QUANTITATIVE EVALUATION OF UMBILICAL CORD AND PLACENTAL INDICES AND PREGNANCY OUTCOME

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DECLARATION

The experimental work described in this thesis was carried out at the Department of Anatomy, School of Medical Sciences, KNUST. This work has not been submitted for any other degree.

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ABSTRACT

Normal morphology of the placenta and umbilical cord is essential for foetal survival and postnatal outcome, therefore this study was designed to evaluate placental and umbilical cord indices and pregnancy outcome. A total of 207 placentae with attached umbilical cords were obtained from Victory Maternity Home and Clinic between November, 2009 and October, 2010 for this study. The results showed a significant difference ($P = 0.018$) in the umbilical cord vein diameter between neonates of normotensive (3.36 ± 0.88 mm) and hypertensive mothers (3.82 ± 0.50 mm). Body and umbilical cord lengths of the term males and females showed significant differences ($P < 0.05$). The umbilical cord length and placental weight had both individual and combined effects on birth weight and body length ($\beta = 0.071 – 9.351$, $P < 0.05$). Wharton's jelly measurements linearly related with birth weight ($\beta = 9.165$, $P = 0.013$), body length ($\beta = 1.071$, $P = 0.005$), and abdominal circumference ($\beta = 1.602$, $P = 0.001$). It is possible that an increase in Wharton's jelly volume improves its protective capacity and this impact favourably on foetal nutrition by enhancing foetoplacental circulation.

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ABBREVIATIONS

GA	Gestational Age
GHS	Ghana Health Service
BW	Birth Weight
BL	Body Length
HC	Head Circumference
AC	Abdominal Circumference
HC/AC	Head Circumference to Abdominal Circumference ratio
PI	Ponderal Index
MjD	Placental major diameter
MiD	Placental minor diameter
MOH	Ministry of Health
PW	Placental Weight
CPA	Chorionic Plate Area
BW/PW	Birth Weight to Placental Weight ratio
dI	Distance of umbilical cord insertion from margin
Sdi	Short distance of umbilical cord insertion from margin
Ldi	Long distance of umbilical cord insertion from margin
CCI	Cord Centrality Index
ECI	Eccentricity Index
UCL	Umbilical Cord Length
UCD	Umbilical Cord Diameter
UCA	Umbilical Cord Area
UCV	Umbilical Cord Volume
UCI	Umbilical Cord Index
AWJ	Area of Wharton's jelly
VWJ	Volume of Wharton's Jelly
UCVD	Umbilical Cord Vein Diameter
UCVA	Umbilical Cord Vein Area
UCVV	Umbilical Cord Vein Volume
A1D	Umbilical cord Artery 1 Diameter

A1A	Umbilical cord Artery 1 Area
A1V	Umbilical cord Artery 1 Volume
A2D	Umbilical cord Artery 2 Diameter
A2A	Umbilical cord Artery 2 Area
A2V	Umbilical cord Artery 2 Volume
PIH	Pregnancy Induced Hypertension
Pre W	Prepregnancy Weight
NWG	Net Weight Gain

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

1.1.1 Determinants of foetal well being

The well being of the foetus is influenced by a number of factors all of which are clearly seen in terms of the birth weight. Such factors include genetics, maternal characteristics, placental and umbilical cord structure and functions. Again, various diverse growth patterns are observed such as differences in thinness, body length, head and abdominal circumferences all of which account for the weight of the baby (Baptiste-Roberts *et al.*, 2008).

The growth of human foetus is limited by the inability of the mother and placenta to adequately supply nutrients and oxygen to the foetus and the consequence of foetal undernutrition is reduced growth and low birth weight (Ounsted *et al.*, 1986; Harding, 2001). However, experimental evidence has it that under such conditions, foetal adaptations occur to respond to failure of the maternal – placental nutrients supply so as to meet the foetal demands (Barker, 1995; Godfrey and Dodson, 2003). The placental nutrient transfer is also affected by the electrochemical gradient, blood flow and morphological characteristics of the placenta e.g. the surface area and thickness (Fowden *et al.*, 2006).

Umbilical cord, the lifeline connecting the foetus to the placenta is mostly assessed for the impedance of the umbilical arteries to blood flow in foetus with or at risk for growth and

developmental abnormalities (Raio *et al.*, 2003). A study investigating, morphologic and morphometric characteristics of the umbilical cord and its components observed that a lean umbilical cord poses a risk to the foetus such that it becomes smaller for gestational age at delivery and also experiences distress during labour (Bruch *et al.*, 1997; Raio *et al.*, 1999; Di Naro *et al.*, 2001a; D'Addario *et al.*, 2002; Raio *et al.*, 2003)

1.2 PLACENTAL CHARACTERISTICS

1.2.1 Placental Weight

Genetically and biologically, the placenta as organ is an integral part of the foetus (Pepe and Albrecht, 1995). It forms placental barrier that filters physically harmful substances from entering into the foetus. It exhibits metabolic, endocrine and immunologic functions. A number of foetal abnormalities have therefore been traced to placental malfunctioning. The gross examination of the placenta, particularly, its weight has been found to be an important source of information in the delivery room for the paediatrician on intrauterine well being of the foetus (Adebami *et al.*, 2007).

Traditionally, the measurements of the placenta weight after delivery forms part of clinical practice in most advanced cultures. However, lack of standard technique in the measurement of the placental weight subjects these values to questioning. Indeed, the interest in placental weight has been found to reflect in its association with coronary heart disease and other complications in the adult life (Godfrey, 2002). Placental weight is known to be a reflection of placental development and functions in early intrauterine environment and correlates with maternal age, gestational age, and parity, history of

maternal diabetes, preeclampsia, birth weight, and route of delivery. Other placental weight correlates include maternal height, weight and serum ferritin (Asgharnia *et al.*, 2008). Also, the role of placental weight in the development of the foetus is seen in terms of birth weight, body length and umbilical cord length (Lo *et al.*, 2002).

1.2.2 Placental Shape and Dimensions

Generally, the placenta or chorionic plate is perceived as round with the umbilical cord inserted into the center. In clinical practice, however, the chorionic plate is not "circular" but the shapes vary from round to oval, bi or multi lobate or could be considered as irregular (Salafia *et al.*, 2010). Factors that influence the shape of the placenta are believed to include; where it is implanted in the uterus, regional variations in the decidua, changes in maternal vascular supply and probably the "manner" of its original implantation (Benirschke *et al.*, 2006). In a study, Salafia et al (2010) concluded that quantifying abnormality of the chorionic plate shape is a useful tool in clinical practice. These researchers observed that abnormal shapes were associated with reduced placental efficiency and therefore hypothesized that abnormal shape is an indication of deformed placental vascular architecture and also as a marker for maternal uetroplacental and foetoplacental vascular pathology that impact negatively on placenta and potential foetal development. An irregular chorionic plate shape has been associated with lower birth weight to placental weight ratio, which presupposes an altered placental function (Yampolsky *et al.*, 2008).

In a placental shape and developmental programming analysis, the following were the observations; the risk of developing hypertension in adult life was associated with reduced placental weight and surface area; pregnant women who experienced preeclampsia had reduced placental weight and more oval placentae; the short placental diameter strongly associated with the severity of preeclampsia (Barker *et al.*, 2010b; Kajantie *et al.*, 2010). Similarly, dimensional analysis has established that the chorionic plate area is a measure of the space occupied by the placenta in the inner wall of the uterus, which in essence, determines the number of potential maternal spiral arteries that are capable of supplying materials to the placenta, whiles thickness reflects in the volume of endocrine and vascular nutrient exchange tissue (Pathak *et al.*, 2010b). According to (Salafia *et al.*, 2005), the diameters of the placenta are perfect measure of the round and/or oval nature of the chorionic plate.

1.3 UMBILICAL CORD CHARACTERISTICS

The umbilical cord also referred to as *Funiculus umbilicalis* or birth cord, perhaps, the only organ of the foetus that dies when life begins. It is structurally and functionally simple, yet it is the foetal lifeline connecting placenta to the foetus for the supply of oxygen, nutrients and transfer of waste materials, processes necessary for the growth and development of the foetus (Ozdemir *et al.*, 2007; Yampolsky *et al.*, 2009). A cross – section of umbilical cord reveals a "dull" white colour on the surface and comprises two umbilical arteries and one vein continuous with the vascular architecture of the placenta. These vessels are supported on the exterior by a protective gelatinous connective tissue

known as Wharton's jelly. The umbilical cord normally has coils ranging between 6 – 10 coils per cord length, and a length of 50 – 60 cm with diameter of 1 – 2 cm (Cunningham *et al.*, 2005).

1.3.1 Umbilical cord vessels

Several studies have reported on the significant variations in the morphology and morphometry of the placenta and umbilical cord vessels between normal and preeclamptic pregnancies. Among such studies is Bruch et al (1997), who demonstrated that growth retarded foetuses have minor umbilical cord cross – sectional area at delivery as compared to normal healthy babies. Di Naro et al (2001) also observed varied umbilical cord diameters and areas during gestation, which were attributed to reduce Wharton's jelly than the umbilical cord vessels themselves. It has been reported that in preeclamptic pregnancies, the umbilical cord arteries were comparatively thicker than uncomplicated pregnancies (Junek *et al.*, 2000). These variations were as a result of the umbilical cord vessels adapting to the altered haemodynamic conditions. The differences could also arise due to reduction in vasodilator or increase in vasoconstrictor substances as a result of a pathophysiologic state (Howard *et al.*, 1987).

1.4 THE PRESENT STUDY

Knowledge about the umbilical cord is important because the vessels in the cord are an essential part of the foetal circulation. The umbilical cord has also been found to be a marker of intrauterine complications. Morphological alterations in the umbilical cord due to its vulnerability to malformations, lesions, mechanical and iatrogenic events

throughout pregnancy, labour and delivery, collectively referred to as umbilical cord accidents, are said to be possible causes of foetal injury or death. These morphological alterations include; umbilical cord attachments to the placenta, extreme umbilical cord lengths, attachments, Wharton's jelly content, cord tensile strength, shape, cord looping, cord knotting, umbilical cord vessel morphology and number. It is estimated that more than 7.6 million perinatal deaths occur each year worldwide; 4.3 million of these are foetal deaths. Ninety-eight percent of perinatal deaths have been said to take place in developing countries, and the perinatal mortality rate is estimated to exceed 55 per 1000 births, which is five times higher than in developed countries (Schindler, 1991). Ghana is no exception to this finding.

The present obstetric and perinatal pathological practices are such that qualitative terminologies are commonly employed to describe the placenta, and umbilical cord insertion. For example, "velamentous", "central", and "marginal" cord insertions, "round" or "oval" placental shape etc.

Little is known about the attempt to quantitatively describe the relationship between measurements such as the size of placenta, shape of the chorionic plate, area of the chorionic plate, distance of the umbilical cord insertion into the centre of the placenta, deviation in placental shape from the traditional normal circular appearance, the area and volume of the umbilical cord and its vessels. In fact, information about these variables and their association with pregnancy and neonatal outcomes is scanty in Ghana. This study is therefore carried out to explore the quantitative association between these placental and umbilical cord variables and neonatal outcomes.

1.5 AIM AND OBJECTIVES

1.5.1 Aim

The aim of this study is to quantitate placental and umbilical cord indices and their association with pregnancy outcome.

1.5.2 Objectives

1. To determine the relationship between maternal indices and neonatal anthropometry
2. To determine the relationship between placental indices and neonatal anthropometry
3. To determine the relationship between umbilical cord morphology and neonatal anthropometry
4. To determine the relationship between umbilical cord vessels morphometry and neonatal anthropometry
5. To determine the relationship between pregnancy induced hypertension mothers and neonatal anthropometry

CHAPTER 2

LITERATURE REVIEW

The umbilical cord is the life – line connection between the foetus and the mother through which materials such as nutrients, oxygen, and fluids necessary for intrauterine life are supplied. In view of this, abnormalities associated with umbilical cord would have adverse effects on the perinatal outcome (Baergen *et al.*, 2001).

Although obstetricians appreciate the major role played by umbilical cord towards the well – being of the foetus, it has been the work of perinatal pathologists which have contributed significantly to the current knowledge of umbilical cord anomalies and the potential effects of these factors on the outcome of pregnancy (Sepulveda, 1999).

The evolution of high resolution ultrasound and colour flow imaging techniques in prenatal care has offered the opportunity to assess the morphological characteristics of the umbilical cord and the detection of conditions which can potentially result in adverse pregnancy outcome (Sepulveda, 1999; Collins, 2002). Recent advancement in ultrasonography has made it a key component of the guidelines for second trimester sonographic examination to evaluate foetal anatomy and growth, placental location and amniotic fluid volume, and examination of the umbilical cord (Sepulveda *et al.*, 2009).

Studies on the morphological and morphometric characteristic of umbilical cord over the years have found positive correlation with perinatal outcome and foetal weight (Goynumer *et al.*, 2008). Over the years, the number of umbilical cord vessels has caught the attention of researchers in assessing the morphology of umbilical cord, since single umbilical cord artery (SUA) and velamentous insertion have been established to be

associated with poor pregnancy outcome (Persutte and Hobbins, 1995). Other umbilical cord abnormalities such as stillbirths, intrauterine growth restriction, non – reassuring foetal heart tracing (NRFHT), Low Apgar Score and meconium staining have been identified with adverse perinatal outcomes (Tantbirojn *et al.*, 2009). Quite a number of obstetric complications could develop from other anomalies involving the placenta and umbilical cord. Morphological characteristics of umbilical cord such as being thin; having velamentous insertion and abnormal coiling contribute to poor perinatal outcomes ((Eddleman *et al.*, 1992; Sepulveda *et al.*, 2003; Ghezzi *et al.*, 2005; Sebire, 2007).

Certain fundamental differences in the structure and function of umbilical cord could put a given foetus at risk. Therefore the ability of one foetus to tolerate certain umbilical cord abnormality over another may be explained in terms of variations in the microstructure, elemental content of umbilical cord vessels, enzymatic content and other biochemical differences in the umbilical cord (Franc *et al.*, 1998; Masuda *et al.*, 1999).

While morphological characteristics such as tensile strength, diameter, umbilical cord circumference, Wharton's jelly content, umbilical cord length and weight could be determined genetically, the umbilical cord development, differentiation, growth and elongation would depend on the sex, nutrient supply and health status of the foetus (Collins, 2002).

2.1 UMBILICAL CORD TENSILE STRENGTH

Although the structure and function of the umbilical cord appear to be relatively simple, it is indeed an amazing organ very necessary for intrauterine life and foetal well-being (Goynumer *et al.*, 2008).

Structurally, it is composed of an outer amniotic layer, porous Wharton's jelly, two umbilical arteries and one vein which function to maintain and protect blood flow to the foetus during grasping, normal movement, forces of labour and in situations of other umbilical cord abnormalities including knots and loops during term pregnancy. As a channel through which blood flows, the umbilical cord varies in its physical dimensions and extracellular matrix composition with maternal characteristics like gestational age, pregnancy disorders, and genetic abnormalities of the foetus (Ferguson and Dodson, 2009).

Though it is not well established in other mammalian umbilical cords, the tissue constituents of human umbilical cord interestingly have biomechanical properties, exhibiting non-linear viscoelastic characteristics with a clear anisotropy of the vein. This appears to be a preventive mechanism to eliminate excessive elongation of the cord that may results in undue restriction of the umbilical cord vessel area as well as interference in the foetal circulation (Pennati, 2001b). Breaking points in human umbilical cord as have been severally reported are indications of differences in the amount of Wharton's jelly, collagen content and muscle layer structure (Vizza *et al.*, 1995). Due to its elasticity, the umbilical cord could stretch up to 12.5% of its original length with an average tensile strength of 2.5% of foetal weight. Consequently, some foetuses may tolerate more

traction and loss of slack during umbilical cord entanglement than others (Ghosh *et al.*, 1984).

2.2 UMBILICAL CORD CIRCUMFERENCE, DIAMETER AND AREA

The cross – sectional areas of umbilical cord components are essential in evaluating foetal weight. A strong correlation between the cross – sectional areas of umbilical cord components and foetal anthropometric parameters has been established (Togni *et al.*, 2007).

Sonographic determination of cross – sectional areas of umbilical cord components reported of the following averages and observations; umbilical diameter of 1.5cm and umbilical circumference 3.6cm after birth (Patel *et al.*, 1989; Weissman *et al.*, 1994), umbilical cord vein diameter of 8mm and artery diameter of 4 mm at term (Collins, 2002). Sonographic umbilical cord diameter and area increase as a function of gestational age. The diameter of umbilical artery increases from 1.2 ± 0.4 mm at 16 weeks to 4.2 ± 0.4 mm at term gestation and umbilical vein diameter varies from 2.0 ± 0.6 mm at 16 weeks of gestation to 8.2 ± 0.8 mm at term gestation (Di Naro *et al.*, 2001b). A successive increase in umbilical cord diameter and cross – sectional area up to 32 weeks of gestation with a subsequent reduction in umbilical cord size was observed in a study by Raio *et al* (1999) in which a significant relationship between umbilical cord diameter, cross – sectional area and foetal anthropometric parameters was also observed. In such similar study, it has been reported that infants born to women with higher prepregnancy weight, the male infant and heavier infants at birth tend to have large amount of Wharton's jelly wrapped around their umbilical cord vessels (Gill and Jarjoura, 1993). A

correlation between Wharton's jelly content, umbilical cord diameter and estimated foetal weight in non – macrosomic foetuses of mothers diagnosed of gestational diabetes has been reported (Weissman and Jakobi, 1997).

2.3 UMBILICAL CORD WHARTON'S JELLY CONTENT

As gestation progresses, the amount of Wharton's jelly becomes most prominent of the umbilical cord components during second and third trimesters. These differences in amount of Wharton's jelly content occurring in normal pregnancies give indication of the circumstances that surround the macroscopic appearance of the umbilical cord (Ghezzi *et al.*, 2001).

The Wharton's jelly is a derivative of the extraembrayonic mesoblast. Its inclusion in the cord substance and subamnionic layers could probably explain their mucoid and compressible nature (Kulkarni *et al.,* 2007). Wharton's jelly, made of collagen fibers forms a network of interconnected cavities, cavernous and perivascular spaces for storage of ground substance of the jelly (Vizza *et al.*, 1996). This ground substance has hyaluronic acid and proteoglycans in an aqueous solution of salts, metabolites and plasma proteins as its constituents (Skulstad *et al.*, 2006).

Wharton's jelly appears to substitute for an adventitia for the umbilical blood vessels, which the umbilical cord vessels lack, binding and encasing them. Speculations are that, the cells of the Wharton's jelly may partake in the regulation of umbilical blood flow, and that, in some instances; the foetal growth could be affected by Wharton's jelly diminution leading to hypoplasia of the umbilical vessels (Gebrane-Younes *et al.*, 1986; Bruch *et al.*, 1997). According to Ghezzi *et al.,* (2001) the ratio of the Wharton's jelly

area to the total umbilical cord area decreases significantly with advancing gestation. This is because the water content of the Wharton's jelly reduces towards the end of pregnancy.

The reduction in the amount of Wharton's jelly could result from an inherited disorder in the deposition of Wharton's jelly, making the umbilical circulation vulnerable to scornful abuse rather than the consequence of foetal disease (Raio *et al.*, 1999). Successive foetal deaths in the same family due to torsion of the umbilical cord resulting from primary absence of Wharton's jelly have been reported (Hersh and Buchino, 1988). However, the absence of Wharton's jelly around the umbilical cord vessels is an unusual cause of perinatal mortality (Kulkarni *et al.*, 2007).

The umbilical cord can be large (thick) enough exceeding an average of 4cm in circumference with average weight of 15g/10cm at term. (Casola *et al.*, 1985; Collins, 2002). Association between large umbilical cord and other foetal structural anomalies including umbilical cord tumour, urachal cysts, umbilical cord mucoid degeneration and omphalomessenteric cyst has been reported. Under such instances, morphological alterations occur at a limited portion of the umbilical cord (Iaccarino *et al.*, 1986; Benirschke and Kaufmann, 1995).

Di Naro *et al.*, (2001) in their study considered the possibility that an abnormally large umbilical cord might be an additional parameter that can help to identify foetuses of mothers having some kind of glucose intolerance during pregnancy. In the same manner, the umbilical cord can be lean (thin), <1cm in circumference and lack Wharton's jelly. Probably, lean cord could be determined by factors such as reduced amount of Wharton's jelly or reduced umbilical cord vessels' cross – sectional areas or by both (Ghezzi *et al.*,

2005). Di Naro *et al* (2001) observed that small umbilical cord vein area and low coiling index characterized large numbers of sonographically lean cords. Post – term (>42weeks) foetuses and intrauterine growth retardation (IUGR) foetuses are associated with lean cord appearances, which could suggest both poor nutrition and lack of glycogen in the foetal tissues(Amiel – Tison and Stewart, 1994; Iffy and Varardi, 1994). In post-term pregnancies, the diameter of the umbilical cord is smaller in patients with oligohydramnios than in those with normal amniotic fluid (Silver *et al.*, 1987). In this regard, it necessary to ensure normal amniotic fluid volume before assessment of abnormal cord can be made (Strong *et al.*, 1992).

Differences in umbilical cord water and molecular contents could result as an independent risk factor for poor pregnancy outcome. The average cross – sectional area of the human umbilical cord is $14cm^2$. Lean (thin) umbilical cords may exhibit differences in blood flow characteristics and are more vulnerable to compression. Consequently, abnormal assessment of the umbilical cord could be done when the amniotic fluid volume is normal (Silver *et al.*, 1987; Gill and Jarjoura, 1993; Collins, 2002).

A highly significant relationship has been established between the presence of a lean umbilical cord (cross – sectional area < 10^{th} percentile) and the delivery of a small – for – gestational age (SGA) infants. Patients with a lean umbilical cord after 20 weeks of gestation potentially, had 4.4 – fold higher risk (95% confidence interval, 2.16 – 8.85) of having an SGA infant than those with a normal umbilical cord (Raio *et al.*, 1999).

2.4 UMBILICAL CORD LENGTH

It is uncertain as what factors control the length of the human umbilical cord; however, both genetic and environmental factors have been associated with the determination of umbilical cord length. It has been reported that growth of the umbilical cord, placenta and body length may be under similar control mechanisms some of which are likely to be genetic in origin (Baergen *et al*., 2001).

The "tension theory" suggests that the length of the umbilical cord is assumed to increase with the tensile force applied to it in the uterus, and the greatest tensile force being the foetal movement which requires adequate space within the amniotic cavity. Any intrauterine constraint of its kind would reduce the tensile force resulting in the length of the umbilical cord being short (Lyndon *et al.*, 1994).

Benirschke (2004) observed that human umbilical cord develops steadily with growing gestation and foetal crown – rump length; and measures approximately 55 cm long at term.

Adverse perinatal outcomes have been observed in excessively short and extremely long umbilical cords. Short umbilical cords are proposed to be less than 40cm whereas long umbilical cords are greater than 70cm long. The umbilical cord length is the only factor documented to exhibit high risk for poor foetal outcome. A strong relation between abnormal umbilical cord and neurological abnormalities and low IQ has been observed (Baergen *et al.*, 2001).

An average length of 50 – 60cm is considered normal in full – term newborn which also reflects intrauterine foetal motility. An abnormally short umbilical cord predisposes the

umbilical cord to rupture, haemorrhage, stricture, malpresentation, prolonged second stage labour, abruption and intrauterine inversion. Whiles excessively long umbilical cord is known to be associated with entanglement, torsion, knots and thromboses. It also strongly associates with high rate of asphyxia during delivery, foetal anomalies, non – reassuring foetal status, respiratory distress, foetal growth restriction and delivery interventions.

Other studies have shown that a positive correlation exists between umbilical cord length and parity, pregnancy weight and foetal sex (Baergen *et al.*, 2001; Stefos *et al.*, 2003). The umbilical cords of male newborns are found to be long than females and term vertex foetuses could have long umbilical cords than term breech foetuses (Calvano *et al.*, 2000).

2.5 UMBILICAL CORD VESSEL NUMBER

The number of umbilical cord vessels is as important as the amount of Wharton's jelly

and cord length during morphological assessment of the umbilical cord. Normally, an umbilical cord would have two arteries and a vein embedded in Wharton's jelly (Gouden, 2003). Yet the umbilical cord vessel number may vary resulting in certain foetal abnormalities. Umbilical cord vessels numbering two, four or five and fused cords in twins have been observed which associated with known foetal anomaly (Cohen *et al.*, 1992; Schimmel and Eidelman, 1998).

Structurally, the walls of umbilical cord arteries and the vein are identical; the intima has a thin layer of endothelial cells, collagen, elastin and a matrix (Pennati, 2001a). Koech *et al* (2008) reported that in preeclamptic cords, there was an increase in thickness of the tunica media and intima in the arteries and higher rate of internal elastic lamina

duplication. However, a reduced vessel diameter and wall thickness in both cord artery and the vein in preeclampsia as against normal pregnancies and pregnancies affected by chronic hypertension have been observed (Inan *et al.*, 2002).

Single umbilical artery (SUA) is the more common congenital abnormality of the umbilical cord, occurring in approximately 0.2 to 1 percent of all human pregnancies (Heifetz, 1984). Again, the prevalence of SUA is known to be between 0.5 – 2.0% in uncomplicated neonates and 1.5 – 7% in aborted and aneuploid (9 – 11%) foetuses. Multiple gestations rank 3 – 7 times higher risk of SUA (Di Naro *et al.*, 2001b). It is assumed that the causes of development of SUA may include primary agenesis, secondary atrophy or atresia, and persistence of the single allantoic artery in the body stalk (Persutte and Hobbins, 1995). Single umbilical artery strongly correlates with stillbirth with an incidence rate of 3 – 20%, more frequent in twins, diabetic pregnancies, commonly associated with long cords and small placentae (Collins, 2002). Early detection of SUA therefore calls for a detailed sonographic study to identify any of the anomalies that associates to SUA (Hamada *et al.*, 2001). Interestingly, the organ systems of the foetus which commonly suffer structural abnormalities as a result of SUA, from mild to severe are cardiac, gastrointestinal, central nervous system, genitourinary, respiratory and musculoskeletal systems (Gouden, 2003).

Majority of SUA exhibit a major than usual arterial diameter, approaching half or equal the diameter of the umbilical vein. The transverse intraluminal umbilical artery diameter measurement is believed to offer the needed support in the identification of this anomaly (Sherer *et al.*, 1997). In a study, all pregnancies identified with SUA 20 to 36 weeks of gestation had umbilical arterial diameter measuring greater than 4mm whiles all

pregnancies with two umbilical arteries had arterial diameter less than 4mm (Persutte and Lenke, 1994).

In their view, Sepulveda *et al* (1996) suggested the use of umbilical vein diameter to arterial diameter ratio instead of the increased arterial diameter in diagnosing SUA. Comparing 55 SUA foetuses with 55 control foetuses with two umbilical arteries, these researchers observed in all except one foetus with SUA that this ratio is ≤ 2; however, none of the controls had a ratio ≤ 2.

2.6 UMBILICAL CORD INSERTION

The umbilical cord is purposefully made to facilitate foetal development until delivery; therefore the cord needs not to detach which in turn demands a specialized anatomy of its insertion to both the foetus and the placenta. Failure of such an attachment would results in foetal demise (Collins, 2002).

The Anatomy of the umbilical cord is such that its point of insertion onto the placenta relies heavily on the implantation of the blastocyst. Umbilical cord usually insert into the placenta at the center (Centric) or near the centre (Eccentric). However, when the blastocyst fails to attach at the embryonic pole, the connecting stalk may attach at the margin or to the smooth adjacent chorion resulting in marginal or velamentous insertions respectively as pregnancy advances in age.

Centric and eccentric umbilical cord insertions are found in more than 90% of all cord insertions into the placenta, this is followed by marginal also known as battledore and the least occurring is velamentous insertion. These are commonly used terminologies for the

purpose of qualitative comparison of cord insertions (Pathak *et al.*, 2010a). The centric and eccentric cord insertions are considered normal and have no medical importance. Marginal cord insertion is known to be associated with vessel rupture, preterm labour, intrauterine growth restriction, stillbirth, and neonatal death. The frequency of velamentous insertion increases with maternal risk factors such as maternal smoking habit, advanced age, or diabetes mellitus and multiple births (Heifetz, 1996).

The distance of umbilical cord insertion from the placental center is clinically established as a good indicator of maternal insufficiency (Whittle *et al.*, 2006a). This can be well explained by the answer to the question, "How might a given placenta size yield different birth weights?" The genetics of the mother affects the constitutionally appropriate birth weight and more so, on the placental weight. Maternal weight gain, medical disorders, environmental exposure and lifestyle including substance abuse, tobacco use, etc. can alter the foetal and the placental growth. With these maternal factors apart, it has been proven that deviation of placental proportions from round and distance of umbilical cord insertion; modify the functional efficiency of the placenta (Yampolsky *et al.*, 2009).

The association of the shape of placenta with the placental efficiency lies in the design of the placental vascular tree which happens to be the only provider of foetal nutrient and oxygen. The chorionic plate vessels produce high capacitance blood distribution machinery to ensure bulk transportation of blood, fast enough from the umbilical cord to the placental villi where nutrient and oxygen are exchanged, and recedes to the umbilical cord again. Variations in the fundamental proportions of the placental disk and the structure of the vascular tree would therefore reduce the level of transportation efficiency, hence the capability of the placental mass to functionally yield foetal mass (Yampolsky *et*

al., 2008). Placentae with non – centrally inserted umbilical cord are characterized by thinly spread vascular coverage, heavy weight, large diameter and are thicker (Yampolsky *et al.*, 2009).

Pathak *et al* (2010), qualitatively define the types of umbilical cord insertions as follow:

Centric insertion is defined as the umbilical cord inserting within 2 cm of the center of the chorionic plate.

Eccentric insertion is defined as the umbilical cord inserting greater than 2 cm from the center and within the margin of the chorionic plate.

Marginal insertion is when the umbilical cord inserts into the margin of the chorionic plate.

Velamentous insertion is when the umbilical cord inserts outside the chorionic margins into the membranes.

These researchers derived indices that describe quantitative association of the umbilical cord insertion into the placenta.

They quantified the cord centrality and eccentricity indices mathematically to describe the nearness or farther the cord insertion is from the placental center and the shape of placenta relative to whether it is circular or ovoid respectively.

According the quantification, the cord centrality is calculated as the ratio of the distance of the umbilical cord insertion from the placental center to the half of the longest (largest) diameter. Whiles eccentricity is also calculated as the ratio of the distance between the

foci to the length of the major axis. Mathematical expressions for these ratios therefore are:

Distance of umbilical cord insertion from placental centre was calculated mathematically according to the Pythagorean Theory;

Distance of Cord insertion (d cm) = $\sqrt{(T_1^2 + T_2^2)}$; where T_1 is the horizontal length or base; T_2 is the vertical height (Figure 1)

Cord Centrality Index (CCI) = $\frac{\text{Distance of umbilical cord insertion from placental center}}{\text{Half of the longest diamter of the placenta}}$

Eccentricity Index (EI) = $\sqrt{1 - (\text{minor axis/major axis})^2}$

The minor the value of the centrality index the more closer the umbilical cord insertion to the placental center from the margin whiles greater value indicates a more distant cord insertion from the placental center and an absolute 1 means a completely marginal insertion. Similarly, minor eccentricity index value means a circular shape of the placenta, and a greater value approaching 1 also represents an elliptical shape of the placenta. With the exception of cases of velamentous insertion, the centrality and eccentric index values range between 0 and 1.

2.7 UMBILICAL CORD INDEX

The umbilical cord is a vital structure necessary for the survival of the foetus and also a fascinating structure that has caught the attention of obstetricians and pathologists. The most interesting feature of the umbilical cord is the degree to which the umbilical cord vessels exhibit helical pattern or coiling within the Wharton's jelly (de Laat Monique *et*

al., 2007). The origin as well as the factors which influence the direction and the number of coiling within the Wharton's jelly is still subjects of interest to study. However, the assumptions are that foetal movements, differential umbilical vascular growth rate, foetal haemodynamic forces, and directional arrangements of muscle fibers within the arterial wall may be the key determinants (Qin *et al.*, 2002).

Umbilical cord coiling is observed by about 10 weeks of gestation and as a result matches with the growth of umbilical cord. This in essence means that coiling develops in the presence of high ratio of amniotic fluid volume to foetal size and hence the foetus achieves coiling by rotating with respect to the implanted placenta (Machin *et al.*, 2000a). The umbilical cord coiling together with Wharton's jelly is thought to provide mechanical support to the umbilical cord vessels which are otherwise more prone to kinking, compression, traction and torsion (Hasegawa *et al.*, 2009).

The umbilical cord coiling is quantitatively assessed by the umbilical cord index, defined as the number of complete coils per the total length of the umbilical cord measured in centimeters (Predanic *et al.*, 2005). By this definition, several studies have been consistent in reporting a normal UCI of about 0.2 in postpartum when the placenta and the umbilical cord are examined, and 0.4 when the examination is performed antenatally by sonography. At term, the normal umbilical cord vessels complete an average of 10 – 11 coils for the length of the umbilical cord inserted between the foetus and placenta (Van Diik *et al.*, 2002). In comparing abnormal and normal umbilical cord coiling at 10^{th} and 90^{th} percentiles for umbilical coil index, previous studies exhibited the following UCI means; Gupta *et al* (2006) calculated UCI mean of 0.13±0.08 as compared to 0.20±0.10

reported by Ercal *et al* (1996), 0.21±0.07 by Strong *et al* (1994) and 0.19±0.10 by Rana *et al* (1995).

However, an abnormal umbilical cord coiling, described as hypocoiled (under coiled) and hypocoiled (over coiled) which are objectively classified as below the 10^{th} percentile and above the 90^{th} percentile respectively, exhibits a strong association with adverse foetal outcomes (Predanic *et al.*, 2005). Therefore an early detection of abnormal cord coiling is an alert threshold of a potential cause of adverse foetal outcome at any future time of gestation (Machin *et al.*, 2000b). In their study, the researchers observed that abnormal coiling occurred in most of cases of foetal demise which could have been impossible to explain.

Hypocoiling is known to cause one or more of the following adverse outcomes; trisomies, preterm delivery, foetal death, increased intrapartum complications, Apgar score less than 7 at 5 minutes, Velamentous cord insertion, single umbilical artery, and interventional deliveries for foetal distress. Hypercoiling on the other hand has been linked with trisomies, small – for – gestational age, foetal asphyxia and single umbilical artery (Pathak *et al*., 2010).

According to a clinical data, umbilical cord abnormalities contribute to about 45% of the causes of intrauterine foetal death, with abnormal coiling occurring in nearly 50%. Of the intrauterine foetal demise associated with hypercoiling, it is observed that foetal end of the umbilical cord is narrow and weak, which presuppose that the foetal side of the umbilical cord, is weakest relative to the whole umbilical cord. For this reason, severe hypercoiling could be the direct cause of sudden foetal death (Hasegawa *et al*., 2009).

On the contrary, some schools of thought argue that abnormal cord coiling (hypocoiling or hypercoiling) is not sufficient to cause adverse foetal outcomes, instead, some other cause could be involved, for instance, umbilical cord insertion or placental size (Predanic *et al.,* 2005). A study conducted by Otsubo *et al* (1999) described a higher percentage (67%) of abnormal cord insertions in foetus with umbilical hypocoiling and only 1.3% in normocoiled foetuses. This relationship may suggest that a single etiologic factor is responsible for both abnormal cord coiling and abnormal cord insertions of the umbilical cord.

Again de Laat Monique *et al* (2007) reported that in a full post – mortem examination and placenta studies, several cases of hypocoiling and hypercoiling were the only abnormalities observed.

2.8 PONDERAL INDEX (PI)

The idea of intrauterine growth restriction, described as low birth weight for gestational age to be the key determinant of infant mortality is superseded by ponderal index. This is because low birth weight (<2500g) alone does not ensure validity of the measurement of foetal growth dysfunctions, hence to facilitate the detection of intrauterine malnutrition, is important to include body length and calculating the ponderal index corrected for gestational age (Colley *et al.*, 1991).

Ponderal index defines body proportionality at birth, thereby differentiating between symmetric from asymmetric growth restrictions and also serving as a measure of the severity of asymmetric growth restriction in neonates. The ponderal index is computed as the ratio of birth weight measured in grams to the cube of crown – heel length in

centimeters and multiplying by 100, [i.e. BW/L^3*100] and is employed by paediatricians to determine neonatal wasting (Landmann *et al.*, 2006).

Characteristically, low birth weight infants suffer higher mortality and neonatal morbidity, show poorer growth, and lower IQs. Rosso (1989) warned of overly relying on the proportionality of growth restricted infants. He alternatively suggested that skeletal growth, as shown by body length and head circumference could exhibit considerable prognostic value for future growth and development of the neonate, whiles soft tissue growth measured by the indices such as the ponderal index, which associate with both body fat and muscle mass could give better prognostic values for short – term complications.

2.9 HEAD AND ABDOMINAL CIRCUMFERENCES

The foetal head and abdominal circumferences provide information on intrauterine growth restrictions. Traditionally, the intrauterine growth restriction has been classified as symmetric and asymmetric growth restrictions. Symmetrically growth – restricted neonates possess low birth weight, yet they may not be thin or wasted, since they show an appropriate weight for their length. Symmetrically growth – restricted neonates may have been adversely affected by genetic, infectious or teratogenic insult early *in utero.* On the contrary, most of them are healthy normal infants (Landman *et al*., 2006).

Asymmetric growth – restricted neonates exhibit disproportionately low birth weights for the body lengths, and majority have suffered chronic hypoxemia and malnutrition *in utero* (Soothill *et al.*, 1987). This occurs late in pregnancy as a result of placental insufficiency

to meet the foetal demand. Consequently, foetal responds to this unfavourable condition by invoking adjustment that maximizes the chances of survival, which includes redistribution of blood flow with more to the brain and heart and less to liver and kidney as well as limiting unnecessary movements. It can be observed on sonography when there is increase in head circumference over the abdominal circumference. Both symmetric and asymmetric growth – restrictions are thus determined by the ratio of the foetal head circumference to abdominal circumference (Enkin *et al.*, 1995; Anarnath *et al.*, 2000).

2.10 BIRTH WEIGHT

Birth weight is a straightforward measure of the outcome of births and is affected by several factors (which could be direct or indirect) necessary for perinatal survival. Available evidence suggest that the influence of birth weight is felt throughout the entire life – time of the individual, and could stimulate the risk of cardiovascular diseases such as hypertension, heart attack and stroke, diabetes and obesity, osteoporosis, breast and prostate cancers and neuro-developmental outcomes (Misra *et al.*, 2009). Birth weight is described as surrogate factor which by itself does not determine, but rather gives indication of the things happening in the intrauterine environment (Godfrey, 1998; Jarvis *et al.*, 2006). The key determinant of birth weight is the transfer efficiency of placental nutrients and oxygen that enable foetal growth and development which also leads to the pathway in explaining why birth weight is connected with mortality and morbidity in infants, children and adults (Misra et al. 2009).

Also, environmental and genetic factors may be the results of association between birth weight and body size later in life (Natalie et al., 2010). With respect to the constitutional growth potential; maternal weight gain, prepregnancy weight, maternal height, parity, age, gestational age, marital status, life - style, heredity, gender of baby, working hours and various socio-economic factors influence size at birth and adulthood (Mamelle et al., 2006, Amagloh et at, 2009). In the developing parts of the world, it has been established that race, nutrition, low pre-pregnancy weight, short maternal stature, and malaria are the major contributing factors to LBW babies (Kramer, 1987). According to a WHO Collaborative Study of Maternal Anthropometry and Pregnancy Outcomes, weight gained at second or early part of the third trimester was the most practical screening for LBW and Intrauterine Growth Retardation (WHO., 2003).

2.11 PLACENTAL WEIGHT

The placenta has complex metabolic and endocrine activities and is important for growth and survival of the foetus in utero. Foetal development is controlled by the equation between foetal metabolic demand and maternal – placental supply which is strictly related to utero – placental blood flow, placental size and its transfer capabilities. Less maternal placental supply than is needed would imply that the foetus must try to adapt to the situation by the modification of its body composition and endocrine status, selecting growth of specific organs and using cardiovascular adaptations (Pardi *et al.*, 2002).

The weight of the placenta can only be measured after delivery, however, the measurements of the delivered placenta shows the systematic development of the placenta right from conception to delivery. The measurement enhances the ability to carefully

observed differences between individual dimensions in intrauterine experience as well as providing a biologically active method to detect the physiology of the foetal experience. The growth of the placenta is directly proportional to its functional efficiency as the only foetal source of both nutrients and oxygen (Salafia *et al.*, 2005). A term placenta measures between 15 to 25 cm in diameter with a thickness of about 3 cm and weighs from 500 to 600g (Sadler, 2004).

Placental size measures, including placental area and thickness, affirm placental efficiency and growth. In the first place, they indicate two different dimensions of placental growth: the area is a reflection of lateral expansion of the chorionic disc; whiles thickness indicates vertical arborization of the villous and vascular nutrient exchange (Salafia *et al.*, 2005; Salafia *et al.*, 2008; Barker *et al.*, 2010a). Secondly, they almost reflect different periods of intrauterine environment adequacy. For example, whereas placental area growth is almost completed by early part of the third trimester, the placental thickness growth mostly occurs late in the third trimester. Thirdly, they may associate with the burden of the foetal cardiovascular system, such as cardiac workload and hemodynamic burden (Salafia et al., 2005).

Also little is known about the relationship between measurements, including the size of the placenta, the shape of the chorionic plate (foetal surface), distance of the umbilical cord insertion from the centre of the placenta and the deviation in placental shape from the usual normal circular appearance and their association with pregnancy and neonatal outcome (Pathak et al., 2010). Various umbilical cord insertions into the chorionic plate are described qualitatively as central, eccentric, marginal (Battledore) and velamentous (membranous). Marginal and velamentous insertions are believed to result from

disturbances of implantation (Kouyoumdjian, 1980). Central and eccentric insertions constitute more than 90%; while marginal and the least frequent is velamentous forms the remaining 10%. On the contrary, factor accounting for the eccentric (paracentral) cord insertion is still not clearly defined. Cord insertion anywhere between central and marginal insertion is commonly considered to be eccentric, yet none of these terms has been quantitatively described (Pathak et al., 2010). The kind of cord insertion may also be defined as how far the insertion point is located from the centre of the placenta, or how close the umbilical cord insertion is to the chorionic plate margin. The distance of the umbilical cord insertion from the placental centre has been suggested as a clinically useful marker of placental insufficiency (Viero *et al.*, 2004; Whittle *et al.*, 2006b).

2.12 BIRTH WEIGHT TO PLACENTAL WEIGHT RATIO

The birth weight to placental weight or foeto-placental weight ratio is calculated as birth weight divided by the placental weight, and is a value mostly considered to reflect a balanced physiologic state between foetal and placental growth. A linear foeto-placental weight ratio (birth weight/placental weight) commonly serves as clinical tool in evaluating foetal well-being and placental health (Salafia *et al.*, 2009).

The foeto-placental ratio is most often affected by pregnancy induced hypertension as a result of placental insufficiency; consequently, foetal growth is affected. In assessing the foetus, the weight of the placenta alone is not sufficient; however, the foeto-placental weight ratio becomes important (Raghunath et al., 2011). Comparatively large placenta relative to birth weight may reflects a relatively inefficient placenta with low ability in translating its own growth into foetal growth (Salafia *et al.*, 2008). In earlier study, it

was reported that foeto-placental weight ratio varies with placental proportions, indicating that differently proportioned placentae exhibit different functional efficiency. Most often, optimal foetal growth could be considered a biologically ‘‘good outcome’’, the baby with a foeto-placental weight ratio of 10:1 would be expected to have a different intrauterine cardiovascular and endocrine ‘‘experience’’ than a baby with a normal foeto-placental weight ratio of 7.5:1.1, or a baby with a foeto-placental weight ratio of 5:1 (Salafia *et al.*, 2007).

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY DESIGN AMD AREA

A longitudinal cross – sectional study was conducted from November 2009 to October 2010 on delivered placentae, foetal anthropometry and maternal socio-demographic characteristics from the Victory Maternity Clinic at Ayigya in the Kumasi Metropolis. The facility has a monthly average of 30 deliveries with an estimated annual average of 360 deliveries.

3.2 STUDY POPULATION

A total of 266 pregnant women who attended prenatal care and delivered at the facility were enrolled to participate in the study. Permission as well as cooperation was obtained from the Midwife in charge and the nursing staffs of the maternity clinic, also informed consent was sought from the mothers. The placentae from normal singleton with known gestational age and live birth neonate delivered at the maternity unit were collected and washed under running tap water to wash off blood smear and clots. The umbilical cord was cut, leaving a length of 2.5 cm from its foetal site of insertion. The specimens were then placed in plastic container filled with formalin (10%) with an airtight lid and kept at room temperature before transporting to the Department of Anatomy laboratory at the School of Medical Sciences - KNUST. All the specimens were labeled with number sticker after washing for the purpose of identification. When the sample was restricted to those with complete data on maternal socio-demographic characteristics, placental gross measurements and foetal indices, the total number of the sample became 207.

3.3 INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria were; women with complete information on their socio-demographic characteristics, known gestational age, singleton pregnancy, live birth neonate and the availability of mother's ANC card, sample with the number sticker attached and is identifiable.

Exclusion criteria were; women with multiple pregnancy, unknown gestational age, unavailability of ANC card and incomplete information on maternal socio-demographic characteristics, sample without number sticker or sticker cannot be read.

3.4 DATA COLLECTION

3.4.1 Sample Preparation

Two hundred and seven (207) placentae with their attached umbilical cords from mothers were collected and tagged with numbers that corresponded with the numbers indicated in the register for foetal indices and placed in a plastic container with 10% formalin. At the Anatomy laboratory samples were washed clean of blood and stored again in a solution of 0.5% formaldehyde in saline for a detailed examination and measurements.

3.5 PLACENTAL VARIABLES

The foetal surface of the placenta was wiped dry and placed on a clean surface after which the following parameters were measured:

3.5.1 Chorionic disc diameters (major, minor)

Diameters (major and minor) of the chorionic disc were recorded in cm using a standard non-elastic tape measure.

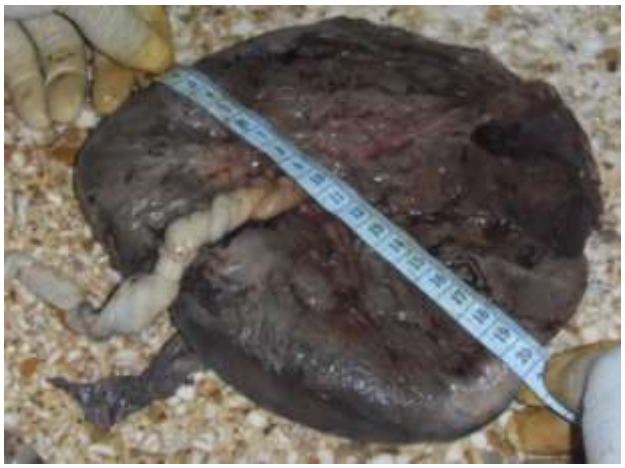


Plate 1: Measurement of the diameters of the placenta

3.5.2 Placental weight

Gross placentae (including umbilical cord and placental membranes) were weighed to the nearest 10 g in the laboratory using a highly sensitive mechanical kitchen scale (Zhongshan Camry Electronic Co. Model: KCH) graduated from 0 – 5000g.

Plate 2: Measurement of placental weight using kitchen scale

3.5.3 *Distance of umbilical cord insertion*

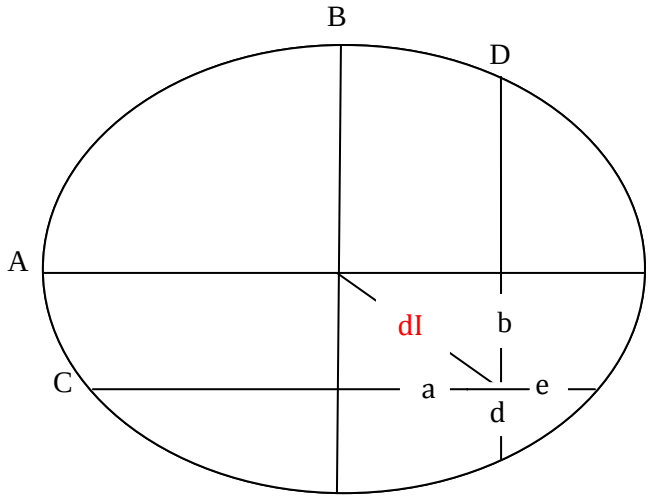


Figure 3 - 1: Description of the placental measurements, a = (½ C) - e, b = (½ D) - d, dI = distance of cord insertion from centre.

Distance of umbilical cord insertion from placental centre was calculated mathematically according to the Pythagorean Theory (Figure 3-1). 'a' was calculated by subtracting 'e'(shortest distance of umbilical cord insertion to the chorionic plate margin on X-axis) from the half of 'C'(X-axis passing through the insertion of umbilical cord). 'b' was calculated by subtracting 'dc'(shortest distance of umbilical cord insertion to the chorionic plate margin on Y-axis) from half of 'D'(Y-axis passing through the insertion of umbilical cord). Since $dc^2 = a^2 + b^2$, where dc is the distance of umbilical cord insertion from the centre. The formula for calculating the distance of the cord insertion from the centre is:

$$\boldsymbol{dI = \sqrt{a^2 + b^2}}$$

$$\boldsymbol{dc = \sqrt{\left(\frac{1}{2C} - e\right)^2 + \left(\frac{1}{2D} - d\right)^2}}$$ (Pathak et al., 2010).

3.5.4 *Cord centrality index (CI)*

It is a ratio that describes the distance of the umbilical cord insertion from the chorionic plate margin. It will range between 0 and 1 (except in cases of velamentous cord insertion, where the value may be greater than 1 as the insertion may be further from the centre than half the longest diameter). The smaller the CI, the closer the umbilical cord insertion to the placental centre; the greater the CI, the further away the cord insertion:

$$\mathbf{CI} = \frac{\textbf{Distance of umbilical cord insertion from the centre}}{\textbf{Half the distance of the larger diameter of the placenta}}$$

3.5.5 *Placental shape: Eccentricity*

Eccentricity is derived from the mathematical formula describing eccentricity for an ellipse/oval. This is the ratio of the distance between the foci to the length of the major axis. The value of an eccentricity should fall between 0 and 1, 0 indicates that the shape of placenta is circular while values towards 1 indicate an elliptical shape of the placenta.

$$\boldsymbol{EI} = \sqrt{\mathbf{1} - \left(\frac{\textbf{Larger Diameter}}{\textbf{Smaller Diameter}}\right)^{\mathbf{2}}}$$ (Pathak et al., 2010).

1. Chorionic plate area (square cm)

The chorionic plate area was estimated by calculation of the area of an ellipse from the measured (cm) major diameter and minor diameters of the chorionic disc using the formula:

$\boldsymbol{A} = \frac{\boldsymbol{\pi * dL * dS}}{\mathbf{4}}$ **;** where A is the chorionic disc area, dL is the major diameter and dS the minor diameter of the placenta (Baptiste – Roberts et al., 2008).

3.6 UMBILICAL CORD MEASUREMENTS

3.6.1 *Length and Diameter*

Each umbilical cord was immediately clamped at delivery and in all cases; 2.5cm umbilical cord stump was left on the neonate. Umbilical cords measurements were made with the umbilical cord still attached to the placenta. The umbilical cord length was measured in its entirety using a standard non – elastic tape measure from the foetal end to its point of insertion into the placenta. The 2.5 cm stump was added to each measurement made. The umbilical cord length measurements were categorized into short, when the measured length was < 40cm, normal, when the measurement was between 40 to 70 cm and long cord if the measurement was > 70 cm (Baergen et al., 2001). The umbilical cord diameter (UCD) was measured with a pair of dividers placed outer - to-outer so that the Wharton's jelly was also included in the measurement. All measurements were made in centimeters. The foetal end of the umbilical cord was sliced with a surgical blade before the diameters of the umbilical cord vessels were measured with a pair of divider and the result transferred onto a standard meter rule to the nearest millimeters.

Plate 3: Umbilical cord attached to its placenta with measuring tape to measure the length

Plate 4: Photograph of umbilical cord showing central insertion into the placenta

Plate 5: Photograph of umbilical cord with eccentric insertion

Plate 6: Photograph of umbilical cord showing marginal insertion into the placenta

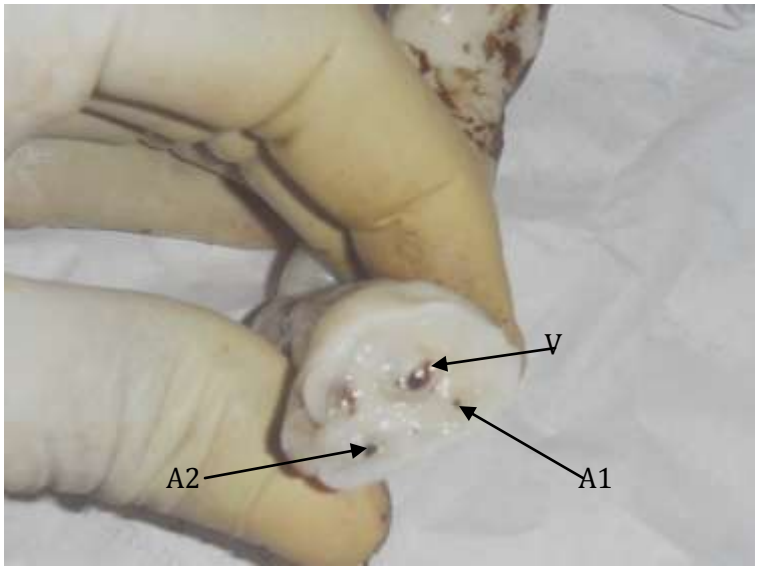


Plate 7: Photograph of umbilical cord showing three vessels

(**V =** Umbilical cord vein, **A1 =** Umbilical cord artery with an average of 2mm from the umbilical cord vein and average of 4mm from the umbilical cord margin**, A2 =** Umbilical cord artery with an average of 6mm from the umbilical cord vein and average of 4mm from the umbilical cord margin)

3.6.2 Cross – sectional area and Volume

The cross-sectional areas of the umbilical cord, umbilical arteries, and umbilical vein in a free loop of the umbilical cord were computed using formula for calculating the surface area of a cylinder with the assumption that the umbilical cord takes the shape of a cylinder. That is:

$\boldsymbol{A = 2\pi r^2 L}$; where $\boldsymbol{r}$ is the radius and $\boldsymbol{L}$, the length of cord vessel

The surface cross-sectional area of the Wharton jelly was computed by subtraction of the total vessel area from the cross-sectional area of the umbilical cord.

Volume of umbilical cord, umbilical arteries, and umbilical vein in a free loop of the umbilical cord were computed using the formula for calculating the volume of a cylinder:

$\boldsymbol{V = \pi r^2 L;}$ where $\boldsymbol{r}$ is the radius and $\boldsymbol{L}$ length of cord vessel

The volume of the Wharton jelly was computed by subtraction of the total vessels volume from volume of the umbilical cord.

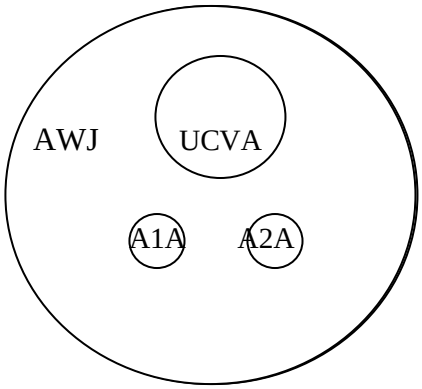


Figure 2: Diagrammatic representation of the umbilical cord.

$\boldsymbol{AWJ = UCA - (UCVA + A1A + A2A),}$

where $\boldsymbol{AWJ}$ is the area of Wharton's jelly, $\boldsymbol{UCA}$ is umbilical cord area, $\boldsymbol{UCV}$ is umbilical cord vein area, $\boldsymbol{A1A}$ is area of artery designated $\boldsymbol{A1}$ and $\boldsymbol{A2A}$ the area of artery designated as $\boldsymbol{A2}$.

Similarly;

$\boldsymbol{VWJ = UCV - (UCVV + A1V + A2V);}$ where $\boldsymbol{VWJ}$ is the volume of Wharton's jelly, $\boldsymbol{UCV}$ is umbilical cord volume, $\boldsymbol{UCVV}$ is umbilical cord vein volume, $\boldsymbol{A1V}$ is volume of artery designated $\boldsymbol{A1}$ and $\boldsymbol{A2V}$ the volume of artery designated as A2.

3.7 INFANT ANTHROPOMETRY

Infant anthropometric parameters including birth weight, body length, head circumference, abdominal circumference and sex were determined in all infants. All measurements were done by the same trained birth attendant within 24 hours after delivery.

Birth weight was measured with Seca 725 mechanical baby weighing scale (Seca Co. Ltd.USA) calibrated in kilograms when the infant is naked. Body length, head circumference and abdominal circumference were measured with a non – elastic standard tape measure to the nearest centimeter when the infant lies in a quiet position.

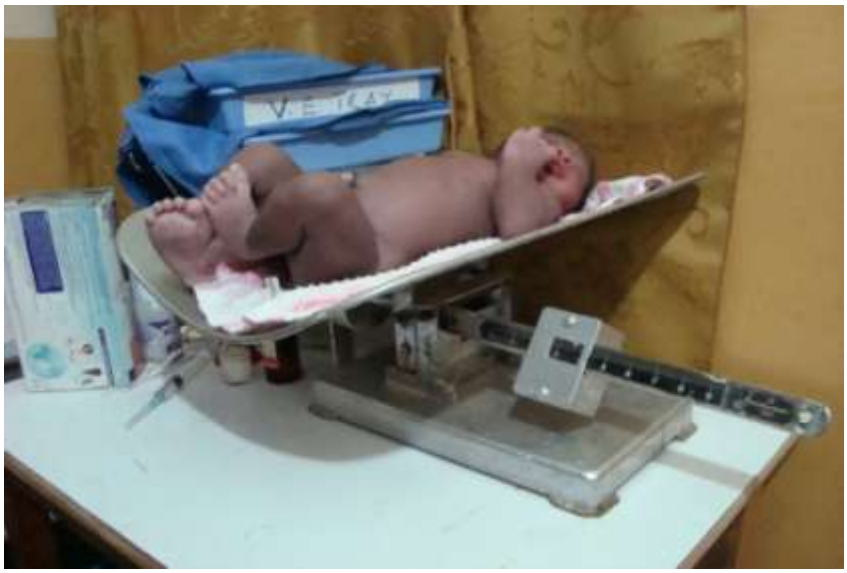


Plate 8: Photograph of Seca 725 Mechanical Baby Weighing Scale with a baby

Ponderal index (PI) was computed as the ratio of birth weight in grams to the cube of body length in centimeters and multiplied by 100;

$$\boldsymbol{PI = \frac{BW}{BL^3} * 100}$$ (Landman et al., 2006),

where BW is the birth weight in grams and BL is body length in centimeters.

Head circumference to Abdominal ratio was calculated by dividing the head circumference measured in centimeters by the abdominal circumference also measured in centimeters;

$$\boldsymbol{\frac{HC}{AC} = \frac{Head\ circumference\ (cm)}{Abdominal\ circumference\ (cm)}}$$

3.8 MATERNAL INDICES

Data on maternal age at delivery, parity, pre-pregnancy weight and the last pregnancy weight measured before delivery, and blood arterial pressure were obtained from records in the Antenatal Cards of the mothers. This card is established by Ministry of Health and Ghana Health Service for the purpose of maintenance of maternal health: medical examinations during pregnancy, condition and progress of the pregnancy, and periodic vaccinations (MOH/GHS., 2000).

Gestational age was expressed in complete weeks from the last menstrual period confirmed by ultrasound scan report. On the basis of gestational age, the infants were categorized into 3 groups:

Term infants were those with gestational age between 37 to 42 weeks. Preterm infants were those with gestational age less than 37 weeks and post term infants had gestational age greater than 42 weeks.

Weight Gain (WG) in kilograms was computed by subtracting the pre-pregnancy weight and the weight of the infant from the last pregnancy weight measured;

$$\boldsymbol{WG = PW - (PreWt + BW)}$$

Where $\boldsymbol{WG}$ is the weight gain, $\boldsymbol{PW}$ is the pregnancy weight and $\boldsymbol{PreWt}$ is the pre-pregnancy weight with $\boldsymbol{BW}$ as the birth weight of infant.

3.9 STATISTICAL ANALYSIS

Data were entered and analyzed in a computer using MS Excel and GraphPad Prism 5 Demo (GraphPad Software, Inc, San Diego, CA). Descriptive statistics (Mean and Standard deviation) were performed for continuous infant, mother, placenta, umbilical cord and vessels variables. The reference intervals (normal range) were specified. Student's **t** test was used to compare the quantitative variable means. The adopted level of statistical significant was $p < 0.05$. Spearman correlation matrix and coefficients were used to determine correlations among various placental, maternal and umbilical cord measurements with the infant anthropometric measures. Multiple linear regressions was used to assess the effect of correlations observed between maternal indices, placental indices, umbilical cord morphology, vessels morphometry and the infant anthropometric parameters. These were presented in graphs (Figures).

CHAPTER 4

RESULTS

4.1 MATERNAL INDICES

Descriptive statistics of maternal indices for the 207 mothers enrolled in the study are presented in Table 1 below. The maternal ages ranged from 16 to 48 years with a mean of 27.71 (SD = 5.95) years. The mean parity was 2.68 (SD = 1.71; range = 1 – 10). Maternal pregnancy weight ranged between 50 and 112 kg with a mean weight of 70.63 (SD = 9.56) kg. The prepregnancy weight had a mean of 63.12 (SD = 8.61) kg, ranging from 46 to 91 kg. Mean net weight gain was 4.29 (SD = 6.09) kg and ranged from -11.20 to 28.00 kg.

Table 1: Descriptive Statistics of Maternal Indices

Variable	Mean ± SD (N = 207)	SE	Range	CoV
Maternal Age (yrs)	27.14 ± 5.95	0.414	16 – 48	21.94%
Parity	2.68 ± 1.71	0.119	1 – 10	64.05%
Pregnancy Weight (kg)	70.63 ± 9.56	0.665	50 – 112	13.54%
Prepregnancy Weight (kg)	63.12 ± 8.61	0.598	46 – 91	13.64%
Net Weight Gained (kg)	4.29 ± 6.09	0.423	-11.20 – 28.0	142.01%

Data are expressed in Mean ± SD, Range with minimum and maximum limits, SD=Standard Deviation, SE=Standard Error,

4.2 FOETAL INDICES

Among the 207 neonates studied, 44.44% were females and 55.56% were males (Figure 1). Foetal characteristics studied are presented in Table 2. The mean gestational age (GA) was 37.09 (SD = 2.89, range = 26 - 50 weeks). Birth weight (BW) had a mean of 3.23 (SD = 0.47) kg, ranging from 0.70 to 4.6 kg. The mean body length (BL) was 45.11 (SD = 4.56cm, range = 14 to 58 cm). The mean head circumference (HC) was 32.90 (SD = 2.89cm, range = 9 to 44 cm). Mean abdominal circumference (AC) was 32.59 (SD = 3.46cm, range = 9 to 40 cm). The ratio of head circumference to abdominal circumference (HC/AC) had a mean of 1.02 (SD = 0.11) with a range of 0.84 to 2.00. The mean ponderal index (PI) was 3.87 (SD = 3.71, range = 1.64 – 54.67).

Table 1: Descriptive statistics of foetal indices

Variable	Mean ± SD (N = 207)	SE	Range	CoV
GA (weeks)	37.09 ± 2.34	0.162	26.0 – 50.0	6.32%
BW (kg)	3.23 ± 0.47	0.032	0.7 – 4.6	14.53%
BL (cm)	45.11 ± 4.56	0.317	14.0 – 58.0	10.11%
HC (cm)	32.90 ± 2.89	0.201	9.0 – 44.0	8.79%
AC (cm)	32.59 ± 3.46	0.240	6.0 – 40.0	10.60%
HC/AC	1.02 ± 0.11	0.007	0.8 – 2.0	10.63
PI	3.87 ± 3.71	0.226	1.6 – 54.7	95.83%

Data are expressed in Mean ± SD, Standard Error, Range with minimum and maximum limits, Coefficient of variation, SD=Standard Deviation, SE=Standard Error, CoV= Coefficient of Variation. BW=Birth Weight, BL=Body Length, HC=Head Circumference, AC=Abdominal Circumference, HC/AC=Head Circumference to Abdominal Circumference ratio, PI=Ponderal Index.

4.3 PLACENTAL INDICES

Table 3 provides the descriptive statistics for the placental indices. The mean major diameter (MjD) of placenta was 18.37 (SD = 2.16; range = 14.0 – 26.0 cm) and the minor diameter (MiD) was 9.11 (SD = 2.83; range = 2.0 – 18.0 cm). The mean placental weight (PW) was 608.40 (SD = 102.60g; range = 380.0 – 900.0g). The chorionic plate area (CPA) had a mean of 133.0 (SD = 48.9 cm^2; range = 37.7 – 96.9 cm^2). Mean birth weight to placental weight ratio (BW/PW) was 5.43 (SD = 1.05) with a range of 1.03 to 7.9. With respect to the distance of umbilical cord insertion from the margin, the mean distance of umbilical cord insertion into the placenta (dI) was 4.83 (SD = 1.75 cm; range = 0.0 – 11.4 cm). The mean long distance of insertion (Ldi) was 8.21 (SD = 2.82; range = 2.0 – 16.0 cm). Whiles the mean short distance of umbilical cord insertion from the margin (Sdi) was 7.66 (SD = 2.77; range = 0.0 – 1 5.0 cm). The mean umbilical cord centrality index (CCI) was 0.53 (SD = 0.56; range = 0.0 – 1.3), and the mean eccentricity index (ECI) was 0.85 (SD = 0.10; range = 0.3 – 1.0).

Table 2: Descriptive statistics of placental indices

Variable	Mean ± SD (N = 207)	SE	Range	CoV
MjD (cm)	18.37 ± 2.16	0.150	14.0 - 26.0	11.76%
MiD(cm)	9.11 ± 2.83	0.197	2.0 – 18.0	31.07%
PW(g)	608.40 ± 102.60	7.129	380.0 – 900.0	16.86%
CPA (cm^2)	133.0 ± 48.90	3.399	37.7 – 296.9	36.76%
BW/PW	5.43 ± 1.05	0.073	1.03 – 7.9	19.27%
dI (cm)	4.83 ± 1.75	0.122	0.0 – 11.4	36.34%
Sdi (cm)	8.21 ± 2.82	0.196	2.0 – 16.0	34.34%
Ldi (cm)	7.66 ± 2.77	0.193	0.0 – 15.0	36.22%
CCI	0.53 ± 0.56	0.014	0.0 – 1.3	36.89%
ECI	0.85 ± 0.10	0.007	0.3 – 1.0	12.35%

Data are expressed in Mean ± SD, Standard Error, Range with minimum and maximum limits, Coefficient of variation, SD=Standard Deviation, SE=Standard Error, CoV= Coefficient of Variation, MjD=Major placental Diameter, MiD=Minor placental Diameter, PW=gross Placental Weight, CPA=Chorionic Plate Area, BW/PW=Birth Weight to Placental Weight ratio, dI= Distance of umbilical cord insertion from the placental margin, Sdi=Short distance of umbilical cord insertion from margin, Ldi=Long distance of umbilical cord insertion from margin, CCI=Umbilical Cord Centrality index, ECI=Eccentricity Index.

4.4 UMBILICAL CORD INDICES

The mean umbilical cord length (UCL) was 42.91 (SD = 9.17; range = 25.0 – 80.0 cm) and the umbilical cord diameter (UCD) was 1.31 (SD = 0.23; range = 0.83 – 2.37 cm, (see Table 4). Umbilical cord area (UCA) had a mean of 180.40 (SD = 51.14; range = 84.5 – 347.30 cm^2). The mean of the umbilical cord volume (UCV) was 60.22 (SD = 26.18;

range = 17.32 – 200.20 $cm^{3.}$ Respective means of the area and volume of Wharton's jelly (AWJ and VWJ) were 79.13 (SD = 38.73; range = 5.33 – 246.80 cm^2) and 53.00 (SD = 24.85; range = 14.38 – 194.10 cm^3). The mean umbilical coiling index (UCI) was 0.17 (SD = 0.08; range 0.00 - 0.49) and that of the number of umbilical cord vessels was 2.99 (SD = 0.16; range 2.0 – 4.0).

Table 3: Descriptive statistics of the umbilical cord indices

riable	Mean ± SD (N = 207)	SE	Range	CoV
UCL (cm)	42.91 ± 9.17	0.637	25.00-80.00	21.37%
UCD (cm)	1.13 ± 0.23	0.016	0.83 - 2.37	17.16%
UCA (cm^2)	180.40 ± 51.14	3.554	84.53 - 347.30	28.34%
UCV (cm^3)	60.22 ± 26.18	1.82	17.32 - 200.20	43.47%
AWJ (cm^2)	79.13 ± 38.73	2.682	5.33 - 246.80	48.95%
VWJ (cm^3)	53.00 ± 24.85	1.727	14.38 - 194.10	46.89%
UCI	0.17 ± 0.08	0.006	0.00 - 0.49	49.35%
No. of Coils	6.83 ± 3.72	0.259	0.00 - 25.00	54.49%

Data are expressed in Mean ± SD, Standard Error, Range with minimum and maximum limits, Coefficient of variation, SD=Standard Deviation, SE=Standard Error, CoV= Coefficient of Variation, UCL=Umbilical Cord Length, UCD=Umbilical Cord Diameter, UCA= Umbilical Cord Area, UCV=Umbilical Cord Volume, AWJ= Area of Wharton's Jelly, VWJ=Volume of Wharton's Jelly, UCI=Umbilical Cord Index.

4.5 MORPHOMETRY OF UMBILICAL CORD VESSELS

The mean umbilical vein diameter (UCVD) was 3.42 (SD = 0.86; range 1.1 to 8.0 mm). The mean diameters of the umbilical cord arteries 1 and 2 (A1D and A2D) were 2.07 (SD

= 0.60; range = 1.0 – 4.0 mm) and 1.98 (SD = 0.56; range = 0.0 – 3.0 mm) respectively. The umbilical cord vein area (UCVA) and volume (UCVV) had respective means of 46.38 (SD = 16.02; range = 12.81 – 126.10 cm^2) and 4.20 (SD = 2.45; range = 35 – 19.61 cm3). The mean area and volume of the umbilical cord artery designated A1 (A1A and A1V) were 28.23 cm^2 (SD = 11.06; range 8.81 – 78.17 cm^2) and 1.59 cm^3 (SD = 1.05; range = 0.22 – 7.79 cm^3) respectively. Similarly, the computed mean area and volume of the umbilical cord artery designated A2 (A2A and A2V) were 26.69 cm^2 (SD = 10.49; range = 0.00 – 75.55 cm^2), and 1.43 cm^3 (SD = 0.88; range = 0.00 – 5.66 cm^3).

Table 4: Descriptive statistics of umbilical vessels morphometry

	Mean ± SD (N = 207)	**SE**	**Range**	**CoV**
UCV D (cm)	3.41 ± 0.86	0.060	1.10 - 8.00	25.15%
A1 D (cm)	2.07 ± 0.60	0.042	1.00 - 4.00	28.90%
A2 D (cm)	1.96 ± 0.56	0.039	0.00 - 3.00	28.42%
UCVA(cm^2)	46.38 ± 16.02	1.114	12.81 - 126.10	34.54%
A1 A (cm^2)	28.23 ± 11.06	0.769	8.81 - 78.17	39.18%
A2 A (cm^2)	26.69 ± 10.49	0.729	0.00 - 75.55	39.28%
UCVV(cm^3)	4.20 ± 2.45	0.17	0.35 - 19.61	58.41%
A1 V (cm^3)	1.59 ± 1.05	0.073	0.22 - 7.79	65.75%
A2 V (cm^3)	1.44 ± 0.88	0.061	0.00 - 5.66	61.53%

Data are expressed in Mean ± SD, Standard Error, Range with minimum and maximum limits, Coefficient of variation, SD=Standard Deviation, SE=Standard Error, CoV= Coefficient of Variation, UCV D=Umbilical Cord Vein Diameter, A1D=Umbilical Cord Artery 1 Diameter, A2D= Umbilical Cord Artery 2 Diameter, UCVA=Umbilical Cord Vein Area, A1A=Artery 1 Area, A2A=Artery 2 Area, UCVV=Umbilical Cord Vein Volume, A1V=Artery 1Volume, A2V=Artery 2 Volume.

4.6 UMBILICAL CORD LENGTH AND POPULATION CHARACTERISTICS

The umbilical cord length was grouped into short (< 40 cm), normal (40 ≥ 70 cm) and long (> 70cm). Out of the 207 umbilical cords studied, 39.62% (82) were short, 59.90% (124) normal umbilical cord and 0.48% (1) long cord. Table 6 compares the outcome characteristics of the study population under the three categories of the umbilical cord length. Significant difference was observed in body length of foetuses with short and normal umbilical cord lengths (43.95 ± 5.15 and 45.82 ± 3.96, P< 0.05). There was also a significant difference in the placental weight of neonates with short and normal umbilical cord lengths (586.20 ± 99.59 and 620.60 ± 99.60, P < 0.05).

Table 5: Umbilical Cord Length and outcome characteristics of study population

	Short UC (N = 82)	**Normal UC (N =124)**	**Long UC (N = 1)**
Maternal Age(yrs)	26.74 ± 5.36	27.35 ± 6.33	32.00 ± 0.00
Delivery Weight (kg)	69.39 ± 8.59	71.48 ± 10.14	68.00 ± 0.00
Parity	2.66 ± 1.76	2.68 ± 1.69	3.00 ± 0.00
Gestational Age (weeks)	36.98 ± 1.88	37.14 ± 2.60	40.00 ± 0.00
Neonatal Birth Weight (kg)	3.20 ± 0.46	3.25 ± 0.48	3.30 ± 0.00
Neonatal Body Length (cm)	43.95 ± 5.15*	45.82 ± 3.96	51.00 ± 0.00
Placental Weight (g)	586.20 ± 99.59*	620.60 ± 99.60	900.00 ± 0.00
Chorionic Plate Area(cm^2)	92.97 ± 14.37	94.87 ± 15.81	103.70 ± 0.00
BW/PW Ratio	5.58 ± 1.11	5.34 ± 0.99	3.67 ± 0.00

Data are expressed in Mean ± Standard Deviation with p –value, *= P<0.05.

4.7 PERINATAL OUTCOME OF NORMOTENSIVE AND HYPERTENSIVE MOTHERS

The clinical characteristics of the umbilical cord vessel components and placenta of the neonates of normotensive and pregnancy induced hypertensive (PIH) mothers are presented in Table 7. There was a significant difference (P = 0.018) in the mean ± SD vein diameter between neonates of normotensive (3.36 ± 0.88) and hypertensive mothers (3.82 ± 0.50). There were no significant differences in the umbilical cord morphometry (length, P = 0.842; umbilical cord diameter, P = 0.389; A1 diameter, P = 0.201; A2 diameter, P = 0.635; area of Wharton's jelly, P = 0.135), foetal indices (Birth weight, P = 0.80; body length, 0.869; and gestational age, P = 0.993) and placental morphometry (Placental weight, P = 0.464; and chorionic plate area, P = 0.083).

Table 6: Characteristics of umbilical cord, placenta and neonate

Variable	Normotensive	PIH	P-value
UC Length (cm)	42.86 ± 9.08	43.27 ± 10.13	0.843
UC Diameter (cm)	1.32 ± 0.23	1.27 ± 0.20	0.389
UC Vein Diameter (mm)	3.36 ± 0.88	3.82 ± 0.50	0.018
A1 Diameter (mm)	2.05 ± 0.60	2.23 ± 0.61	0.201
A2 Diameter (mm)	1.97 ± 0.58	1.91 ± 0.68	0.635
Area of WJ (cm^2)	80.51 ± 38.69	67.46 ± 37.95	0.135
Birth Weight (kg)	3.23 ± 0.48	3.20 ± 0.41	0.809
Body Length (cm)	45.12 ± 4.58	44.95 ± 4.51	0.869
Gestational Age (weeks)	37.09 ± 2.44	37.09 ± 1.31	0.993
Placental Weight (kg)	610.20 ± 103.90	593.20 ± 91.62	0.464
Chorionic Plate Area (cm^2)	135.10 ± 48.83	116.00 ± 47.23	0.083

Data are expressed in Mean ± Standard Deviation with significant difference at p-value <0.05. PIH=Pregnancy Induced Hypertension

4.8 BIRTH MEASUREMENTS OF TERM AND PRETERM FOETUSES IN RELATION TO SEX

Of the 207 foetuses studied 63.77% (132) were term, 35.26% (73) preterm and 0.97% (2) post term. The distribution of the term foetuses was 57.58% (76) males and 42.42% (56) females while the number of preterm foetuses comprised 50.68% (37) males and 49.32% (36) females. The comparison of the mean ± SD birth measurements of term males and females, preterm males and females, term males and preterm males, and term females and preterm females are shown in Table 4-8. Significant difference in body lengths of the term males and females was observed (45.83 ± 4.08 and 44.32 ± 3.86, P = 0.034). In addition, there was a significant difference in the umbilical cord lengths of term males and females (48.33 ± 4.08 and 46.82 ± 3.86, P = 0.034).

Table 4-7: Birth measurements of term and preterm foetuses in relation to sex

	BW (kg)	BL (cm)	UCL (cm)	HC (cm)	AC (cm)	PI
Term						
Male	3.21±0.37	45.83±4.08	48.33±4.08	33.17 ± 2.27	32.79 ± 2.67	3.50 ± 1.16
Female	3.26±0.49	44.32±3.86*	46.82±3.86*	32.70 ± 2.25	32.75 ± 2.24	3.90 ± 1.24
Preterm						
Male	3.26±0.62	45.00±4.40	47.50 ± 4.40	32.70±2.86	32.16 ± 4.30	3.62 ± 0.88
Female	3.19±0.46	44.64±6.30	47.14 ± 6.30	32.69 ± 4.47	32.36 ± 5.19	4.93 ± 8.56

Data are presented in Mean ± SD. Comparison of means between male and female, p value < 0.05 is considered significant, SD= Standard Deviation.

4.9 COMPARISON OF CHARACTERISTICS OF MALE AND FEMALE NEONATES

The clinical measurements of male and female neonates are compared in Table 9. There was no significant difference between the males and females foetal indices (Gestational age, P = 0.107; birth weight, P = 0.937; body length, P = 0.062), umbilical cord morphometry (Umbilical cord length, P = 0.525; head circumference to abdominal circumference ratio, P = 0.367) and placental morphometry (Placental weight, P = 0.076; chorionic plate area, P = 0.081; birth weight to placental weight ratio, P = 0.134) as well as ponderal index (P = 0.134).

Table 8: Perinatal outcome in relation to foetal sex

Variable	Female (N = 92)	Male (N = 115)	P - Value
Gestational Age (weeks)	36.79±2.41	37.32±2.27	0.1071
Birth Weight (kg)	3.23±0.48	3.23±0.46	0.9368
UC Length (cm)	42.45±8.77	43.27±9.50	0.5247
Body Length (cm)	44.45±4.93	45.63±4.19	0.0622
HC/AC Ratio	1.01±0.09	1.02±0.12	0.3674
Placental Weight (kg)	622.50±97.64	597.00±105.40	0.076
Chorionic Plate Area (cm^2)	139.70±52.85	127.70±45.04	0.0809
BW/PW Ratio	6.80±5.42	6.02±1.07	0.134
Ponderal Index	4.30±5.42	3.52±1.07	0.1339

Data are expressed in Mean ± Standard, N= Number, P-value<0.05 was considered significant, UC=Umbilical Cord, HC/AC=Head Circumference to Abdominal Circumference ratio, Birth weight to Placental Weight ratio.

4.10 DISTRIBUTION OF QUALITATIVE CHARACTERISTICS OF UMBILICAL CORD AMONG MALE AND FEMALE NEONATES

The prevalence of qualitative characteristics of the umbilical cord and its distribution among the male and female neonates in the study population are shown in Table 10. The prevalence of eccentric, central, marginal and velamentous umbilical cord insertions were 59.42%, 32.85%, 7.25% and o.48% respectively. Central umbilical cord insertion was more prevalent in females (33.70; 95% CI = 24.84 – 43.86) than in the males (32.17; 95% CI = 24.31 – 41.19). Eccentric umbilical cord insertion prevalence was higher in the female population (60.87; 95% CI = 50.64 – 70.22) than males (58.26; 95% CI = 49.12 – 66.87). On the contrary, marginal umbilical cord insertion prevalence was high in the male population (8.7; 95% CI = 7.29 – 20.52) than females (5.43; 95% CI = 2.04 – 12.40). Only one velamentous umbilical cord insertion was observed in the male population constituting 0.87%.

The prevalence of number of umbilical coils less than 10^{th} percentile was 3.86 and between 10^{th} – 90^{th} percentile was by far the most prevalent (86.96) with 9.18 showing number of coils greater than the 90^{th} percentile in the total population. The number of umbilical coils less than 10^{th} percentile was slightly higher in the males (4.35; 95% CI = 1.61 – 10.03) than in the female population (3.26%; 95% CI = 0.72 – 9.55). However, both sexes had equal prevalence of number of umbilical cords between 10^{th} – 90^{th} percentiles (86.96) with slight variations in their 95% CI (male = 79.48 – 92.04 and females = 78. 42 – 92.53). On the other hand, the female population showed a higher prevalence of number of umbilical cord coils greater than 90^{th} percentile (9.78; 95% CI = 5.03 – 17.76) than males (8.70; 95%CI = 4.63 – 15.43).

In the total population, right handed coiling was more prevalent (74.88%) as compared to 25.12% left handed coiling. The female population had higher left handed coiling (29.35; 95% CI = 20.99 – 39.37) than the males (21.75; 95% CI = 15.13 – 30.18). However, right handed coiling in males was 78.26 (95% CI = 69.82 – 84.87) whiles that of the females was 70.65 (95% CI = 60.63 – 79.01). The prevalence of number of UC vessels was 1.45 for two – vessel UC and 98.55 for normal UC. The observed two – vessel UC was in the male population (2.61; 95% CI = 0.56 - 7.72). The distribution of three – vessel UC among the male and female was 97.39 (95% CI = 92.28 – 99.44) and 100 (95% CI = 95.19 – 100.00) respectively.

Table 9: Prevalence of umbilical cord characteristics and its distribution among male and female neonates

		Males (N = 115)				Females (N = 92)			
	Total (207)	**n/N**	**Prev(%)**	**Prev.Ratio**	**95% CI**	**n/N**	**Prev.(%)**	**Prev.Ratio**	**95% CI**
UC INSERTION									
Central	68 (32.85%)	37/115	32.17	ref (1)	24.31 -41.19	31/92	33.70	1.05	24.84-43.86
Eccentric	123 (59.42%)	67/115	58.26	ref (1)	49.12 -66.87	56/92	60.87	1.04	50.64 -70.22
Marginal	15 (7.25%)	10/115	8.70	1.60	7.29 - 20.52	5/92	5.43	ref (1)	2.04 - 12.40
Velamentous	1 (0.48%)	1/115	0.87	ref (1)	0.01 - 5.40	0/92	0.00	0	0.00 - 4.81
NO. OF COILS									
< 10^{TH} Percentile	8 (3.86%)	5/115	4.35	1.33	1.61 - 10.03	3/92	3.26	ref (1)	0.72 - 9.55
10 - 90^{TH} Percentile	180 (86.96%)	100/115	86.96	1	79.48 -92.04	80/92	86.96	ref (1)	78.42 -92.53
> 90^{TH} Percentile	19 (9.18%)	10/115	8.70	ref (1)	4.63 - 15.43	9/92	9.78	1.12	5.03 - 17.76
COILING PATTERN									
Left Handed	52 (25.12%)	25/115	21.74	ref (1)	15.13 -30.18	27/92	29.35	1.35	20.99 -39.37
Right Handed	155 (74.88%)	90/115	78.26	1.11	69.82 -84.87	65/92	70.65	ref (1)	60.63 -79.01
NO. OF UC VESSELS									
Two Vessel Cord	3 (1.45%)	3/115	2.61	ref (1)	0.56 - 7.72	0/92	0	0	0.00 - 4.81
Normal Cord	204 (98.55%)	112/115	97.39	ref (1)	92.28 -99.44	92/92	100	1.03	95.19 -100

Data is expressed in percentage of prevalence and prevalence ratio with 95% confidence interval. N = Total number of male population and total female population, n = number of male population with a particular umbilical cord characteristic and female population with a particular umbilical cord characteristic, 95% CI = Ninety five percent confidence interval,

4.11 SPEARMAN CORRELATIONS AMONG FOETAL AND PLACENTAL INDICES

A statistically significant negative correlation was observed between gestational age and the distance of umbilical cord insertion into the placenta (r^2 = -0.181, P = 0.009) and the umbilical cord centrality index (r^2 = -0.168, P = 0.015) as shown in Table 11. Birth weight showed positive significant correlation with the major placental diameter (r^2 = 0.166, P = 0.017), placental weight (r^2 = 0.212, P = 0.002), and birth weight to placental weight ratio (r^2 = 0.462, P = 0.00001). A negative correlation was observed between body length and the minor diameter (r^2 = -0.167, P = 0.016). However, body length positively correlated with placental weight (r = 0.158, P = 0.023) and ponderal index (r^2 = 0.179, P = 0.010). Birth weight to placental weight ratio correlated with both head circumference and abdominal circumference (r^2 = 0.288, P = 0.0001 and r^2 = 0.206, P = 0.003) respectively.

Table 10: Spearman Correlation between foetal and placental indices

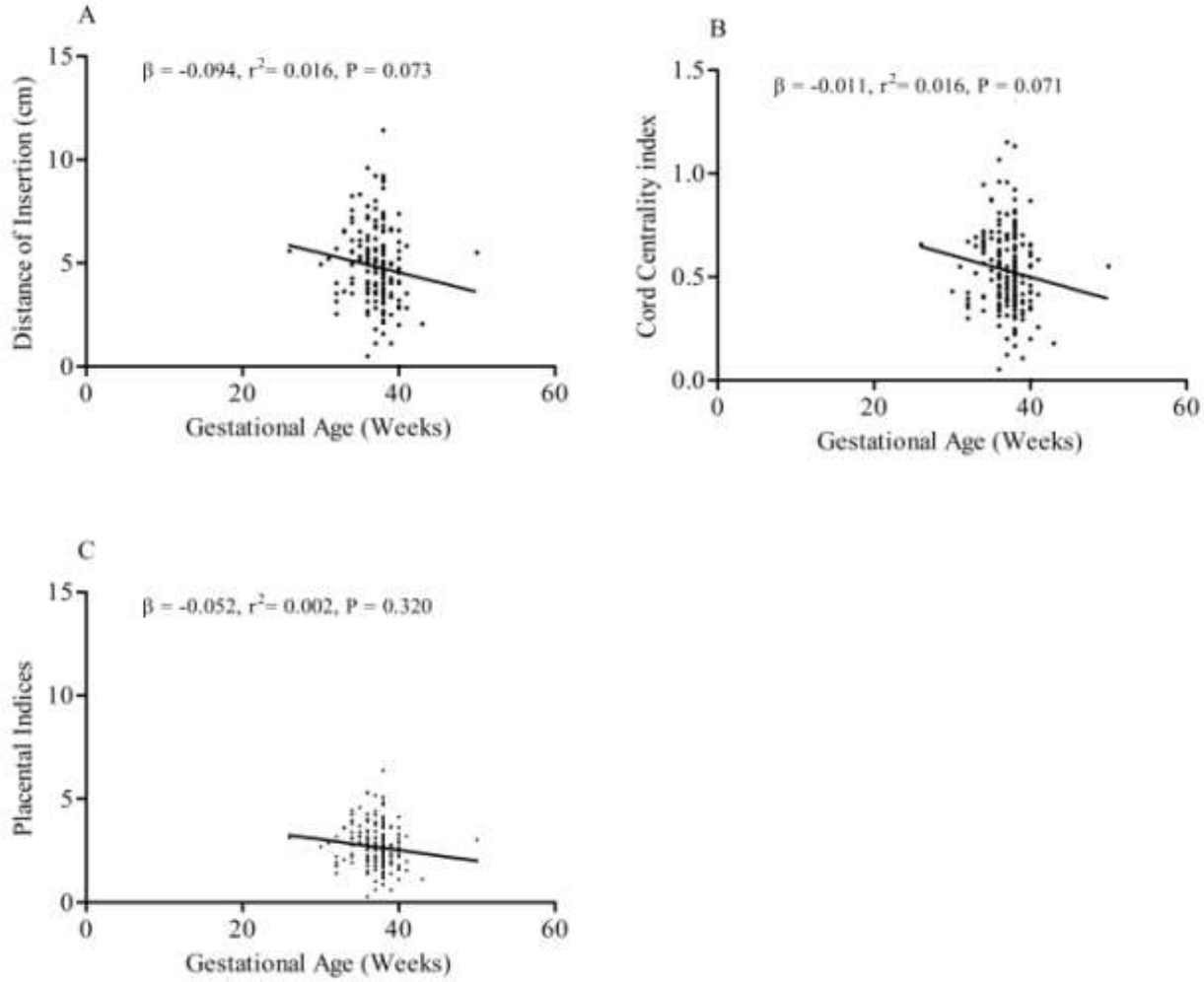
P-Value <0.05 was considered significant with a *, P<0.01 with ** and P < 0.001 with ***, GA=Gestational Age, BW=Birth Weight, BL=Body Length, HC=Head Circumference, AC=Abdominal Circumference, LD=Large Diameter, SD=Small Diameter, T1=Longest distance between point of umbilical cord insertion into the placenta and margin, T2=Shortest distance between point of umbilical cord insertion into the placenta and margin, GPW=Gross Placental Weight, CPA=Chorionic Plate Area, BW/PW= Birth Weight to Placental Weight ratio, d=Computed distance of umbilical cord insertion into the placenta. CCI=Umbilical cord Centrality Index, ECI=Eccentricity Index.

	LD(cm)	SD(cm)	T1(cm)	T2(cm)	GPW(g)	CPA(cm^2)	BW/PW	d(cm)	CCI	ECI
GA(weeks)	0.015	0.007	0.039	-0.097	0.097	0.021	-0.035	-0.181**	-0.168*	-0.021
BW(kg)	0.166*	0.046	0.052	0.107	0.212**	0.093	0.462***	0.119	0.056	0.003
BL(cm)	0.003	-0.167*	-0.039	0.020	0.158*	-0.112	0.132	0.101	0.096	0.179*
HC(cm)	0.037	0.090	0.070	-0.008	0.001	0.089	0.288***	0.082	0.063	-0.078
AC(cm)	0.083	0.085	0.063	0.057	0.116	0.094	0.206**	0.012	-0.024	-0.070

4.12 LINEAR REGRESSION ANALYSIS OF PLACENTAL INDICES AGAINST FOETAL INDICES

The significant correlations observed between gestation age with distance of cord insertion and umbilical cord centrality index in Table 11 were further analyzed with linear regression analysis. Although, statistically insignificant, these placental measurements showed an inverse relationship with gestational age, as illustrated in Figure 3A, 3B and 3C.

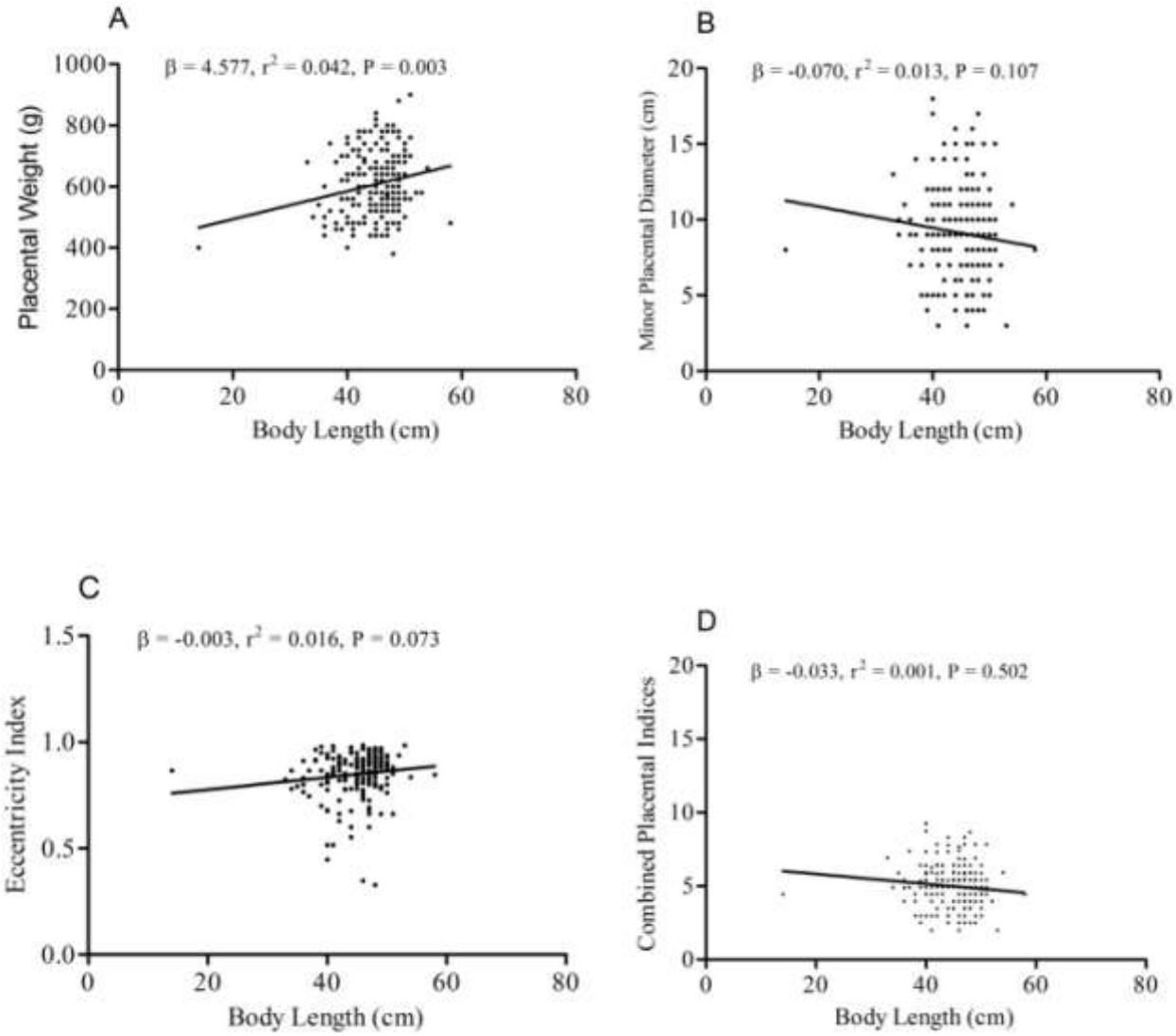
Figure 3: Linear regression graph of distance of cord insertion, cord centrality index and combined placental indices against gestational age



Again, linear regression analysis was carried out on the placental measurements which showed significant correlations with body length. Placental weight had significant linear relation with

body length (β = 4.577, r^2 = 0.042, P = 0.003) (Fig. 4A). Minor placental diameter (β = -0.070, r^2= 0.013, P = 0.108) (Fig. 4B) and eccentricity index (β = 0.003, r^2= 0.016, P = 0.072) (Fig. 4C) as well as the combined effect of these measurements (β = -0.033, r^2= 0.001, P = 0.502) (Fig. 4D) did not show any significant linear relations with body length.

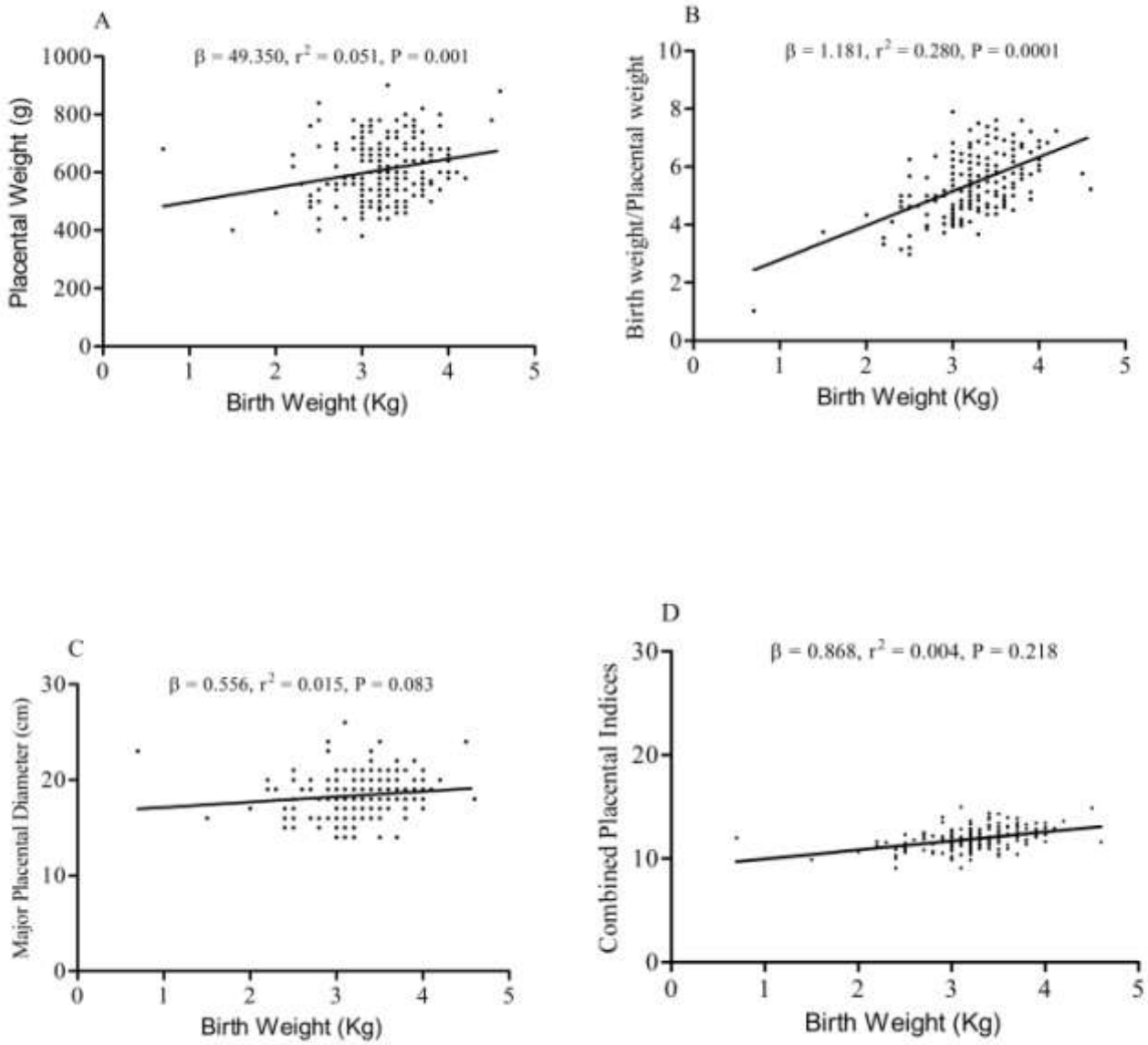
Figure 4: Linear regression graph of placental weight, minor diameter, eccentricity index and the combined placental indices against body length



The significant correlations between birth weight and the various placental measurements were analyzed with linear regression and the observations made were that a gram increase in placental

weight nearly increases birth weight by 50% (β = 49.3350, r^2= 0.051, P = 0.001) (Fig. 5A). Birth weight to placental weight ratio had significant linear relation with birth weight (β = 1.181, r^2= 0.280, P = 0.0001) (Fig. 5B), however, there were no statistically significant relations between birth weight and major placental diameter (β = 0.556, r^2= 0.015, P = 0.083) (Fig. 5C) and of their combined effect (β = 0.868, r^2= 0.004, P = 0.218) (Fig. 5D).

Figure 5: Linear regression graph of placental weight, birth weight /placental weight, major placental diameter and the combined placental indices against birth weight



4.13 SPEARMAN CORRELATION BETWEEN MATERNAL AND FOETAL INDICES

Spearman correlation values for maternal and foetal indices are shown in Table 12. Maternal age showed statistically significant correlation with birth weight ($r^2 = 0.143$, $P < 0.05$). Strong positive correlation was observed between maternal age and abdominal circumference ($r^2 = 0.214$, $P < 0.001$). Parity showed statistically significant correlation with the head circumference ($r^2 = 0.163$, $P < 0.05$). Significant positive correlations were observed between pregnancy weight with the following; gestational age ($r^2 = 0.139$, $P < 0.05$), birth weight ($r^2 = 0.192$, $P < 0.01$), head circumference ($r^2 = 0.190$, $P < 0.01$), and ponderal index ($r^2 = 0.241$, $P < 0.001$). Prepregnancy weight (PreW) significantly correlated with ponderal index ($r^2 = 0.193$, $P < 0.01$). A statistically significant correlation was observed between net weight gain (NWG) and abdominal circumference ($r^2=0.183$, $P<0.01$).

Table 11: Spearman correlation between Maternal and Foetal indices

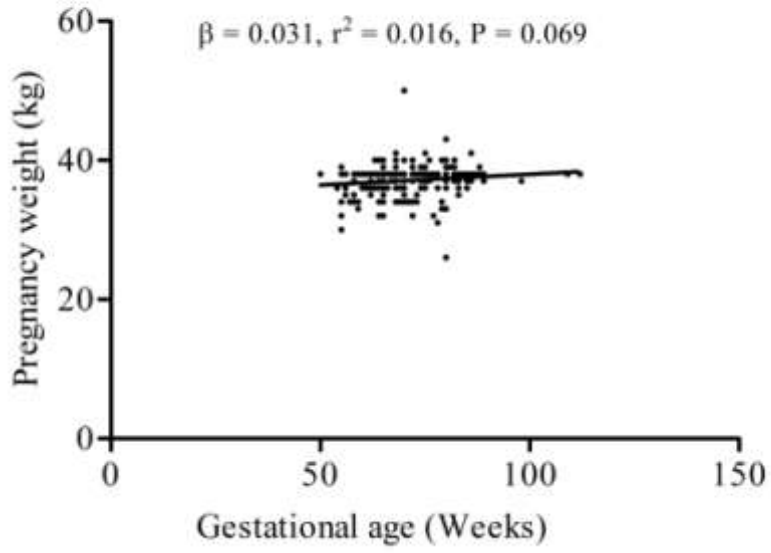
	GA(wks)	BW (kg)	BL (cm)	HC (cm)	AC (cm)	HC/AC	PI
Age (Yrs)	-0.025	0.143*	-0.011	0.068	0.014***	0.067	0.055
Parity	-0.029	0.12	0.017	0.163*	0.056	0.107	0.019
PW (kg)	0.139*	0.192**	-0.108	0.190**	0.275	-0.119	0.241***
PreW (kg)	0.082	0.096	-0.104	0.066	0.127	0.07	0.193**
NWG (kg)	0.123	0.063	0.025	0.108	0.183**	-0.087	0.017

P-Value <0.05 was considered significant with *, p<0.01=** and p<0.001=***, PW=Pregnancy Weight, PreW=Prepregnancy Weight, NWG=New Weight Gain

4.14 LINEAR REGRESSION ANALYSIS OF MATERNAL INDICES AGAINST FOETAL INDICES

Although pregnancy weight showed significant correlation with gestational age, the result of the linear regression analysis indicates that it had no effect on gestation ($\beta = 0.031$, $r^2 = 0.016$, $P = 0.069$) (Fig.6).

Figure 6: Linear regression graph of pregnancy weight against gestational age



The maternal age and pregnancy weight showed significant correlation with birth weight (Table 12), however, linear regression analysis of these measurements with birth weight showed that maternal age had no relation with birth weight ($r^2 = 0.010$, $P = 0.157$) (Fig. 7A). Instead, pregnancy weight showed significant linear relation with birth weight ($r^2 = 0.059$, $P = 0.0004$) (Fig 7B). The combined effect of these maternal indices showed no statistically significant linear relationship with the birth weight ($r^2 = 0.004$, $P = 0.202$) (Fig. 7C).

Figure 7: Linear regression graph of maternal age, pregnancy weight and the combined maternal indices against birth weight

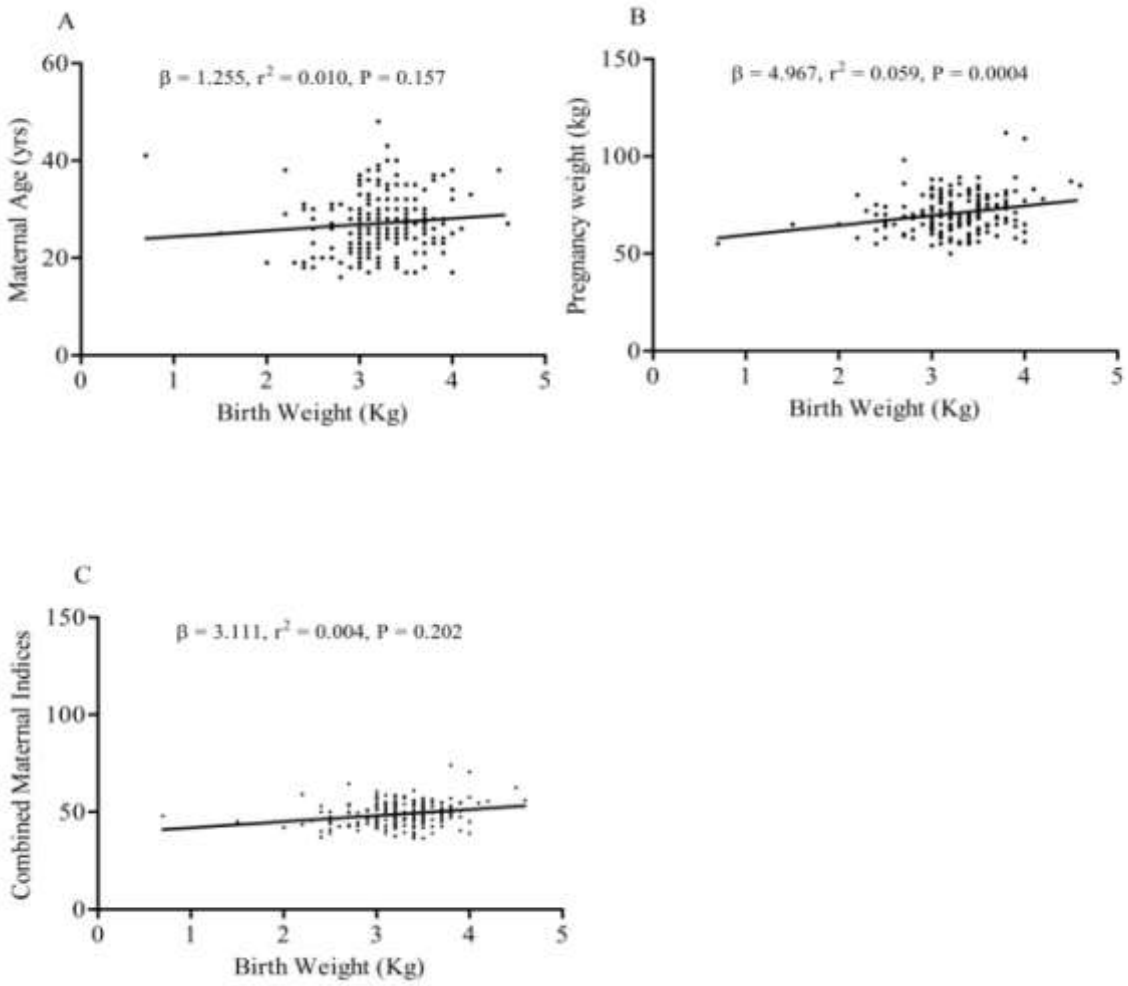
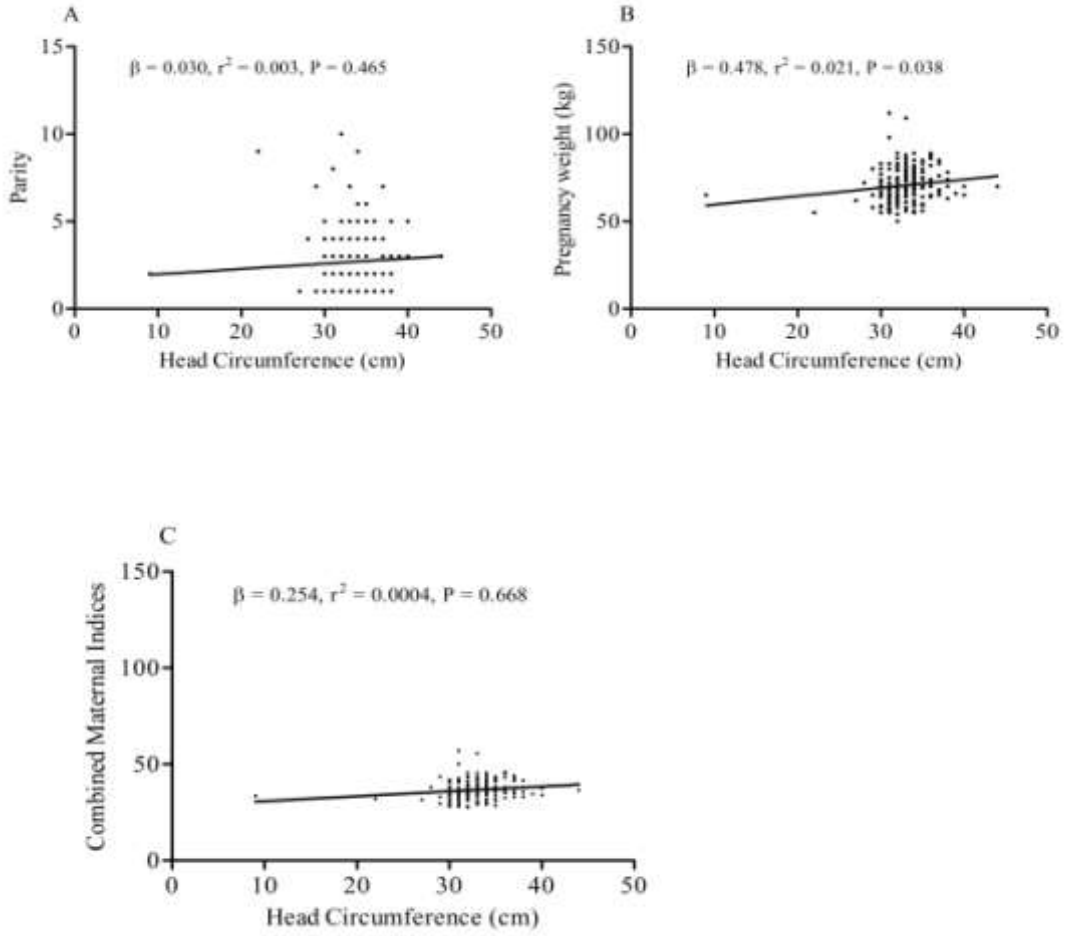


Figure 8 shows that although parity correlated with head circumference, there was no linear relation between them (r^2= 0.003, P = 0.465) (Fig. 8A). However, pregnancy weight showed significant linear relation with head circumference (r^2= 0.021, P = 0.038) (Fig. 8B). When these measurements were pooled together, their combined effect did not show statistically significant linear relation with the head circumference (r^2= 0.0004, P = 0.668) (Fig. 8C).

Figure 8: Linear regression graph of parity, pregnancy weight and the combined maternal indices against head circumference



In addition, maternal age and net weight gain correlated with abdominal circumference and subsequent linear regression analysis indicated no significant linear relation between maternal age, net weight gain and the abdominal circumference as illustrated in Figure 9A, B and C respectively.

Figure 9: Linear regression graph of maternal age, net weight gain and the combined maternal indices against abdominal circumference

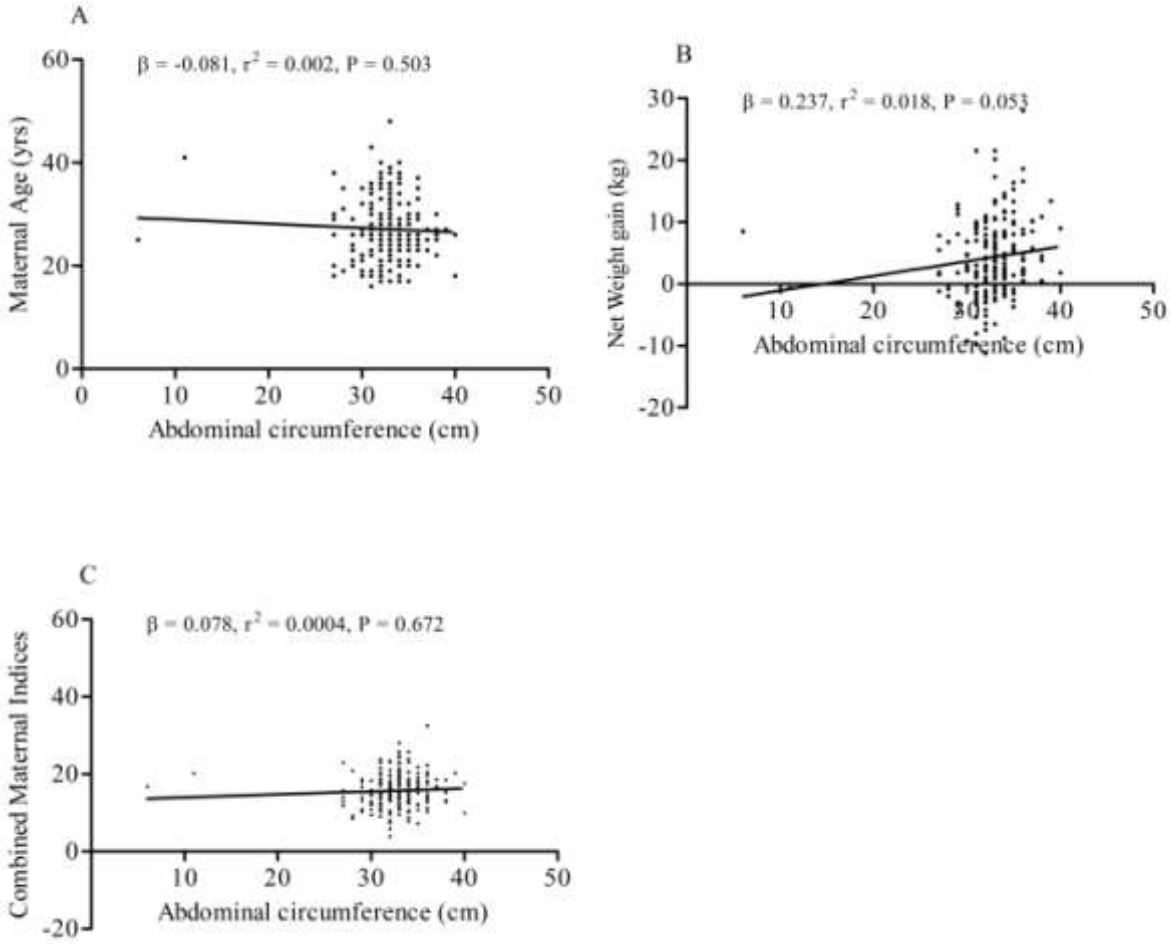
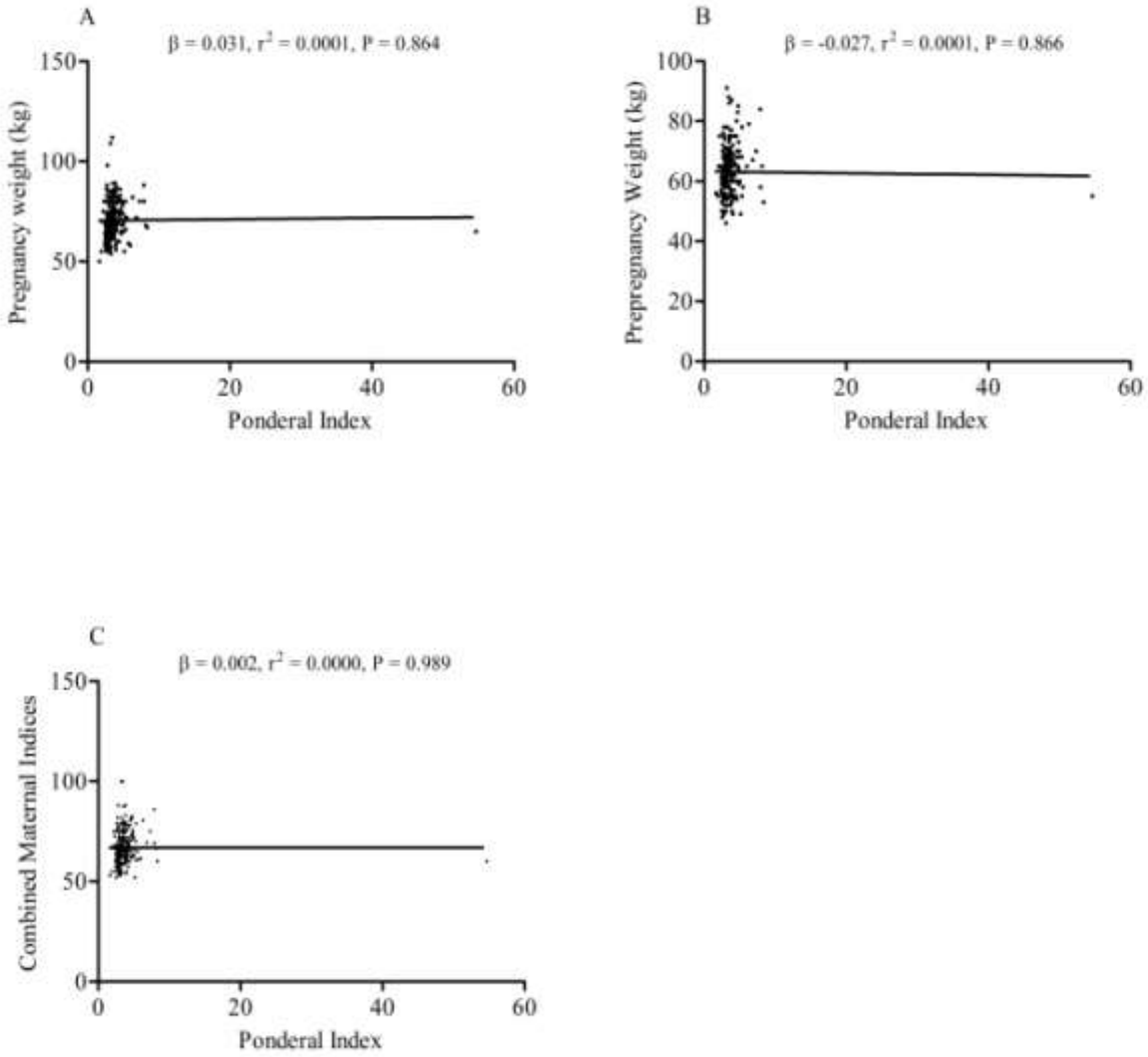


Figure 10 below shows that the linear relation between pregnancy weight and prepregnancy weight with ponderal index was virtually non – existing. Though pregnancy weight and prepregnancy weight exhibited significant correlation with ponderal index, there was no linear relation between pregnancy weight and ponderal index ($\beta = 0.031$, $r^2 = 0.0001$, $P = 0.8637$) (Fig. 10A) and between prepregnancy weight and ponderal index ($\beta = -0.027$, $r^2 = 0.0001$, $P = 0.866$) (Fig. 10B). The cumulative effect of these maternal indices on ponderal index was statistically insignificant ($\beta = 0.002$, $r^2 = 0.0000$, $P = 0.989$) (Fig. 10C).

Figure 10: Linear regression graph of pregnancy weight, prepregnancy weight and the cumulative effect against ponderal index



4.15 SPEARMAN CORRELATION MATRIX OF FOETAL INDICES AND UMBILICAL CORD VESSEL MORPHOMETRY

Gestational age showed significant correlation with the artery designated as A2 volume (r^2 = 0.153, P < 0.05) and its area (r^2 = 0.152, P < 0.05). Birth weight had significant positive correlation with the following; umbilical cord diameter (r = 0.178, P < 0.05), umbilical cord

volume ($r^2 = 0.162$, $P < 0.05$), and the volume of Wharton's jelly ($r^2 = 0.174$, $P < 0.05$). Body length also showed significant positive correlation with the umbilical cord length ($r^2 = 0.221$, $P < 0.01$), umbilical cord area ($r^2 = 0.194$, $P < 0.01$), umbilical cord volume ($r^2 = 0.169$, $P < 0.05$), the umbilical cord vein area ($r^2 = 0.137$, $P < 0.05$), A2 area ($r^2 = 0.145$, $P < 0.05$) and its volume ($r^2 = 0.137$, $P < 0.05$), the area and volume of Wharton's jelly ($r^2 = 0.161$, $P < 0.05$ and $r^2 = 176$, $P < 0.05$) respectively. Significant correlation was observed between abdominal circumference and umbilical cord diameter ($r^2 = 0.168$, $P < 0.05$) as well as umbilical cord area ($r^2 = 0.158$, $P < 0.05$) and volume ($r^2 = 0.176$, $P < 0.05$). It also correlated with the Wharton's jelly area ($r^2 = 0.140$, $P < 0.05$) and volume ($r^2 = 0.183$, $P < 0.01$). The area of Wharton's jelly showed strong significant negative correlation with the umbilical cord vein diameter ($r^2 = -0.305$, $P < 0.001$), the A1 diameter ($r^2 = -0.370$, $P < 0.001$) and A2 diameter ($r^2 = -0.0397$, $P < 0.001$).

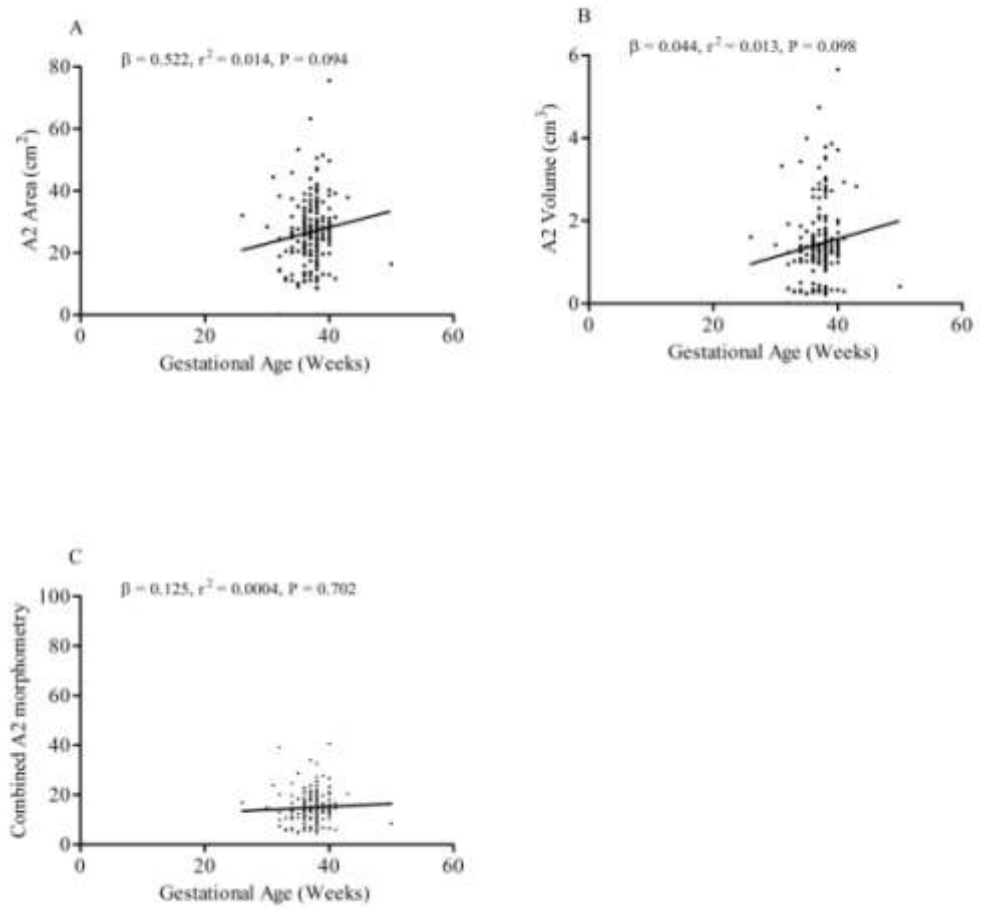
Table12: Spearman correlation matrix between foetal indices and umbilical cord vessels morphometry

	GA	BW	BL	HC	AC	UCL	UCD	UCVD	A1D)	A2D	UC V	UCA	UCVV	UC VA	A1V	A1A	A2V	A2A	VWJ	AWJ
GA	1																			
BW	0.041	1																		
BL	0.079	0.360ǂ	1																	
HC	-0.019	0.415 ǂ	0.111	1																
AC	0.122	0.463 ǂ	0.134	0.460 ǂ	1															
UCL	0.063	0.045	0.221†	-0.035	0.084	1														
UCD	0.049	0.178*	0.077	0.077	0.168*	0.070	1													
UCVD	0.074	0.103	0.011	0.048	0.018	0.075	0.275 ǂ	1												
A1D	0.099	-0.025	-0.031	-0.114	0.013	0.115	0.191 †	0.657 ǂ	1											
A2D	0.135	0.014	-0.012	-0.005	0.023	0.095	0.164*	0.619 ǂ	0.830 ǂ	1										
UCV	0.051	0.162*	0.169*	0.056	0.176*	0.573 ǂ	0.834 ǂ	0.269 ǂ	0.211 †	0.196 †	1									
UCA	0.057	0.132	0.194 †	0.033	0.158*	0.782	0.641 ǂ	0.228 †	0.200 †	0.187 †	0.953 ǂ	1								
UCVV	0.088	0.099	0.095	0.026	0.045	0.467 ǂ	0.275 ǂ	0.906 ǂ	0.622 ǂ	0.584 ǂ	0.476 ǂ	0.522 ǂ	1							
UCVA	0.093	0.103	0.137*	0.022	0.061	0.652 ǂ	0.257 ǂ	0.774 ǂ	0.559 ǂ	0.528 ǂ	0.564 ǂ	0.655 ǂ	0.965 ǂ	1						
A1V	0.109	0.004	0.094	-0.118	0.034	0.595 ǂ	0.184 ǂ	0.553 ǂ	0.833 ǂ	0.698 ǂ	0.454 ǂ	0.552 ǂ	0.741 ǂ	0.786 ǂ	1					
A1A	0.109	0.018	0.108	-0.099	0.05	0.656 ǂ	0.183 †	0.528 ǂ	0.791 ǂ	0.665 ǂ	0.487 ǂ	0.600 ǂ	0.744 ǂ	0.809 ǂ	0.994 ǂ	1				
A2V	0.153*	0.051	0.137*	-0.016	0.049	0.588 ǂ	0.155*	0.502 ǂ	0.649 ǂ	0.809 ǂ	0.438 ǂ	0.542 ǂ	0.694 ǂ	0.749 ǂ	0.860 ǂ	0.866 ǂ	1			
A2A	0.152*	0.067	0.145*	-0.006	0.069	0.641 ǂ	0.154*	0.478 ǂ	0.615 ǂ	0.768 ǂ	0.466 ǂ	0.582 ǂ	0.694 ǂ	0.765 ǂ	0.856 ǂ	0.872 ǂ	0.994 ǂ	1		
V WJ	0.048	0.174*	0.176*	0.069	0.183 †	0.530 †	0.846 ǂ	0.130	0.081	0.062	0.980 ǂ	0.921 ǂ	0.333 ǂ	0.429 ǂ	0.329 ǂ	0.367 ǂ	0.315 ǂ	0.348 ǂ	1	
A WJ	-0.008	0.13	0.161*	0.061	0.140*	0.415 ǂ	0.649 ǂ	-0.305 ǂ	- 0.370 ǂ	-0.397 ǂ	0.743 ǂ	0.701 ǂ	-0.098	0.030	-0.081	-0.031	-0.090	-0.044	0.843	1

4.16 LINEAR REGRESSION ANALYSIS OF FOETAL INDICES WITH UMBILICAL CORD VESSEL MORPHOMETRY

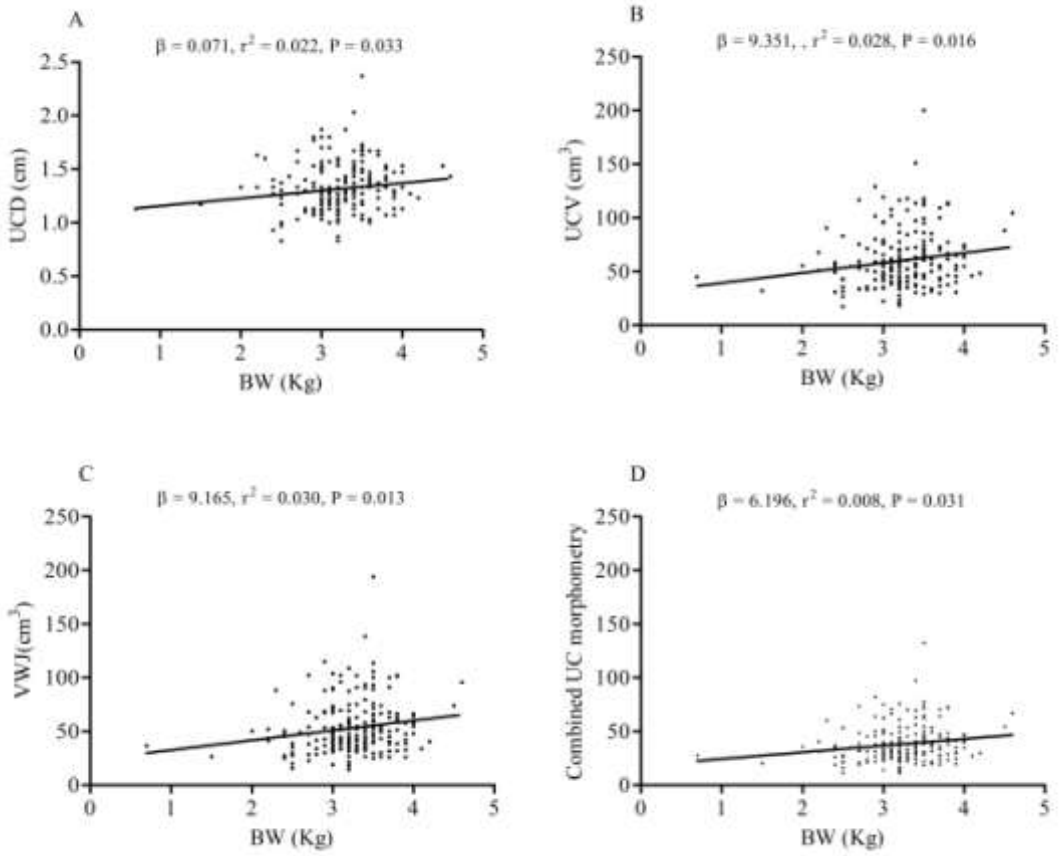
The correlation observed between A2 area and the volume with GA in the Spearman correlation matrix (Table 13) was analyzed using linear regression. A2 area showed no relation with GA ($\beta = 0.522$, $r^2 = 0.014$, $P = 0.094$) (Fig. 11A). Similarly A2 volume did not show significant linear relation with the GA ($\beta = 0.044$, $r^2 = 0.013$, $P = 0.098$) (Fig. 11B). The combined result of these artery morphometry also showed no significant relation with GA ($\beta = 0.125$, $r^2 = 0.0004$, $P = 0.702$) (Fig. 11C).

Figure 11: Linear regression graph of A2 area, volume and the combined morphometry against gestational age



Umbilical cord diameter, volume and Wharton's jelly volume correlated significantly with birth weight (Table 13). Linear regression analysis of these umbilical cord measurements yielded the following results; the UCD showed significant linear relation with BW ($\beta = 0.071$, $r^2 = 0.022$, $P = 0.033$) (Fig. 12A). UCV exhibited significant linear relation with BW ($\beta = 9.351$, $r^2 = 0.028$, $P = 0.016$) (Fig. 12B). Significant linear relation was observed between VWJ and BW ($\beta = 9.165$, $r^2 = 0.030$, $P = 0.013$) (Fig. 12C). The cumulative effect of these UC morphometries on birth weight was statistically significant ($\beta = 6.196$, $r^2 = 0.008$, $P = 0.010$) (Fig. 12D)

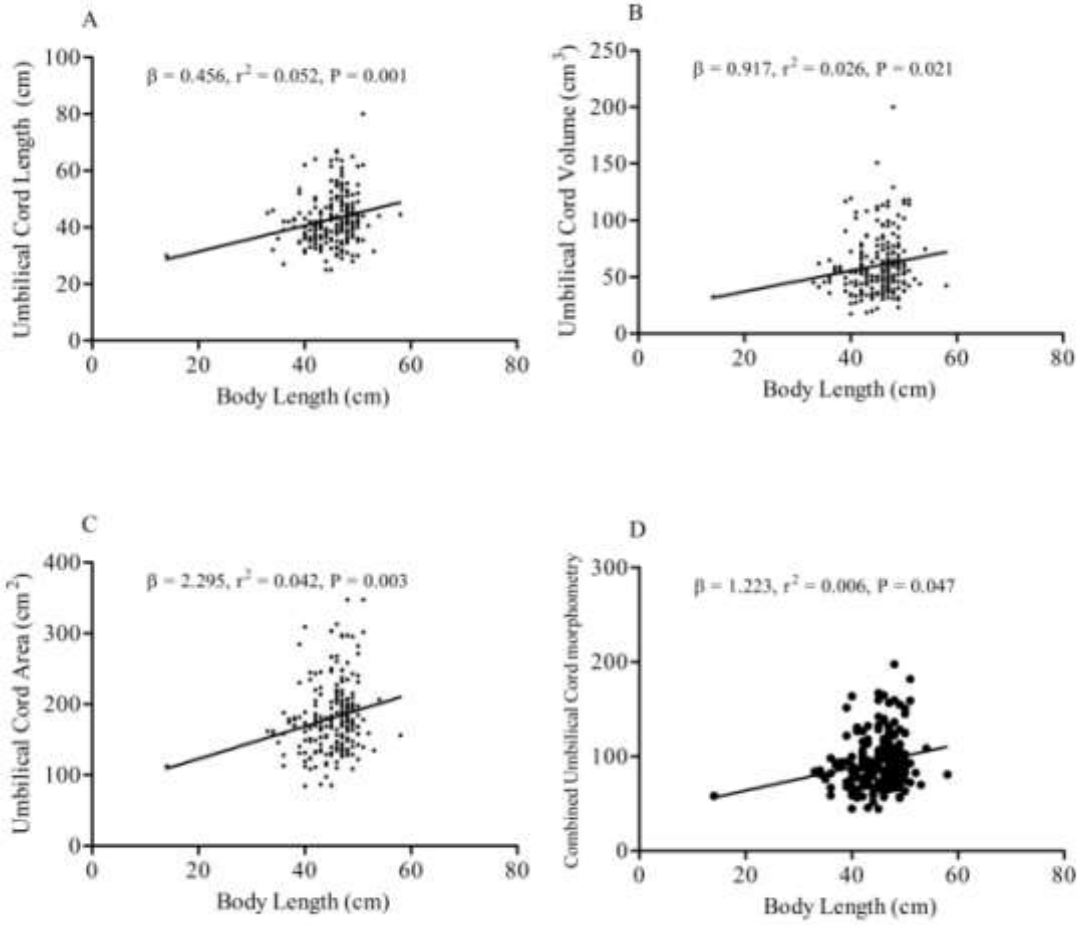
Figure 12: Linear regression graph of UCD, UCV, VWJ and the combined umbilical cord morphometry against BW



The correlations observed in Table 13 between UCL, UCV and UCA with BL were significant. Further investigation using linear regression analysis yielded similar results. UCL

showed significant linear relation with BW (β = 0.456, r^2 = 0.052, P = 0.001) (Fig. 13A). There was a significant relation between UCV and BL (β = 0.917, r^2 = 0.026, P = 0.021) (Fig. 13B). Linear relation observed between UCA and BL was significant (β = 2.295, r^2 = 0.042, P = 0.003) (Fig. 13C). The combined effect of these umbilical cord measurements on body length showed significant linear relationship (β = 1.223, r^2 = 0.006, P = 0.047) (Fig. 13D).

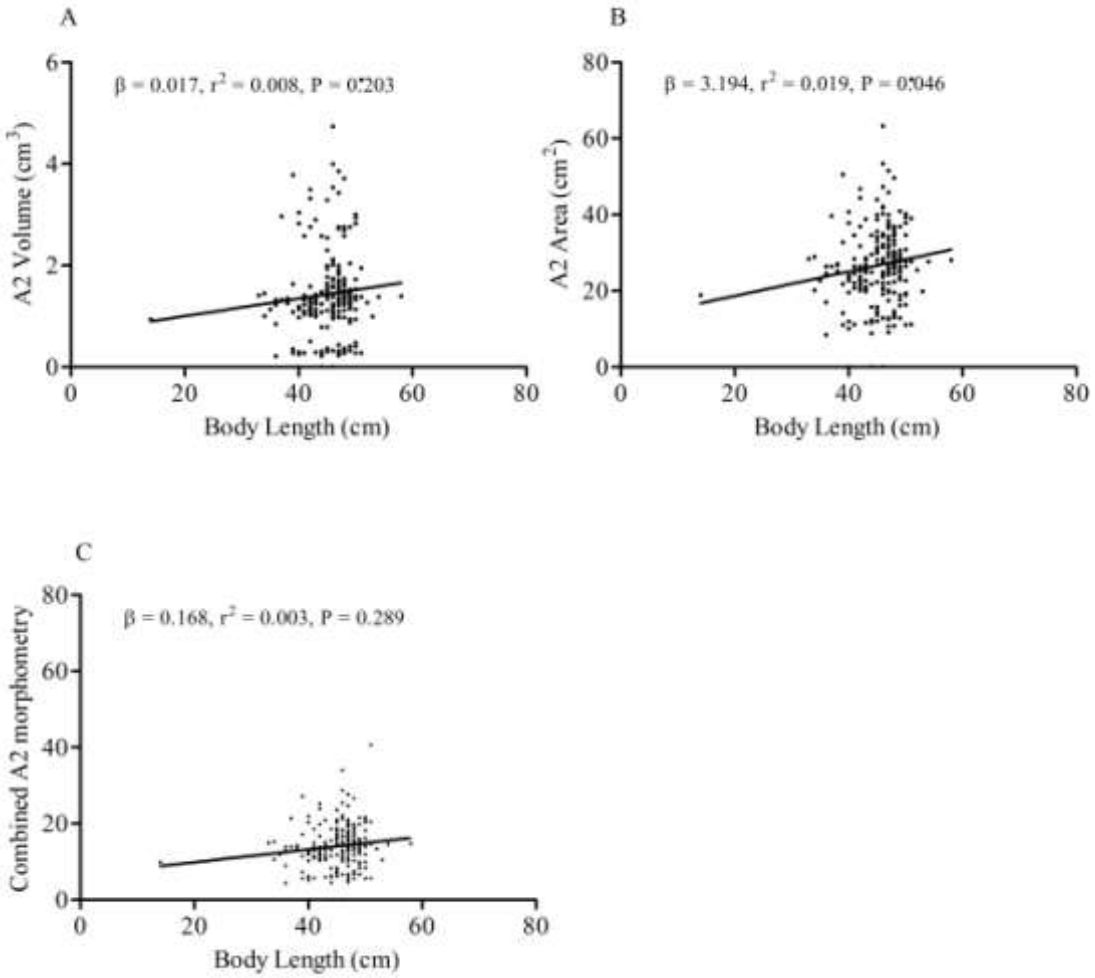
Figure 13: Linear regression graph of UCL, UCV, UCA and Combined morphometry against BL



The volume and area of umbilical cord artery (A2) correlated with body length and in a linear regression analysis, it was observed that A2 volume showed no significant relation with body length (β = 017, r^2 = 0.008, P = 0.203) (Fig. 14A). However, A2 area showed significant

relation with body length (β = 3.194, r^2 = 0.019, P = 0.046) (Fig. 14B). The overall effect of these A2 measurements did not show significant relation with body length (β = 0.168, r^2 = 0.003, P = 0.289) (Fig. 14C).

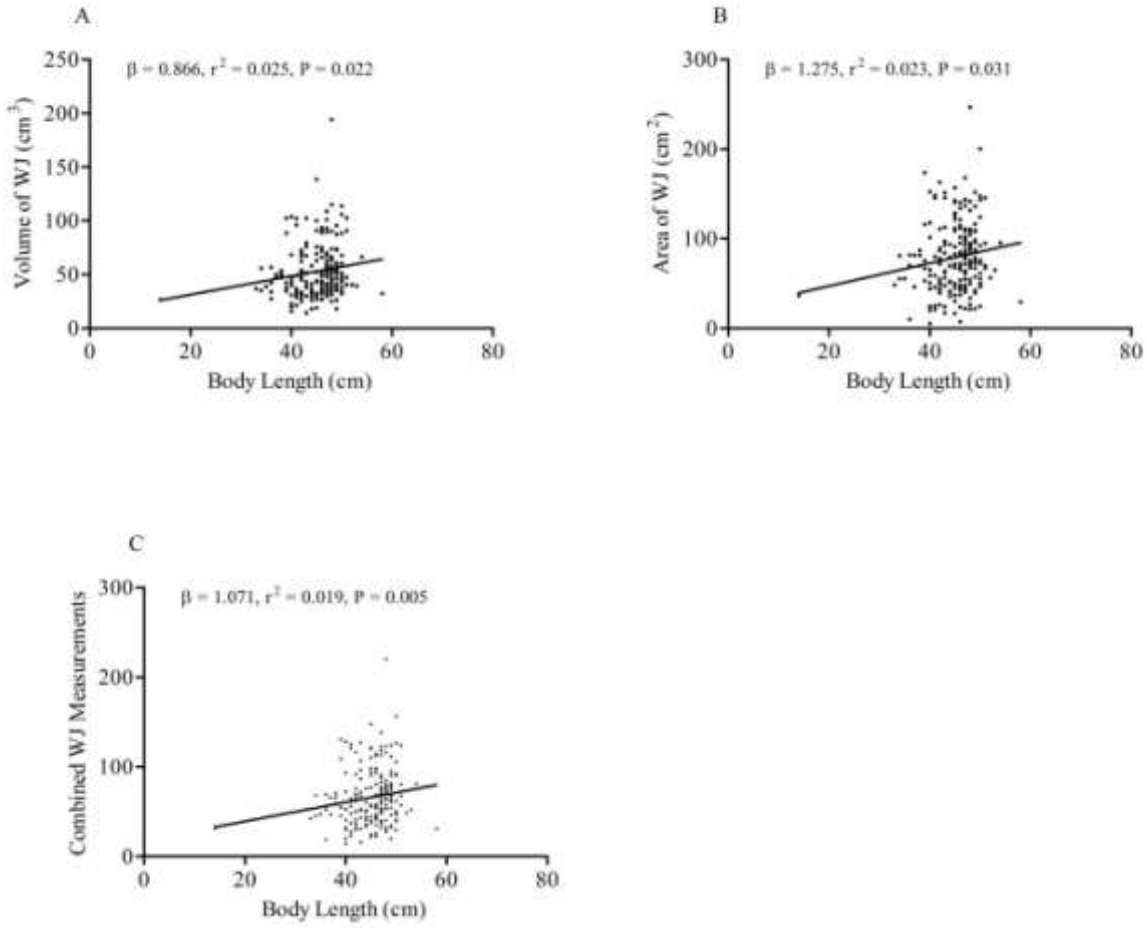
Figure 14: Linear regression graph of A2 volume, area and combined A2 morphometry against body length



Linear regression analysis of Wharton's jelly volume and area against body length supported the significant correlations observed between these measurements in the Spearman correlation matrix. Wharton's jelly volume showed strong linear relation with the body length (β = 0.866, r^2 = 0.025, P = 0.022) (Fig. 15A), and of Wharton's jelly area with body length (β = 1.275, r^2 = 0.023, P = 0.031) (Fig. 15B). A highly significant linear relation was observed between the

combined effect of the Wharton's jelly volume and area with body length (β = 1.071, r^2 = 0.019, P = 0.005) (Fig. 15C).

Figure 15: Linear regression graph of volume, area and combined measurements of WJ against body length



The correlations reported between UCD, UCV and UCA with AC in Table 13 were further analyzed with linear regression. It was observed that UCD showed significant relation with the AC (β = 0.009, r^2 = 0.019, P = 0.048) (Fig. 16A). The UCV significantly related with the AC (β = 1.261, r^2 = 0.028, P = 0.017) (Fig. 16B). The linear relation between the UCA and AC was significant (β = 2.623, r^2 = 0.031, P = 0.0116) (Fig. 16C). The combined effect of the

UC measurements, however, showed no significant linear relation with abdominal circumference ($\beta = 1.298$, $r^2 = 0.003$, $P = 0.172$) (Fig. 16D).

Figure 16: Linear regression graph of umbilical cord diameter, volume, area and combined umbilical cord morphometry against AC

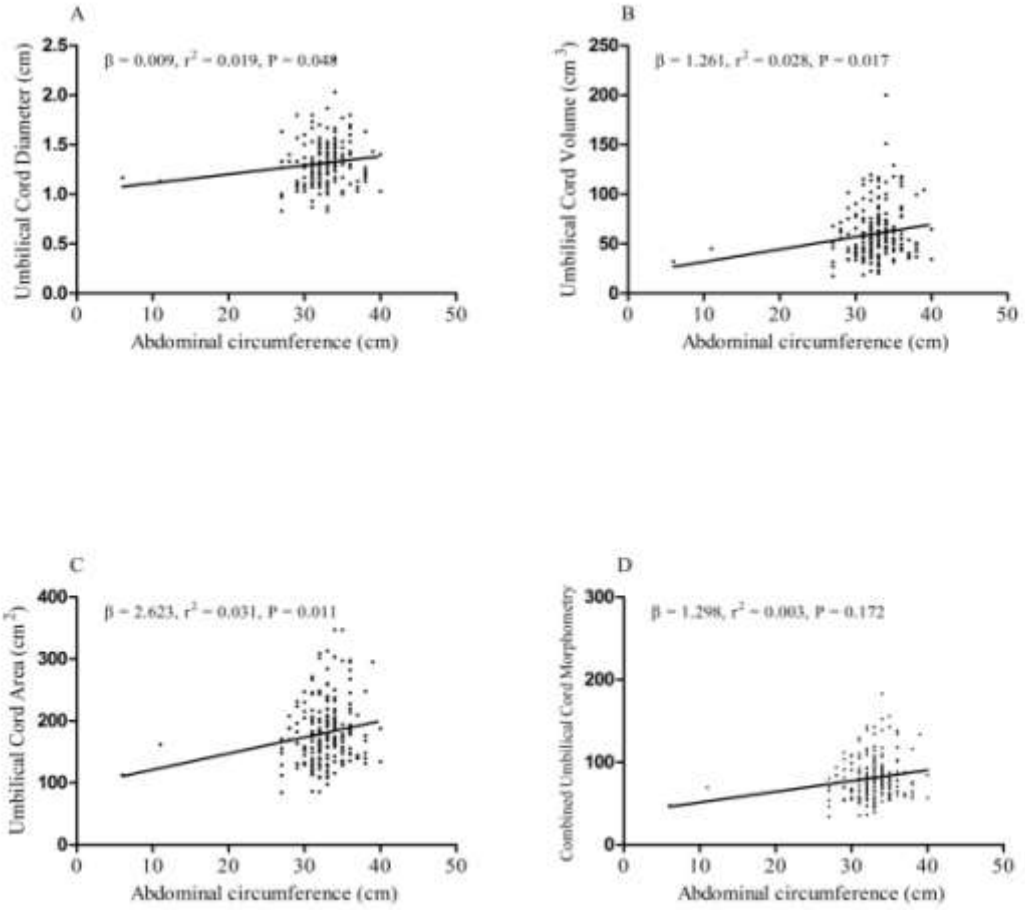
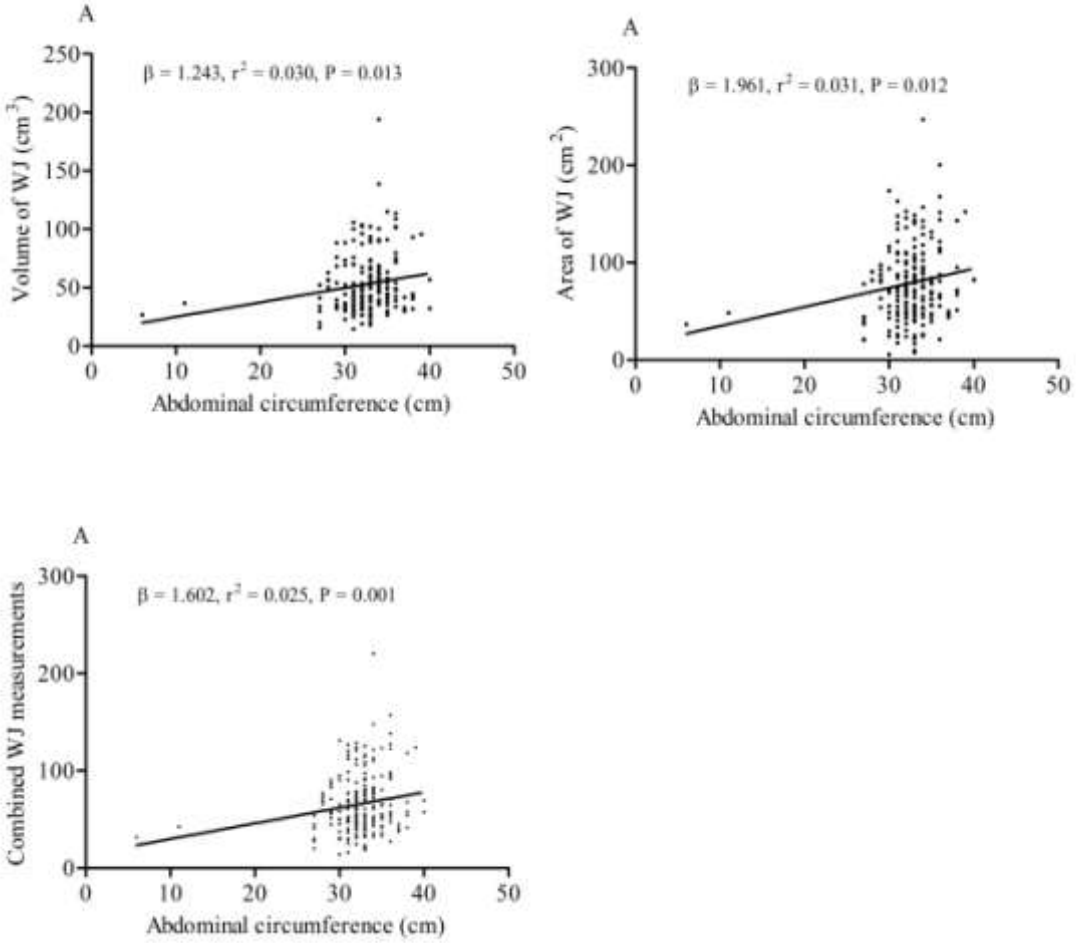


Figure 17 demonstrates the relationships of Wharton's jelly volume and area with abdominal circumference after linear regression analysis. It was observed that Wharton's jelly volume showed significant linear relation with abdominal circumference ($\beta = 1.243$, $r^2 = 0.030$, $P = 0.013$) (Fig. 17A). The linear relation observed between area of Wharton's jelly and abdominal circumference was significant ($\beta = 1.961$, $r^2 = 0.031$, $P = 0.012$) (Fig. 17B). The cumulative effect of the Wharton's jelly parameters measured exhibited strong statistically

significant relation with abdominal circumference (β = 1.602, r^2 = 0.025, P = 0.001) (Fig.17C).

Figure 17: Linear regression graph of volume, area and combined measurements of WJ against Abdominal circumference



CHAPTER 5

DISCUSSION

5.1 UMBILICAL CORD LENGTH

The percentage distribution of short, normal and long umbilical cord lengths were 39.61%, 59.90%, and 0.49% respectively. The classification of umbilical cords in the present study is based on previous reports; umbilical cords less than 40cm in length were considered short and between 40cm and 70cm were classified as normal with those longer than 70cm being long. Although reference standards for cord length have been reported, variations exist in the definition of short and long umbilical cords (Naeye, 1985; Yetter, 1998; Mutihir and Pam, 2006; Abaidoo *et al.*, 2008). Empirically, the umbilical cord continuously grows in length until birth with majority of the umbilical cords nearly equally the same in length as the neonate. Benirschke (2004) observed that human umbilical cord develops steadily with growing gestation and foetal crown – rump length; and measures approximately 55 cm long at term. Human neonates exhibit wider variations in terms of the length of their umbilical cord, and results of several studies support this finding (Nnatu. 1991; Jayal et al., 1994; Stefos et al., 2003). In spite, of these publications which try to address the issues of umbilical cord development, the control mechanisms of the length of the umbilical cord is still unknown (Benirschke, 2004). However, umbilical cord length is believed to be influenced by environmental and genetic factors as well as exposure to certain sweeteners. Environmentally, foetal movement in the uterus in a way exerts influence on cord length as stated in the "tension theory" (Lyndon et al., 1994). However, the overall umbilical cord length assumes a narrow distribution with few abnormally short or long umbilical cords (Baergen et al., 2001). Benirschke (2004) observed that in excessive lengths, much of the cord develops early in gestation whiles sufficient space still remains available for easy foetal mobility.

Benirschke's assumption was validated with the reasons that the cords of foetuses with severely reduced movement such as osteogenesis, imperfecta, thanatophoric dwarfism, muscular dystrophy, are evidently short. Again if the amniotic band develops early in gestation and attaches the foetus with adhesion to the placental surface, the umbilical cord becomes short. Also in multiple pregnancies such as twins, the foetuses show slightly short umbilical cords than in normal singleton pregnancy, this could probably stem from the fact that there is reduced space for movements. In addition, the author reported that children with trisomy 21 have short umbilical cords which may be due to the fact that they generally have limited intrauterine motility.

Benirscke (2004), in an experiment of intrauterine curarization of rodents in which there is loss of foetal motion observed that umbilical cord length significantly correlated with foetal movement. Adinma et al. (1993) found evidence of genetic predetermination of umbilical cord length when the length of umbilical cord positively correlated with birth weight and placental weight. Neonates affected with reduced foetal motion syndromes such as Down's syndrome, skeletal dysplasia and long – term neurological abnormalities are associated with shortened umbilical cord (Benirschke, 1994). It has been reported that infants with syndromes associated with excessive somatic growth as in Beckwith – Wiedemann syndrome did have excessively long umbilical cord. In the same study, it was evidenced that women with existing history of excessive long cord were at high risk of having babies with long umbilical cords (Baergen, 2001). Nnatu (1991) in his study of the length of human umbilical cords in an African population, observed highly significant correlation between the length of umbilical cord and the weights of the neonate and placenta and concluded that the umbilical cord length could serve as a predictive indicator for the outcome of foetal and placental weights.

The strong correlation between body length and umbilical cord length with maximal absolute value presuppose that these variables indicate important independent dimensions of foetal growth. The normal and short umbilical cord lengths of neonates did not show significant difference with maternal characteristics. Evidence accumulating suggests that the frequent and habitual intake of high amount of certain sweeteners in pregnancy exerts toxic effects on the foetus.

Greater percentages of the consumed sweeteners are able to move across the placental (Rodero et al., 2010). Sucralose ingestion for instance, is one of numerous studies carried out to show that placenta is permeable to a lot of sweeteners which interfere with the circulatory and endocrine functioning of the placenta resulting in an insult to the permeability of the membranes which tend to lead to reduced placental functions, foetal weight and umbilical cord length (De Mato et al., 2006).

Aspartame is a synthetic sweetener with low calorie content and has sweetening capacity of 180 to 200 times more than that of sucrose. Portela et al. (2007) in an experimental study also discovered the effects of gradual build up derived from chronic administration of aspartame and stated that its consumption could result in accumulation of formaldehyde products which may well explain the chronic effects induced in sensitive tissues following aspartame utilization. These researchers made mention that the umbilical cord is a trustworthy indicator of foetal movement, as it is influenced by the regular movement and the space available in the uterine cavity. Formic acid produced during aspartame metabolism is believed to be the key causative metabolite responsible for the detrimental effects of acute intoxication in humans and animals (Butchko et al., 2002). Therefore when aspartame is consumed during gestation, it may gradually affect foetal mobility resulting in shortening of the umbilical cord. An

experimental study carried out by Rodero et al. (2010), found that reduced umbilical cord length was associated with lessening of uterine foetal growth as result of the reduced uterine space and concluded that consumption of sucralose (a sweetener) at a prescribed dosage of 30mg/kg/day by gavage means to rat dams from day 10 to day 14 of pregnancy, resulted in diminished foetal weight and umbilical cord length presupposing the movement of sucralose across the placental membrane. Contrary to the above finding, pharmacokinetic evidence suggests that almost 85% of sucralose is not absorbed, but is excreted in an intact form in the faeces and has absorption rate of only 15% of the consumed dosage through passive diffusion (McNeil, 2007).

There was no significant difference between the birth weight and placental weights of the neonates with short and normal cord lengths; this was also confirmed by the fact that there was no correlation between umbilical cord length and birth weight. Instead, placental weight positively correlated with umbilical cord length. There was also a significant difference in the body length of neonates with short cord and normal umbilical cord lengths. This finding is in line with Baergen et al. (2001*)* in which they suggested that growth of the umbilical cord, placenta and body length may be under similar control mechanisms some of which are likely to be genetic in origin.

Increased parity has been associated with long umbilical cord. Sornes and Bakke (1989) found positive correlation between parity and cord length with the suggestion that increasing parity leads to an increase intrauterine size, which in turn allows for increased foetal mobility and results in an increase in the umbilical cord length. However, this study together with Baergen et al. (2001) could not infer on this finding. Stefos et al. (2003) found no correlation between parity and cord length. Instead, they reported a positive correlation between placental weight and birth weight but not body length.

5.2 NORMOTENSION AND PREGNANCY INDUCED HYPERTENSION (PIH):

Pregnancy–Induced Hypertension (PIH) is described as blood pressure ≥ 140mmHg/90mmHg after 20 weeks of gestation in the absence of significant proteinuria in a woman without prior hypertension (National High Blood Pressure Education Group, 2000). In this study, no significant differences in the arithmetic means of the gestational age, birth weight, placental weight and umbilical cord length were observed, which clearly contradicts with the findings of Koech and coworkers (2008). In the present study, although there were no significant differences between normotensives and PIHs with respect to the umbilical cord and arterial diameters and the amount of Wharton's jelly, these parameters did follow the usual reported trend of the normotensive having larger values than the PIHs. However, significant difference in the vein diameter was observed between the neonates of normotensive mothers and pregnancy induced hypertensive mothers respectively, with the PIHs having larger vein diameter. This observation contravenes with previous reports in which significant reduction in diameters of the umbilical cord and vessels have been recorded (Ilie et al., 2007). This morphological variation of the umbilical cord vein could be an indication of some important postnatal and foetal haemodynamic deficiencies. This is because Javier et al. (2009) stated that altered endothelial cell function is a key factor associated with vascular disorders which is crucial in foetal growth and development. These authors also observed, particularly in pregnancies affected by gestational diabetes and preeclampsia, a dysfunction of the umbilical cord vein endothelia. Therefore the larger diameter of the cord vein could be as a result of reduced or atrophy of the vein endothelial cells. Kinare (2008) reported that umbilical vein varix should be considered a risk factor for poor perinatal outcome, as such whenever there is evidence of umbilical cord varix, a careful search for evidence of other anomalies are necessary. The occurrence of structural differences in placenta and umbilical cord vessels of

normotensive and hypertensive pregnant women have been reported, and these variations associate with thickness in diameter of the umbilical cord (Ilie et al., 2007).

Inan et al. (2002) found reduced luminal areas in both artery and vein thickness in preeclampsia relative to normal pregnancy complicated with chronic hypertension. The observed differences were noticed in the media and intima of the umbilical cord vessels, contributing significantly to alteration in the haemodynamic conditions associated with pregnancy induced hypertension. Koech et al. (2008) in a study found that gestational ages, birth weights, and placental weights were significantly lower in pregnancy induced hypertensive mothers than in normotensive mothers, with mean gestational age for normotensive being greater than that of pregnancy induced hypertension. They recorded mean birth weight for the normotensive which was also higher than the PIHs. The mean placental weights for these two categories were 435.2 g (SD 107.0) and 371.4g (SD 62.0) respectively. It is possible that pregnancy induced hypertension (PIH) is one of several important causes of intrauterine growth restriction, preterm birth, low birth weight and perinatal mortality. It is also associated with increased placenta – uterine resistance.

5. 3 MEAN MEASUREMENTS OF NEONATAL SEX AT PRETERM AND TERMS:

The mean birth weight, body length, umbilical cord length, head circumference, abdominal circumference head to abdominal circumference ratio and ponderal index of preterm and term males and females are presented in table 7. With the exception of body length and umbilical cord length, there were no significant differences between these birth measurements of term male and female neonates, although it was observed that the term males had slightly higher values than term females in almost all the measurement but not birth weight and ponderal

index. The term females had slightly higher birth weight and a significantly short body length than the term males and their ponderal index was also high although it was statistically insignificant. This suggests that the term females had better soft tissue growth than in the term males.

Again, no significant difference was found when term and preterm neonates of the same sex were compared. Term males had long body length than the term females. This finding is in line with earlier observation in a study conducted by Li et al. (2003) in which the mean body length of males and females were recorded as 50.2 cm (SD 2.3) and 49.40 cm (SD 1.90) with z-score -1.0 ± 0.9 respectively. Jaya et al. (1995) recorded mean body length of term male neonates as 47.7 cm (SD 2.15) and that of term females as 47.6cm (SD 2.31), but found no significant difference between them. This finding runs contrary to the current study and could be the socio-demographic characteristics of these two different study populations. Several publications have reported hyperactivity of the male foetus and hypothesized that male neonates normally have higher birth weight and higher body length than their female counterparts (Li et al., 2003). A study conducted by Misra et al. (2009), recorded mean birth weight values of male and female neonates which indicated that males were heavier than females. The speculation for this hypothesis was that male foetal growth is compelled by extra – placental effects such as the presence of hormone testosterone which makes male foetal growth less responsive to variations in placental growth than females.

5.4 CORRELATION BETWEEN PLACENTAL INDICES AND FOETAL INDICES

In the present study there was significant positive correlation between birth weight, placental weight and the largest placental diameter. There was also a strong significant correlation

between birth weight and birth weight to placental weight ratio. This finding supports fact that the placental diameter enlarges with increase in birth weight. This could be explained in terms of the structural organization of the chorionic plate vascularization. The chorionic plate vessels form a high capacitance and low resistance of foeto – placental vascularization linking the umbilical cord vessels to the sites of oxygen and nutrient exchange in the placental villi. The large diameter may lead to wider distribution of chorionic vessels to allow for efficient exchange of materials at the placental villi with the umbilical cord vessels; a situation that is crucial for foetal development. In support of this view is a suggestion that the placental surface is caused to divide from implantation in order that growth along the major axis leads to maximal diameter which is qualitatively and quantitatively different from growth along the minor axis (Thornburg et al., 2009).

The developmental and functional characteristics of the placenta can be observed in the placental weight which correlated positively with birth weight in this study. This correlation establishes the fact that placental weight increases with corresponding increase in birth weight, however, placental sufficiency could be influenced by the umbilical cord morphology and vessel morphometry. Since short and normal umbilical cord length exhibited significant difference with placental measurements, it could be speculated that placental weight and its largest diameter could exert their influence on birth weight.

Gross placental measures entail more than just its weight and include the growth of different placental parts and its varied functions which in theory influence birth weight by different mechanisms (Salfia et al., 2008). This study, however, found that placental weight alone contributed to 36.5% of birth weight variation, with the rest of the gross placental measurements accounting for 28.2%. Little et al. (2003) found strong correlation of placental

weight with birth weight. Significantly positive association of placental weight and other gross placental measurements with birth weight has also been reported (Baptiste – Robert et al., 2009).

The current study recorded a strong positive association between birth weight and birth weight to placental ratio. The observation here was that if placental weight sharply increases more than birth weight, this ratio will fall and should birth weight effect become greater than placental weight, then there will be a rise in the ratio. According to Misra et al. (2009) any of the placental measures or ranges of variables exhibiting such relationship could be a potential indicator of a foetus with exceptional intrauterine environment. They therefore hypothesized that either of the unbalanced relationships marks stressful foeto – placental physiologic state.

In this study there was a strong negative correlation of body length with the smallest placental diameter and a positive correlation with the eccentricity index. Interestingly, whereas birth weight positively correlated with the largest diameter, body length negatively correlated with the smallest diameter of the placenta. Eccentricity index quantitatively measures the shape of the placenta in relation to how round or oval it is. Therefore the speculation is that as the smallest diameter reduces, the chorionic plate tends to be more round thereby allowing for excellent chorionic vessel distribution for placental functional efficiency. This results in a corresponding alteration in body length. It has been observed that irregular placental shapes are associated with low birth weight to placental weight ratio, presupposing that they are in association with altered placental function (Pathak et al., 2010). It is also reported, for example that minor placentae size restricts transfer of nutrients whiles major placentae distribute nutrients to itself, thereby affecting foetal size (Harding, 2001). Salafia et al. (2010) also observed significant correlation of irregular placental shape and reduced placental

efficiency. Hence, any variation in placental architecture could potentially reduce placental functional efficiency.

Birth weight to placental weight ratio exhibited strong positive correlation with head circumference and abdominal circumference. This current finding also points to the placental functional efficiency hypothesis, because the placenta is the interface which mediates between foeto – maternal intrauterine supply environment. Therefore placental sufficiency is essential for excellent delivery of nutrients, oxygen and hormones for foetal development. Since placental weight positively correlated with birth weight, it is also important that their ratio correlates with other foetal growth measures.

Salafia et al. (2006) reported that in comparative terms, a large placenta relative to birth weight could be an indication of a correspondingly relative placental inefficiency in translating its own growth into foetal growth. This is in agreement with a study which reported that, a lack of correlation of birth weight to placental weight ratio with other foetal size indicators diminishes the importance of this ratio (Williams et al., 1997).

5.5 CORRELATION BETWEEN MATERNAL INDICES AND FOETAL INDICES

This study found a positive significant correlation of maternal age with birth weight. This relationship is an indication of an increase in maternal age having corresponding increase in birth weight. A possible explanation could be based on three factors which include biological immaturity, preventive health practices and socioeconomically disadvantaged environment. It could be suggested that young mothers are still growing, therefore in physiological terms the high nutrients demand of young age and the pregnancy, results in competition for nutrient needed for the growth of the foetus. According to Scholl et al (1994), young mothers, are less

likely to mobilize enough fat reserves in late pregnancy to facilitate foetal growth, but rather reserve them for their own progressive development. Also the health seeking behaviour among young mothers is quite different from older mothers in the sense that prenatal care of older mothers is better with respect to frequency of visits to healthcare provider and their first time of reporting their pregnancies.

Studies have found that delayed prenatal care is often the reason for low birth weight (Graham, 1981). Geronimus (1987) observed that if a young mother receives good prenatal care; their birth outcomes are similar to those of older mothers. Borja and Adair (2003) reported that young mothers are less likely to commence prenatal care early in pregnancy as well as show fewer visits to a high quality healthcare provider. In addition, young mothers tend to be socioeconomically disadvantaged which goes a long way to affect their dietary quality during pregnancy. Gutierez and King (1993) observed that in developed countries, young mothers show poor dietary intake during pregnancy. Undernutrition among adolescents in developing countries is most often carried into pregnancy which affects the growth and development of the foetus (Kurz. 1996).

Parity correlated positively with head circumference; however, linear regression of parity against head circumference (Fig.4-7) showed that parity has no influence on head circumference development. The relationship could presuppose an asymmetric foetal growth, which might be a reflection of the head gaining advantage of growth relative to the growth of other foetal dimensions, resulting in conditions that adversely affect the pregnancy. This correlation could be in line with the general agreement that parity is favoured by pregnancy outcomes of which head circumference is no exception. However, in an earlier study by

Shajari et al. (2006), there was a significant increase in the head circumference, birth weight and body length of multiparae than in primiparae.

Pregnancy weight was also found to correlate significantly with gestational age. Pregnancy weight reflects nutritional, health and socioeconomic status of the pregnant woman. Therefore as gestation progresses with no adverse pregnancy conditions, the expectation is that pregnancy weight increases correspondingly. Again, it is clear that a successful pregnancy requires a significant amount of amniotic fluid for both foetal growth and maternal physiologic well – being. It has been reported that an average pregnant woman, by mid-gestation would accumulate above 1 litre of plasma volume with an increase in water content, as well as fat – free body mass. By 30 weeks of gestation, the maternal body water content rises averagely, 6 litres more than the non – pregnant woman (Beall et al., 2007).

There was significant correlation of pregnancy weight with birth weight. Linear regression analysis confirmed a significant effect of pregnancy weight on birth weight (Fig 8B). Pregnancy weight, as the sum of prepregnancy weight, the unborn foetal weight and the net weight gained actually affects the birth weight of the neonate. It is indeed, a true reflection of the nutritional and health status of the pregnant woman. Generally, the intrauterine life of the foetus depends on maternal nutrition, health and lifestyle and as such the relationship suggests that a well nourished and healthy pregnant woman is more poised to deliver a heavy or an appropriate – for – age baby. This finding essentially requires public health attention, in that improvement in the nutritional status during antenatal care could significantly reduce low birth weight especially among rural dwelling mothers. Maternal nutrition as reported by Thame et al (2001) is evaluated by the maternal weight and rate of weight gain in pregnancy that significantly affects birth weight. In another study, Thame et al (2007) observed that

among the various maternal variables, an increase in maternal lean body mass was solely the most essential variable which influenced birth weight.

A strong positive correlation of pregnancy weight with head circumference was observed in this study. The increase in head circumference with pregnancy weight could be attributed to the increase in size of the brain and the great deal of bone formation. Although speculative, it is believed that with the increase in pregnancy weight, the foetal demand for nutrient and oxygen would be met when placental exchange, metabolic and endocrine functions are efficient. Again, in theory, foetal demand for calcium increase due to its rapid growth and bone formation. It is also observed that maternal calcium intake increases and 1, 25 dihydroxyvitamin D_3 and parathyroid hormone secretion rise to ensure that the increased calcium demand of the foetus is met to facilitate bone formation activities, particularly, the skull bones (Rhoades and Tanner, 2004).

This variation in maternal measures which appropriately predict birth size or proportionality could reflect the duration of gestation during which various growth trajectories are most influenced by the maternal environment (Walker et al., 2003).

The significant association of ponderal index with pregnancy weight confirms an earlier observation of this study in which pregnancy weight significantly showed positive correlation with birth weight. Although insignificant, body length exhibited a negative correlation with pregnancy weight; it therefore means that when pregnancy weight correspondingly increases with birth weight, the ponderal index automatically increases as well. This could suggest that pregnancy weight serves as an indicator of nutritional status of the mother which has direct effect on the birth weight of the foetus. The pregnancy weight in this study is found to relate to almost all the growth trajectories.

It has been reported that maternal nutrition in late pregnancy significantly influences the ponderal index of the neonate at birth (Andreasyan et al., 2007). Brown et al (2002), observed positive correlation of pregnancy weight with ponderal index, but not head circumference or birth weight. Maternal nutrition during pregnancy could therefore confer on the foetus a disease risk in later life by means of the neonate's body composition instead of a mere foetal size variation at birth (Andreasyan et al., 2007).

Prepregnancy weight strongly correlated positively with ponderal index. This finding is in support of the fact that, in general, the effects of nutrition cut across all spheres of human life, especially in developing countries where adolescent mothers are more likely to transmit undernutrition conditions into their pregnancies. As such prepregnancy nutritional behaviour could alter the quality and health status of the neonate (Kurz 1996; Yucel and Cinar, 2009).

Pregnancy weight gained showed a positive correlation with abdominal circumference. This could mean that abdominal viscera and muscles were not "sacrificed" to the benefit of the growth of other body organs. It could therefore serves as an indicator of a symmetric growth. Weight gained in early pregnancy has been reported as an important predictor of foetal size at birth. This could possibly be through foeto – placental sufficiency (Thames et al., 2004). It has also been observed that the rate of weight gain in late pregnancy significantly associates with a lower risk of delivering a low – birth – weight baby (Walker et al., 2003).

5.6 CORRELATION BETWEEN UMBILICAL CORD VESSELS' MORPHOMETRY AND FOETAL INDICES

Morphologic and morphometric characterization of the umbilical cord components could greatly assist in improving on the adverse maternal and foetal outcomes. With the exception

of head circumference, this study found significant relationship of umbilical cord vessel morphometry with all other foetal measures. Recent advancement in ultrasound technology has enhanced the study of morphometric variation of the umbilical cord vessel association with foetal outcome at birth (Togni et al., 2007). For instance, evaluation of umbilical cord artery impedance to blood flow helps in identifying foetuses vulnerable to growth and developmental disorders (Raio et al., 2003).

The most unique observation in this present study is that foetal head circumference and the first artery (A1 defined as umbilical cord artery with an average of 2mm from the umbilical cord vein and average of 4mm from the umbilical cord margin, Ghezzi et al., 2005); never in anyway correlated with any of the umbilical cord components' morphometry. This could possibly be that almost all the contribution of the umbilical cord components morphometry in respect of the rate of transport, diffusion, distribution and exchange of materials necessary for healthy growth and development are directed to different body parts other than the head. In fact, the uniqueness of all the changes that occurs in foetal life has been the deceleration in growth rate of the head. Measurements at various gestational ages had it that, at the onset of the 12^{th} week of gestation, the size of the head is half the crown – rump length, and at the beginning of the 20^{th} week of gestation the size of the head becomes one third of the crown – heel length and at birth it measures approximately one fourth of the crown – heel length (Sadler and Montana. 2002).

Notwithstanding, in this study, the cross-sectional area and the volume of the second artery

(A2 defined as umbilical cord artery with an average of 6mm from the umbilical cord vein and average of 4mm from the umbilical cord margin, Ghezzi et al., 2005) significantly correlated with the gestational age. Using the area and volume of the umbilical cord artery eliminate the

problem of segmental reduction in umbilical cord artery as well as the fact that the vessel may not be absolutely circular in shape after birth. Also the use of volume has an added advantage over the area in that it gives a pictorial view of the total arterial space available for blood flow velocity determination at the various gestational ages. This is in line with the findings of Togni et al. (2007) in which a statistically significant correlation was found between the cross – sectional area of the umbilical cord arteries and gestational age.

The present study showed that umbilical cord diameter, volume and the volume of Wharton's jelly showed positive significant correlation with birth weight. The umbilical cord is the link between the developing foetus and placenta. Birth weight measures the nutritional status of neonate therefore the current finding explores the possibilities of the umbilical cord influencing birth, realizing the metabolically active role it plays when placental sufficiency is achieved. The Wharton's jelly is a connective tissue and facilitates diffusion through its interconnected cavities of water and growth metabolites to and from the umbilical cord vessels and the amniotic fluid (Raio et al., 1999; Ghezzi et al., 2001). This observation is also in agreement with a study conducted by Raio et al. (1999) in which both umbilical cord diameter and area correlated with foetal anthropometric parameters. Various anatomic investigations into the umbilical cord structure have observed that umbilical cord in the face of foetal intrauterine growth restriction and hypertensive disorders with normal umbilical artery Doppler parameters exhibited reduced total vessel area and Wharton's jelly area in comparison with normal foetuses (Bruch et al., 1997; Inan et al., 2002).

Abdominal circumference measurement which is among the four pillars of biometric measures in the evaluation of foetal size actually reflects abdominal visceral development. With the exception of umbilical cord length, abdominal circumference was found to have significant

correlation with the rest of umbilical cord morphometric indices such as umbilical cord diameter, volume, area, and amount and volume of Wharton's jelly. This relationship confirms the abdominal circumference's position as a strong signal for foetal growth. Available evidence suggests that the size of abdominal circumference has effect on clinical management decisions such as, the need for series of ultrasonography, foetal monitoring and/or delivery (Smulian et al., 2001). Again this finding, points to the fact, an early morphometric assessment of the umbilical cord components could be of valuable benefit to obstetricians since it prompts them of healthy or the adverse nature of the pregnancy (Ghezzi et al., 2001).

Foetal body length was found to show a strong positive correlation with umbilical cord length, area and volume as well as umbilical cord vein area, A2 area and volume and the Wharton's jelly area and volume. Furthermore, a significant difference in body length was observed between neonates with short and normal umbilical cord lengths (Table 5). The current study did not find evidence to support the fact that umbilical cord length is influenced by the tension theory. However, this study is of the view that in addition to the tension theory as have been reported severally (Miller et al., 1982; Soernes and Bakke. 1986; Katsumata et al., 1991 and Lyndon *et al.*, 1994), genetic factors undoubtedly influence the determination of umbilical cord length. Indeed, it has been established that insulin – like growth factor I (IGF – I) and insulin – like growth factor binding protein 3 (IGFBP – 3) play very important role in foetal growth during pregnancy (Endocrine Review, 2006). Various studies have reported a relationship between umbilical cord blood IGF –I and other measurements of foetal growth including birth length, crown – rump length, ponderal index and placental weight (Ashton et al., 1985; Fant et al., 1993; Klauwer et al., 1997; Ostlund et al., 1997; Ong et al., 2000; Vatten et al., 2002). The vascular architecture of the umbilical cord is not only fascinating in terms of morphology,

but also from the functional interpretation perspective. For instance, whereas an abnormal ratio of Doppler systolic/diastolic may indicate pathologic circulation of the neonate that leads to intrauterine retardation, normal values show foeto-placental circulation associated with small foetal size (Chang et al., 1993; Bartha et al., 1998; McCowan et al., 2000).

The body length relation with the areas and volumes of the umbilical cord vessels manifests the haemodynamic state of umbilical cord blood flow velocity. It has been found that in cases of continuous diminution in the flow velocity of umbilical cord blood with increased foeto-placental obstruction, structural alteration in the umbilical cord vessels is induced. And as a compensatory mechanism for the insufficient transfer of nutrient, foetal growth velocity is significantly decreased (Raio et al., 2003).

CHAPTER 6

SUMMARY OF MAIN FINDINGS, CONCLUSION AND FUTURE WORK

6.1 SUMMARY OF MAIN FINDINGS

The combined prevalence of eccentric and centric insertions of the umbilical cord into the placenta was 92.27%. About 87% of the umbilical cords coiling were within the 10^{th} – 90^{th} percentile. The prevalence of right handed coiling was 74.88% and that of normal umbilical cords (umbilical cords with three vessels) was 98.55%. This suggests that majority of the umbilical cords were in their normal morphological states.

This study observed that neonates who had short umbilical cord length were shorter in body length than those with normal umbilical cord length (43.95±5.15 cm and 45.82±3.96 cm; $P<0.05$) and lower placental weight (586.20±99.59g and 620.60±99.60; $P<0.05$).

Significant difference was observed in the umbilical cord vein diameter of neonates of normotensive and pregnancy induced hypertensive mothers (3.36±0.88 mm and 3.82±0.50; $P = 0.018$) respectively. This could probably be due to histopathological variations in both groups, which may be crucial to the developing foetus. Term males and females exhibited significant differences in body and umbilical cord lengths (45.83±4.08 cm and 44.32±3.86 cm; $P< 0.05$).

Correlation observed between maternal and foetal indices were; maternal age and birth weight ($r^2=0.143$, $P<0.05$); age and abdominal circumference ($r^2=0.214$, $P<0.001$); parity and head circumference ($r^2=0.163$, $P<0.05$); pregnancy weight with gestational age ($r^2=0.190$, $P<0.01$), birth weight ($r^2=0.192$, $P<0.01$), head circumference ($r^2=0.190$, $P<0.01$), and ponderal index ($r^2=0.241$, $P<0.001$); prepregnancy with ponderal index ($r^2=0.193$, $P<0.01$). These

demonstrate that there are corresponding increases in foetal indices as those maternal indices increase. Pregnancy weight showed significant effect on birth weight (β=4.967, P=0.004) and head circumference (β=0.478, P=0.038). Placental weight had influence on body length (β=4.577, P=0.003) and birth weight (β=49.350, P=0.001). Birth weight to placental weight ratio also showed significant effect on birth weight (β=1.181, P=0.0001).

The volume and area of Artery A2 showed positive correlation with gestational age and body length, it was only the Artery A2 area that had significant effect on body length. The umbilical cord length, volume and area showed significant correlation with birth weight and body length. They each had effect on body length development. Their combined state also showed to have influence on body length. The umbilical cord diameter and volume had both individual and combined effects on birth weight. This probably, could be due to the role the umbilical cord plays in nourishing the foetus and the contribution each of its vessel morphometry. Wharton's jelly volume and area were found to positively correlate with birth weight, body length and abdominal circumference. They individually as well as in their combined state influence the development of birth weight, body length, and abdominal circumference. Wharton's jelly is known to be a metabolically active tissue and its contribution to the development of foetus, especially in body length and the visceral organs should not be overlooked.

6.2 CONCLUSIONS

In the present study, umbilical cord vein diameter was larger in neonates of pregnancy induced hypertensive mothers. Therefore systematic prenatal monitoring of the

haemodynamics of foeto-placental circulation could reduce the incidence of morphological alterations in the new-born babies of PIH mothers.

Pregnancy weight and placental weight appear to be key factors influencing the development of head circumference, birth weight and body length of the foetus.

The role of umbilical cord indices and Wharton's Jelly content in foetal nutrition is well established; therefore the strong linear regression relationships observed in this study may suggest that umbilical cord and Wharton's jelly measurements linearly related with body length, abdominal circumference and birth weight of the foetus.

These quantitative data on the umbilical cord and placenta provide baseline values for further studies.

6.3 FUTURE WORK

Future studies using larger sample sizes involving health facilities from other parts of the country should be conducted.

Detail analysis of microscopic morphometry of placental and umbilical cord characteristics may be informative in studies tracing origins of prenatal and postnatal outcome of the newborn.

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