*et al*., 2010; Dobbs *et al*., 2014).It is well known that alterations in the maternal environmentduring prenatal life can have long-term effects on thephysiology and health of the offspring and that the nature ofthese effects differs between females and males (Watkins *et al*., 2011; Barker*et al*., 2013).

In this work, male foetuses had higher values than female foetusesof all the foetalcharacteristics observedexcept for placenta thickness where that of female foetuses was a few millimeters higher but with no statistically significant difference.This agrees with the work done by Onubogu*et al*(2017) showing that neonates male-to-female ratio of anthropometric characteristics wasapproximately 1:1 and as such no significant difference. Although there was no statistically significant difference in the foetal parameters according to sex, the observation in differences identify the existence of sex-based distinctions in foetal genomicinteraction with the prenatal environment. Among the first environmental challengesconfronting the developing foetus is the mother herself (Verburg*et al*., 2016). Indeed, subsequent to her geneticcontribution, the mother provides the initial environment in which fetal gene expressionoccurs, and is the site of the earliest epigenetic effects (Lopez *et al*., 2008; Gabory*et al*., 2009; Lampl*et al*., 2010; Gabory*et al*., 2013).

From an evolutionary perspective, sexual dimorphism indevelopmental programming probably reflects the differentialvalue of males and females for sexual propagation (Tamimi*et al*., 2003; Danborno*et al*., 2007; Kirchengast, 2014).Although the phenomenon has been well described, themechanism by which sexual dimorphism in developmentalprogramming is achieved has hitherto been unknown (Dobbs *et al*., 2014). Currentfindings lead to the hypothesis that sexual dimorphism resultsbecause female and male embryos respond differently toenvironment-driven alterations in secretion of maternallyderived embryokines (Dobbs *et al*., 2014; Verburg*et al*., 2016; Kalisch-Smith *et al*., 2017).

Several works have been done using human and animal models to understand the formation, function and adaptation of the placenta between the sexes. Current knowledge of early developmental structure isrestricted to the blastocyst stage, where some studies suggestmales develop faster than females (Gardner*et al*., 2010; Kalisch-Smith*et al*., 2017).This is largelybased on assessment of blastocyst size or cell number, includingallocation to either the trophectoderm (TE) or inner cell mass (ICM) (Tan *et al*., 2016;Kalisch-Smith *et al*., 2017).In assisted reproduction procedures, growth rates ofhuman preimplantation embryos were found to be sex dependentafter intracytoplasmic sperm injection (ICSI) but not after *in vitro*fertilisation (IVF) (Dumoulin*et al*., 2005; Kalisch-Smith *et al*., 2017). Reason for the difference have been attributed to the *in vitro* nature of the procedure and in some cases, use of superovulation to generatelarge quantities of embryos both of which are stressors to preimplantation development,and so maypotentially confound the determination of inherent sex differences (De waal*et al*., 2012; Kalisch-Smith *et al*., 2017).

There was significant correlation between placenta thickness (PT), foetal weight (FW) and gestational age (GA). Indeed, some authors have been advocating for the addition of PT to the plethora of foetal parameters used in estimating GA and FW(Ohagwu*et al*., 2009; Nagwani*et al*., 2014; Singhal and Potdar,2016).Umbilical cord length has also been suggested as a means of estimating GA by some authors (Eze*et al*., 2014).

All the foetal parameters routinely used for estimating GA show a linear growth throughout the duration of the pregnancy. In this research, there was a strong positive correlation between PT and other foetal parameters which agrees with the works of (Hoddick*et al*., 1985; Karthikeyan*et al*., 2012; Kaushal*et al*., 2015).Some authors have stated that at no time should a normal PT exceed 4 cm throughout the period of gestation (Hoddick*etal*., 1985; Lee *et al*., 2012). Mean PT in this work exceeded 4 cm but less than 5 cm which agrees with the work of Ohagwu*et al*(2009).

Most maternal anthropometric parameters did not correlate with foetal growth parameters except for maternal weight which shows constant relationship both in the second and the third trimester gestation.Ethnic differences was observed in abdominal circumference, foetal weight and placenta thickness. Also, placenta thickness correlates with foetal growth parameters and will be able to predict foetal weight and gestational age.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The result of this study shows that the mean placenta thickness for normal Nigerian pregnant women is 3.61 ± 0.34 in the second trimester while third trimester is 4.45 ± 0.47which has been observed in previous studies within the population. There was no statistically significant difference when foetal parameters were grouped according to parity. Grouping foetal parameters according to maternal level of education and ethnic group, showedsignificant difference in abdominal circumference, foetal weight and placenta thickness.The test for sexual dimorphism in foetal growth parameters yielded no statistically significant difference in this study even though male foetuses had higher values than females.

Maternal parameters such as weight, foot length and breadth, right hand 2D:4D ratio significantly correlated with foetal growth parameters but not height, digit lengths, hand length and breadth. Maternal factors such as ethnicity and level of education had more influence on placenta thickness in the second trimester.

Placenta thickness showed significant correlation with all foetal growth parameters and high predictive value for foetal weight and gestational age, and so can be used as an adjunct to date pregnancy and estimate foetal weight.

Ethnic differences and socio economic status that are very important in determining an individual's phenotypic appearance and well being, seems to have an intrauterine origin as suggested by the outcome of this research.

6.2 Recommendations

Based on the findings of the present study, the following recommendations are formulated:

i Integrating the knowledge of placenta thickness into normal recommended practice when obtaining foetal growth parameters by sonographers as during routine antenatal ultrasound scan, it can be difficult to image the biparietal diameter due to the head being engaged in the cervix or excessfoetalmovement hampering a clean femoral length cut.

ii Continuous training of sonographers and obstetricians to consider adding other foetal parameters as a means of dating foetusesand estimating foetal growth.

iii Establishment of a national sonographic foetal data collection scheme to make for easier research and have normal reference values and develop formulas for Nigerian foetuses.

iv More higher population sample research across different ethnic groups in Nigeria to make for a more wholistic inclusion of its diversity.

v More synergy between gynaecologists, obstetricians and sonographers to enable

optimal care for mother and foetus during pregnancy.

6.3 Contribution to Knowledge

This include the following:

i. Mean placenta thickness for normal pregnant Nigerian women is 3.61 ± 0.34 in the 2^{nd} trimester and 4.45 ± 0.47 in the third trimester, $p < 0.001$.

ii Ethnic differences exist in ultrasonographic foetal growth parameters. TheOthers group showed the highest values in abdominal circumference with a mean value of 29.76 ± 3.42, 28.94 ± 3.21 for Hausa and 28.48 ± 3.01 for Fulani.Mean foetalweight was 2.31 ± 0.66, 2.18 ± 0.62 and 2.08 ± 0.56 for Others, Hausa and Fulani ethnic group respectively. While the Fulani group had the placenta thickness with a value of 3.69 ± 0.34, 3.66 ± 0.33 for Others and 3.56 ± 0.34 for Hausa, $p < 0.05$.

iii. Highest placenta thickness for level of education was in the tertiary group with a mean value of 3.67 ± 0.32, $p < 0.05$.

iv. Significant positive relationshipbetween maternal left foot length, right and left foot breadth with placenta thickness of 0.164, 0.147 and 0.236 respectively. Significant relationship also observed between foetal heart rate and right foot breadth of 0.174, $p < 0.001$.

v. Prediction equation generated for foetal weight using placenta thickness; $y = 0.1648x + 0.0958$ in the second trimester and $y = 0.5218x – 0.1381$ for third trimester. While prediction equation for gestational age using placenta thickness is $y = 1.3507x + 18.514$ for second trimester and that of third trimester is $y = 2.6151x + 20.981$, $p < 0.001$.

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APPENDIX I

LETTER OF INTRODUCTION

Dear Sir/Madam,

My name is Shehu Abdullahi from the Department of Human Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria, Kaduna state.

I am a Masters student in the above mentioned department conducting a research titled **"A Correlative Study of Foetal Sonographic Parameters and Placental Thickness with Maternal Anthropometry Among Pregnant Women in Zaria, Nigeria"**. I will like to be given permission to use your facility as my research center.

Please accept my assurance that any information obtained from your center during this work will be in strict confidence.

I hope you will be of immense assistance to this study.

Thank you.

Yours sincerely

Shehu Abdullahi

APPENDIX II

CONSENT FORM

CONSENT TO PARTICIPATE IN RESEARCH

A CORRELATIVE STUDY OF FOETAL SONOGRAPHIC PARAMETERS AND PLACENTAL THICKNESS WITH MATERNAL ANTHROPOMETRY AMONG PREGNANT WOMEN IN ZARIA, NIGERIA

You are being requested to participate in a research study conducted by Shehu Abdullahi: Masters Student, Professor S. S. Adebisi and Dr. B. Danborno: Lecturers and Supervisors of this research, all of the Department of Anatomy, Faculty of Medicine Ahmadu Bello University, Zaria. This study will contribute to the M.Sc. Dissertation of the student Shehu Abdullahi.

If you have any questions or concerns about the research, please feel free to contact Professor S. S. Adebisi and Dr. B. Danbornoall of the Department of Anatomy, Faculty of Medicine Ahmadu Bello University, Zaria.

PURPOSE OF THE STUDY

This study is designed to establish the normal placental thickness among Nigerian pregnant women and use it to correlate with other standard sonographic dating parameters.

PROCEDURES

If you volunteer to participate in this study, we would ask to take the following parameters:

1. Data on height, weight, digit length, hand and feet length and breadth, questions on your socioeconomic status, number live births, still births or abortions will be taken.

2. Ultrasound will then be used to take fetal parameters like Femoral Length (FL), Biparietal Diameter (BPD), Head Circumference (HC), Occipitofrontal Diameter (OFD), Abdominal Circumference (AC), Gestational Age (GA), Fetal Weight (FW), Fetal Heart Rate (FHR) and we will also measure placenta thickness (PT).

   The duration for each participant is about 20 minutes, no follow up is required and research results will be available as a hard copy free of charge to each participant on request.

POTENTIAL RISKS AND DISCOMFORTS

There are no documented risks or discomforts to any participant in all the procedures described.

POTENTIAL BENEFITS TO PARTICIPANTS AND SOCIETY

Will help to improve maternal care provided by healthcare givers.

The Nigerian society will get an increase in the pool of valuable research and scientific data.

PAYMENT FOR PARTICIPATION

Participation in this research is totally voluntary, no payment should be expected.

CONFIDENTIALITY

Every effort will be made to ensure confidentiality of any identifying information that is obtained in connection with this study. Data such as names of participants, phone numbers, addresses and history will be strictly guarded and excluded from any correspondence as regards this study.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may exercise the option of removing your data from the study. The investigator may withdraw you from this research if circumstances arise that warrant doing so.

RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. This study has been reviewed and received ethics clearance through the Department of Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria. If you have questions regarding your rights as a research participant, contact the Department of Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria or the lead researcher Shehu Abdullahi (08066029299).

SIGNATURE OF RESEARCH PARTICIPANT

I have read the information provided for the study "(A CORRELATIVE STUDY OF FOETAL SONOGRAPHIC PARAMETERS AND PLACENTAL THICKNESS WITH MATERNAL ANTHROPOMETRY AMONG PREGNANT WOMEN IN ZARIA, NIGERIA)" as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

PleaseInitial Box

1. I confirm that I have read and understand the information sheet ☐

   for the above study and have had the opportunity to ask questions.

   ☐

2. I understand that my participation is voluntary and that I am free

   to withdraw at any time, without giving reason.

   ☐

3. I agree to take part in the above study.

Name of Participant	Date	Signature

Name of Researcher	Date	Signature