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Relationship between Maternal Lipid Profile Level at Delivery and Neonatal Birth Weight

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ABSTRACT

Background: Birth weight is a reflection of fetal growth and maternal health during pregnancy and low birth weight has been associated with negative impacts on the health and survival rate of the babies. **Objective:** To determine the lipid profile levels in pregnant women at delivery and their association with neonatal birth weight. **Materials and Methods:** The study participants comprised of 200 healthy pregnant women and their new born babies. Serum triglyceride (TG), total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) were determined by spectrophotometric method, while low density lipoprotein cholesterol (LDL-C) was calculated using Friedewald equation. Data was analyzed using Student-t-test, analysis of variance and Pearson correlation coefficient. **Results:** The gestational age of pregnant women who gave birth to babies with low birth weight (LBW) babies were significantly higher than mothers who gave birth to neonates with normal birth weight (NBW) ($p<0.05$). The anthropometric measurements; birth weight, head circumference, recumbent length and ponderal index were significantly lower in babies with low birth weight than in normal birth weight($p<0.05$). Maternal TC and TG levels were significantly higher in those who gave birth to babies with NBW than mothers who gave birth to babies with LBW, but differs with maternal LDL-c ($p<0.05$). The LDL-c correlated inversely with birth weight ($r= -0.205; p<0.05$) while TC ($r=-0.261$; $p<0.05$), TG ($r=0.240; p<0.05$) correlated positively with neonatal birth weight respectively. **Conclusion:** These findings established a relationship between maternal lipid levels and birth weight of neonates. It is concluded that lipid profile levels may predict neonatal birth weight and may be routinely done during antenatal investigation.

Keywords: Maternal lipid, newborn, birth weight, body mass index

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INTRODUCTION

Birth weight of babies is a reflection of fetal growth and maternal health during pregnancy (1). Over 90% of low birth weight (LBW) babies were reported to be born recently in low income countries with majority in Asia and sub-Saharan African (1). Low birth weight is a sign that identifies neonates at increased risk of morbidity and mortality (2). Some authors have shown that infants born with low birth weight had five-fold increased risk of mortality than adequate for gestational age infants (2). Others have suggested that sub-optimal lipid levels during pregnancy may change fetal lipid metabolism which ultimately affect birthweight of the neonates (3,4). Variations in the hormonal and metabolic changes that occur during pregnancy also contribute to changes in the lipid profile in healthy pregnant women. It was observed that alterations of lipid metabolism in normal pregnancy occurs in two phases (5); during the first two trimesters, lipid metabolism is mainly anabolic causing an increase in lipid synthesis and fat storage in preparation for the exponential increases in fetal energy needs in late pregnancy. This increase in lipid synthesis between 10 and 30 weeks of pregnancy is promoted by maternal hyperphagia seen in early pregnancy as well as an increase in insulin sensitivity. The up-regulation in insulin sensitivity stimulates fatty acid synthesis in adipocytes and stimulates the expression of lipoprotein lipase, which results in the increased uptake of fatty acids from circulating triglyceride rich lipoproteins. Additionally, the increased production of progesterone, cortisol, leptin, and prolactin contribute to the increased fat storage (6). There is also significant hypertrophy of the adipocytes to accommodate increased fat storage (6). Lipid metabolism in the third trimester is in a 'net catabolic phase', which is driven by a decrease in insulin sensitivity. Pregnancy induced alterations in lipid metabolism during pregnancy can be caused by several exogenous factors such as maternal malnutrition, inflammation and infections which could lead to imbalance in lipid levels and adverse birth outcomes (1).

Birth weight is the body weight of a baby measured immediately after parturition. According to the World Health Organization, the average birth weight of neonates is 3.5kg, although between 2.5kg and 4.5kg is regarded as normal. Birth weight less than 2.5kg is considered as low birth weight (7). Low birth weight is mainly caused by intrauterine growth restriction, prematurity or both. It contributes to several adverse health outcomes, which include neonatal mortality and morbidity, poor cognitive development and metabolic diseases later in life (7).

Studies have indicated that maternal dyslipidaemia can predict the occurrence of pregnancy complications and adverse perinatal outcomes (4). When combined with maternal risk factors and other blood biochemical indices, it has higher predictive value. It was reported that elevated maternal TG and non-esterified fatty acid metabolism were correlated with excessive fetal growth (8). The Amsterdam Born Children and their Development cohort study observed that maternal TG concentrations in early pregnancy were linearly related with the prevalence of pregnancy-induced hypertension (pre-eclampsia), induced preterm birth and marcrosomia (9). Studies conducted in women diagnosed with Gestational Diabetes Mellitus also showed

that maternal TG and non-esterified fatty acid concentrations in late pregnancy are positively correlated with newborns' birth weight, body mass index (BMI) and fat mass (8). Some other authors reported that high concentrations of HDL-c and LDL-c in the third trimester were significantly associated with an increased risk of low birth weight (4,10). Also, some authors reported that mothers who gave birth to infants with low birth weight had significantly higher concentrations of HDL-c(11,12).

However, the reports of association between maternal lipid parameters and low birth weight of babies have not been consistent. Some authors have reported that none of maternal lipids was independently associated with birth weight or the risk of low birth weight (13). Others were of the opinion that neonatal birth weight was inversely associated with HDL-c at late gestation only in overweight/obese women (14). While Wang *et al.*, (15) reported that maternal TG was an independent predictor of neonatal birth weight, low birth weight and macrosomia in non-diabetic, non-obese pregnant women. Little is known about maternal lipid levels at delivery and birth weight of infants among Nigerians. The needs for accurate prediction of neonatal weight using lipid profile levels is imperative as this may enable prompt interventions to optimize the maternal and birth outcomes. It is for this reason that this study was designed to determine the relationship between maternal lipid profile levels and birth weight of neonates among apparently normal pregnant women at delivery.

MATERIALS AND METHODS

Study Population and Design

This is a cross-sectional study of 200 healthy pregnant women attending antenatal clinics at the Departments of Obstetrics and Gynecology, Stella Obasanjo Hospital, Benin City. They were consecutively enrolled for the study. The gestational age was calculated by counting in weeks from the first day of the last menstrual period.

Ethical Consideration

Ethical approval was obtained from the Ethics Committee of the Edo State Hospitals Management Board, Benin City (Reference: A.926/438 dated 5/1/2018) and informed consent was obtained before the commencement of the study. Demographic and clinical information wereobtained using structured questionnaires.

Inclusion Criteria:

All healthy pregnant women of 18years and above expecting singleton, who attended antenatal clinic throughout the pregnancy and reported for delivery were included. Pregnant women who carried their pregnancy to full term and delivered either by vaginal and cesarean section were also included.

Exclusion Criteria:

Pregnant women with complications such as diabetes mellitus, cardiovascular diseases, and those who had parity more than four (4) were excluded. Also, obstetric conditions that could cause small for gestational age babies like preterm deliveries, bad obstetric history, abruption placenta previa, and congenital anomalies of the baby, pregnancy-induced hypertension, polyhydramnios, endocrine disorders, or other severe maternal illnesses, clinical signs of infection, benign tumors and malignancies were excluded.

Sample Preparation:

Five millilitres of venous blood was collected from pregnant women who were admitted at the onset of labor, into lithium heparin container and labeled appropriately. The blood was spun at 3000 rpm for 10minutes to obtain plasma. The plasma was separated into clean plain tube and was stored at -20^0 C until analysis for lipid profile concentrations was done.

Sample Size Determination

The sample size for this study was determined using the sample size determination for health studies formula:

$N=Z^2pq/d^2$ (16)

Where:

N is the desired sample size

Z is the standard deviation set at 1.96.

P is the prevalence of delivery of small for gestational age in Nigeria put at 14% (17).

= 0.14

q is (1-p) = (1-0.14) =0.86

d is precision in proportion of one, set at 5% = 0.05

Then, $N= 1.96^2 \times 0.14 \times 0.86/0.0025 = 185$

Therefore, 200 subjects were recruited for this study.

Anthropometric Measurements

Maternal weights were measured by the Suvarna electro digital body weighing scale(Suvarna, India). This was done with the scale placed flat on the ground surface, thereafter, the subjects stood on it bare footed with minimum clothing and the readings recorded. Also, the maternal height (m) was taken using Seca 213-Scale Galore metric Stadiometer (USA) attached to a wall, the measurements were taken with the subjects standing as their head, shoulder blades, buttocks and heels touch the measuring rod on the stadiometer and facing forward.

Body mass index (BMI) was calculated by dividing the weight (kg)/ height (m^2).

Birth weight of the neonates, head circumference, and recumbent length were measured by digital infant scale, flexible metal tape measure, and Seca 416 portable Infantometer respectively. The ponderal index (PI) was calculated as Birth weight (gr)/ Body length $(cm)^3 \times 100$, to assess the fetal growth pattern.

Gestational age, measured in weeks completed, wasbased primarily on the last menstrual period and ultrasound estimation while the parity was obtained from the antenatal record.

Low birth weight was defined as a birth weight below 2.5kg compared to normal birth weight ≥2.5kg (18) while SGA was characterized as birth weight for gestational age less than 10^{th} percentile of the INTERGROWTH-21^{ST}standards for birth weight when compared with adequate for gestational age (AGA) ≥10^{th} percentile of the INTERGROWTH-21^{ST} standards for birth(19)

Lipid profile Determination

Triglyceride (TG), total cholesterol (TC), and HDL-c were determined by spectrophotometric method using reagents kits supplied by Randox Laboratories, Crumlin, Antrim, UK(20).

Estimation of Total Cholesterol

Enzymatic endpoint (CHOD-PAP) method (20) was used to estimate the total cholesterol.

Principle

Cholesterol esterase hydrolyses esterified cholesterol to free cholesterol. The free cholesterol is oxidized in the presence of cholesterol oxidase to form hydrogen peroxide which further reacts with phenol and 4-aminoantipyrine by the catalytic action of peroxidase to form red quinoneimine dye complex. The intensity of

the colour formed is proportional to the amount of cholesterol present in the sample.

Serum Triglycerides Determination (20)

Principle

Lipoprotein lipase hydrolyses triglyceride to glycerol and fatty acids. The glycerol formed with ATP in the presence of glycerol kinase forms glycerol-3-phosphate which is oxidized by the enzyme glycerol phosphate oxidase to form hydrogen perioxide. Hydrogen perioxide further reacts with phenolic compound and 4 – aminoantipyrine by the catalytic action of peroxidase to form a red coloured quinoneimine dye complex. Intensity of the colour formed is directly proportional to the amount of triglycerides present in the sample.

Determination of High Density Lipoprotein- cholesterol (20)

Principle

Low density lipoprotein (LDL and VLDL), very low density lipoprotein (VLDL) and chylomicron fractions of cholesterol are precipitated quantitatively by addition of phosphotungstic acid in the presence of magnesium ions. After centrifugation, the cholesterol in the HDL fraction which remains in the supernatant, is then determined using the same method for the cholesterol assay.

Determination of low density lipoprotein-cholesterol (LDL-c) (21)

Fridewald formula was employed as LDL-cholesterol (mmol/l) = Total cholesterol-(TG/2.2 +HDL-cholesterol)(20).

Determination of Very low density lipoprotein-Cholesterol (VLDL-c) (21)

Concentration of VLDL =Concentration of triglyceride(mh/dL)/5

Quality Control

Control sera were used monitor the performance of assay procedures: SPINTROL H Normal and Pathologic (Ref. 1002120 and 1002210). (20)

If control values are found outside the defined range, the instrument, reagents and calibrators were checked for problems.

Statistical Analysis

The data obtained wereanalyzed using the statistical package for the Social Science Program (SPSS) Version 21.0 (Chicago, IL, USA). The values represented as Mean ± Standard Deviation. Student's t-test, and Analysis of Variance (ANOVA) were used to compare means between the groups while Pearson correlation coefficient was used to assess the relationship between the measured parameters in maternal and birth weight. A $p<0.05$ was considered statistically significant.

RESULTS

The 200 subjects that participated in this study were between the age of 24 and 36 years. The mean age of women who gave birth to Small for gestational age (SGA) babies was 29.3±4.70 years, and Appropriate for gestational age (AGA) babies was 29.7±5.28 years. There was no significant difference ($p>0.05$) in the mean age of both group of women. The difference between the height, weight, and BMI of women in both groups were not significant ($p>0.05$). The mean gestational age for SGA (38.7±1.22) was significantly lower ($p<0.03$) than AGA (39.3±1.33) (table 1).

Table 2 shows the comparison of anthropometric measurements based on neonatal birth weight. The birth weight ($p<001$), head circumference ($p<0.04$), recumbent length ($p<0.04$) and ponderal index ($p<0.04$) were significantly lower in

babies with Small for gestational age than Appropriate for gestational age.

Table 3 indicates the comparison of maternal serum lipid levels based on birth weight of babies. Maternal serum TC ($p<0.001$), TG($p<0.001$), LDL-C ($p<0.005$), were significantly lower in mothers who gave birth to babies with SGA compared to those who gave birth babies with AGA, but the difference in the mean levels of maternal HDL-c ($p>0.05$) was not significant.

Table 4 shows the correlation between maternal lipid profile parameters and Birth weight of Babies. There was a significant positive correlation between maternal TC and birth weight of babies ($r=0.261$; $p<0.01$), TG and birth weight of babies ($r=0.240$; $p<0.01$),but LDL-c correlated negatively ($r=-0.205$;$p<0.005$) with birth weight of babies. Conversely, the positive correlation between maternal serum HDL-c and birth weight of babies was not significant.

Table 5 shows the comparison of lipid profile levels in maternal serum based on body mass index of mothers. Serum TC, TG and LDL-c levels increased with increasing BMI of mothers while HDL-c decreased with increasing BMI of mothers. The differences in the levels of TC and HDL-c were significantly different while TG and LDL-c were statistically significant.

Table 1: Comparison of Some Anthropometric Characteristics of Mothers who gave Birth to Small for Gestational age and Appropriate for Gestational age Babies.

Characteristics	Small for gestational age (SGA) n =41	Appropriate for gestational age (AGA) n=159	t-value	p-value
Maternal age(years)	29.3±4.70	29.7±5.28	0.067	0.5
Weight (kg)	81.5±7.30	79±11.1	0.808	0.421
Height (m)	1.68±0.102	1.64±0.0782	1.65	0.102
BMI (kg/m^2)	29.2±3.88	29.4±3.57	0.174	0.862
Gestational Age (weeks)	38.7±1.22	39.3±1.33	2.17	0.031

Table 2: Comparison of Anthropometric Measurements of Babies Based on Neonatal Birth Weight

Anthropometric Parameters	SGA n=41	AGA n=159	P-value
Birth weight (Kg)	2.34±0.3	3.47±0.4	0.01
Head Circumference (cm)	32.3±1.3	34.4±2.8	0.04
Recumbent length (cm)	50.2±0.5	54.6±0.3	0.04
Ponderal Index (g/cm^3)	2.14±0.5	2.45±0.2	0.02

Table 3: Comparison of Maternal blood lipid levels based on birth weight of babies

Parameters	Small for Gestational Age (< 2.5 kg) n= 41	Appropriate for Gestational Age (>2.5kg) n=159	t value	p value
Cholesterol (mg/dL)	160±15.0	188±41.0	3.52	0.001
Triglycerides (mg/dL)	126±37.4	160±33.0	4.89	0.001
HDL-c (mg/dL)	47.4±13.6	50.2±51.7	0.28	0.78
LDL-c (mg/dL)	122±15.8	85.3±25.8	2.86	0.005

HDL-c=high density lipoprotein-cholesterol; LDL-c= low density lipoprotein cholesterol. Note: Mothers with higher TC and TG and low LDL–C had babies with AGA.

Table 4: Correlation of Maternal Lipid profile Parameters with Birth weight of Babies

Correlation	R-Value	P-value
TC vs Birth weight of Babies	0.261	0.001
TG vs Birth weight of Babies	0.240	0.001
HDL-c vs Birth weight of Babies	0.109	0.205
LDL-c vs Birth weight of Babies	-0.205	0.005

TC=total cholesterol; TG=triglycerides; HDL-c= high density lipoprotein cholesterol; LDL-c=low density lipoprotein cholesterol

Table 5: Comparison of Lipid profile Levels in Maternal Blood Samples Based on Body Mass Index of mothers (Mean ± SD)

Parameters	Body	Mass	Index(Kg/m^2)		
	18.5-24.9 n=14	**25.0-29.9 n=92**	**≥30.0 n=96**	**F value**	**P value**
Cholesterol (mg/dL)	161±56.4	186±34.9	188±39.7	3.47	0.033
Triglycerides (mg/dL)	138±46.2	159±35.2	156±32.7	2.51	0.084
HDL-c (mg/dL)	64.6±6.30	56.5±6.97	40.2±6.79	3.55	0.031
LDL-c (mg/dL)	63.1±15.5	90±85.9	95.3±27.7	1.95	0.145

HDL-c= high density lipoprotein cholesterol; LDL-c=low density lipoprotein cholesterol

DISCUSSION

Abnormal birth weight has been implicated as one of the leading risk factors for neonatal morbidity and mortality (1). Birth weight is a reflection of fetal growth and maternal health during pregnancy. Maternal undernutrition during gestation can cause metabolic stresses which may ultimately lead to adverse fetal growth and birth outcomes (1). It has also been associated with negative impacts on the health and survival of the baby and the mother. The early identification of abnormal birth weight neonates is essential for any comprehensive initiative to improve their chances of survival. Research has indicated that maternal dyslipidaemia can predict the occurrence of pregnancy complications and adverse perinatal outcomes (3,4). All the neonates with LBW were also SGA in this study and were analyzed together.

The findings from this study revealed that gestational age of neonate has a role to play in the birth weight of the neonate. The gestational age for SGA was significantly lower than AGA when compared. This result was in accordance with result from Zohdi *et al.,* (22), who reported that SGA may be due to preterm birth (short gestation <37 completed weeks). This may be attributed to being born too early and the fetus was not afforded the time in the uterus to grow and gain weight because much of a baby's weight is gained during the last weeks of pregnancy.

The anthropometric measurements; weight, height, ponderal index, recumbent lengths for SGA babies were significantly lower than AGA babies. This result is in conformity with previous report by Landau *et al.,* (23), whose findings revealed that SGA babies had lower anthropometric measurements compared to AGA babies. These significantly lower anthropometric measurements can be linked to long standing intra-uterine insults, particularly those occurring during the early phase of fetal development (23).

Serum TC, TG and LDL-c levels increased with increasing BMI of mothers while HDL-c decreased with increasing BMI of mothers. The differences in the levels of lipid parameters could be due to fat mass in the mothers. During early pregnancy there is an increase in body fat accumulation, associated with both hyperphagia and increased lipogenesis (23,24). The increased lipid production during pregnancy is necessary as an energy store to fulfill maternal and fetal metabolic needs while maternal hypertriglyceridemia, especially towards late gestation, has an important role as a source of TG for milk formation just before parturition. This increase in lipid deposition in mothers increases the mother body weight, and predisposes them to being overweight or obese during pregnancy, thereby marginally increasing their body mass index. The result for triglyceride concentration between the BMI categories differs from the finding of Geraghty *et al.,* (25). The authors eluded the difference to altered metabolism or possibly increased levels of insulin resistance in pregnant women with overweight or obese. The insignificant difference in triglyceride concentration between the BMI categories observed in our study can be linked to physiological increase in maternal TG especially towards the late gestation which has an important role as a source of TG for milk formation just before parturition. The

significantly lower levels of HDL-c with BMI increase observed in this study aligns with that of Mudd *et al.,* (26). The significantly lower HDL-C levels in obese and overweight mothers was attributed to both an enhancement in the uptake of HDL-c by adipocytes and an increase in the catabolism of apolipoprotein A-1 on HDL particles (26). The significantly higher TC levels observed among overweight and obese mothers in our study is consistent with previous studies (24,27). Saigal and Doyle (28) highlighted how energy metabolism during pregnancy differs between women in overweight and normal weight BMI categories.

The maternal lipid profile levels were compared in women that had LBW babies and those that had NBW. The levels of TC, TG were significantly higher among women that had NBW babies than those that had LBW babies. Conversely, LDL-C levels was significantly lower in women that had babies with LBW than those with NBW. Serum TC and TG correlated positively with neonatal birth weight, while LDL-C correlated inversely with neonatal birth weight of babies. This is an indication that lipid levels play significant developmental roles in foetus. Levels of lipid profile in mothers during pregnancy impact on neonates birth weight and could have adverse metabolic sequelae in the development of metabolic diseases later in life of the neonates (29). It has been recognized that inadequate nutrients during pregnancy can cause a permanent damage to the developing child's organs and tissue functions. Sub-optimal lipid levels during pregnancy may not be sufficient to cater for the exponential increases in fetal energy needs in late pregnancy.

Conversely, adequate diet in the proverbial 1000days window of opportunity lays a good foundation for health, development and economic well-being of the children (30). The pathophysiological mechanisms associating pregnancy lipid concentrations with risk of LBW may arise early during the anabolic phase of pregnancy (1). The women with significantly higher TC and TG during pregnancy had heavier infants which suggest that adequate TC and TG during pregnancy could influence fetal growth development and birth weight than and those with lower TC and TG levels.

The TC and TG levels were significantly higher in mothers with NBW babies than mother LBW babies indicating a profound influence on neonatal birth weight.The positive relationship between maternal TC levels and birth weight of babies in this study is consistent with previous studies (31-33). They observed that circulating maternal cholesterol levels during third trimester correlated positively with neonatal birth weight. Conversely, women with LBW neonates had a significantly lower TC levels compared to women with NBW neonates (1,10). Chen *et al.,* (10) postulated that the association between low TC in LBW may be connected with malnutrition. Maternal undernutrition during pregnancy causes metabolic stress that affects fetal programming signal causing long lasting effects on the infants. It can lead to permanent alterations in structure and function of important physiological systems (29).

The maternal LDL-c levels correlated inversely with the neonatal birth weight, and the level was significantly higher in the mothers who had LBW neonates than NBW neonates. This was not in conformity with previous studies (1,31). Our study raised another controversy that significantly higher maternal LDL-c levels at delivery may be associated with an increased risk of LBW. Similar finding was recently reported in literature (10). In a study by Pecks *et al.,*

(34), pregnancies with intrauterine fetal growth retardation were associated with lower LDL-c concentrations. Serizawa *et al*., (35) indicated that lower maternal LDL-c levels in the second trimester were associated with an increased risk of delivering an SGA infant at term. The latter study concluded that the hormonal imbalance underlying insulin resistance complicates intrauterine growth restricted pregnancies by reducing the consumption of LDL-c and lowering the triglyceride levels. In our study, we excluded women with gestational diabetes mellitus, and diabetes. Thus, we believe that our results were unlikely to be influenced by hormonal imbalances underlying insulin resistance. However, these mechanisms need to be further explored.

CONCLUSION

This study indicated a relationship between the maternal lipid profile levels and neonatal birth weight. Significantly positive correlation was observed between the TC,TG and neonatal birth weight while LDL-c level correlated negatively with neonatal birth weight. Also, BMI among pregnant women was associated with maternal lipid levels. It is suggested that lipid profile levels be routinely done as part of antenatal screening tests. This will enable adequate intervention by health caregivers to avoid the delivery of infants with LBW.

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REFERENCES

1. Okala SG, Sisse EA, Sosseh F, Prentice AM, Wooliett LA, Moore SE. Maternal plasma Lipid levels across pregnancy and the risks of small for gestational and low birth weight: a cohort study from rural Gambia. BMC Preg Childbirth, 2020;20;153.

2. Gracia-Basteiro, A.L, Quinto, L, Macete, E, Bardaji,A, Gonzalez, R, Nhacolo, A et al Infant mortality and morbidity associated with preterm and small for gestational age birth weights in Southerm Mozambique: a retrospective cohort study Plos One, 2017;12(2):e0172533

3. Wild R, Weedin EA, Wilson D. Dyslipidaemia in pregnancy. Clin Cardiol, 2015; 33(2):209-215

4. Jin WY, Lin SL, Hou RL, Chen XY, Han T, Jin Y. et al. Associations between maternal lipid profile and pregnancy complications and perinatal outcomes: a population-based study from China. BMC Preg Childbirth, 2016;16:60

5. Wiznitzer A, Mayer A, Novack V, Sheiner E, Gilutz H, Malhotra A, Novack L. Association of Lipid Levels During Gestation With Preeclampsia and Gestational Diabetes Mellitus. Obstet Anesthesia Digest, 2011;31(1): 35.

6. Blackburn S. Maternal, Fetal, and Neonatal Physiology: A Clinical Perspective, 2017 (5th ed.). Saunders p.23-26.

7. World Health Organization.Global nutrition targets 2025: low birth weight policy brief. Geneva 2014, www.int/nutrition/publication. Accessed 02/12/2021

8. Herrera E, and Ortega-Senovilla H. Lipid Metabolism During Pregnancy and its Implications for Fetal Growth. Current Pharmaceut Biotechnol 2014;15(1): 24–31.

9. Vrijkotte TGM., Krukziener N, Hutten BA, Vollebregt KC, van Eijsden M, Twickler M B. Maternal Lipid Profile During Early Pregnancy and Pregnancy Complications and Outcomes: The ABCD Study. J Clin Endocrinol Metab, 2012;97(11): 3917–3925.

10. Chen Q, Chen H, Xi F, Sagnelli M, Zhao B, Chen Y.et al. Association between maternal blood lipids levels during pregnancy and risk of small-for-gestational-age infants. Scientif Reports, 2020;10(1): 4–7.

11. Kramer MS, Kahn SR, Dahhou M, Otvos J, Genest J, Platt RW et al. Maternal Lipids and Small for Gestational Age Birth at Term. J Pediatr, 2013;163(4): 983–988.

12. Wang H, Dang Q, Zhu H, Liang N, Le Z, Huang D et al. Associations between maternal serum HDL-c concentrations during pregnancy and neonatal birth weight: a population-based cohort study. Lipids Health Dis, 2020;19(1): 4.

13. Retnakaran R, Ye C, Hanley AJG, Connelly PW, Sermer M, Zinman B et al. Effect of maternal weight, adipokines, glucose intolerance and lipids on infant birth weight among women without gestational diabetes mellitus. Can Med Assoc J, 2012;184(12): 1353–1360.

14. Misra VK, Straughen JK, Trudeau S. Maternal serum leptin during pregnancy and infant birth weight: The influence of maternal overweight and obesity. Obesity, 2013;21(5):1064–1069.

15. Wang X, Guan Q, Zhao J, Yang F, Yuan Z, Yin Y et al. Association of maternal serum lipids at late gestation with the risk of neonatal macrosomia in women without diabetes mellitus. Lipids Health Dis, 2018;17(1): 2.

16. Lwanga SK, Lemeshow S. Sample size determination in health studies; a practical manual. IRIS, World Health Organization, 1991.

17. World Health Organisation. Fact Sheet No 290—Millennium Development Goals (MDGs).2015.Available from: einghttp://www.who.int/mediacentre/factsheets/fs290/en/# accessed 10/02/2021

18. Kramer MS. Determinants of low birth weight; methodological assessment and meta-analysis. Bull World Health Organization, 1987;65(5):663-737.

19. Villar J, Altman DG, Purwar M, Noble JA, Knight H.E, Ruyan P et al. The Objectives, Design and Implementation of INTERGROWTH-21ST Project. Brit J Obstet Gynaecol,2013; 120(Suppl 2):9-26.

20. Randox Laboratories Limited, Manual/RX Monza. Total Cholesterol, HDL-Cholesterol and Triglyceride. Enzymatic Colorimetric Method Manual.

21. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the Concentration of Low-Density Lipoprotein Cholesterol in Plasma, Without Use of the Preparative Ultracentrifuge. Clin Chem, 1972;18(6): 499–502.

22. Zohdi V, Sutherland MR, Lim K, Gubhaju L, Zimanyi M, Black MJ. Low birth weight due to intrauterine Groth Restriction and/or Preterm Birth:Effects on Nephron number and long-term Renal Health. Int J Nephrol 2012;2012:136942.

23. Landau D, Stark S, Weatherborn M. Differences in Body Composition between Appropriate Gestational Age and Small Gestational Age infants at term. Obstet Gynecol, 2019;133(1):53S

24. Martin U, Davies C, Hayavi S, Hartland A, Dunne F. Is normal pregnancy atherogenic? Clin Sci, 2009; 96(4): 421–425.

25. Geraghty AA, Alberdi G, O'Sullivan EJ, O'Brien EC, Crosbie B, Twomey PJ et al. Maternal Blood Lipid Profile during Pregnancy and Associations with Child Adiposity: Findings from the ROLO Study, PLoS One, . 2016;11(8):e0161206.

26. Mudd LM, Holzman CB, Catov JM, Senagore PK, Evans RW. Maternal lipids at mid-pregnancy and the risk of preterm delivery. Acta Obstet Gynecol Scandinavica, 2012;91(6):726–35.

27. Rebholz SL, Burke KT, Yang Q, Tso P, Woollett LA. Dietary fat impacts fetal growth and metabolism: uptake of chylomicron remnant core lipids by the placenta. Am J Physiol, Endocrinol Metab 2011;301(2):E416–425.

28. Saigal S, Doyle LW. An overview of mortality and sequelae of preterm birth from infancy to adulthood. Lancet. 2008;371(9608):261–269.

29. Okunade KSOA. Predictive significance of low maternal serum cholesterol concentrations in early pregnancy on low birth weight in term neonates. Afri J Med Health Scis. 2017;16:94–98.

30. Emokpae MA and Odungide EE. Childhood Malnutrition: a Potential Risk of Metabolic Diseases in Adulthood, J Basic Applied Med Scis, 2020;1(1):48-60.

31. Mortorell R. Improved Nutrition in the first 1000 days and Adult Human Capital and Health. American J Hum Biol, 2017;29(2):1

32. Schaefer-Graf UM, Graf K, Kulbacka I, Kjos SL, Dudenhausen J, Vetter K, et al. Maternal lipids as

strong determinants of fetal environment and growth in pregnancies with gestational diabetes mellitus. Diabetes Care. 2008;31(9):1858–1863.

33. Kulkarni SR, Kumaran K, Rao SR, Chougule SD, Deokar TM, Bhalerao AJ et al. Maternal Lipids Are as Important as Glucose for Fetal Growth (Findings from the Pune Maternal Nutrition Study). Diabetes Care, 2013; 36:2706–2713.

34. Abdel-Hamid TA, AbdelLatif D, Ahmed E, Abdel-Rasheed M, Mageed AA. Relation between Maternal and Neonatal Serum Lipid Profile and Their Impact on Birth Weight, Am J Perinatol, 2020 doi: 10.1055/s-0040-1721690.

35. Pecks U, Bornemann V, Klein A, Segger L, Maass N, Alkatout I et al. Estimating fetal cholesterol synthesis rates by cord blood analysis in intrauterine growth restriction and normally grown fetuses. Lipids Health Dis, 2019;18(1): 3.

36. Serizawa K, Ogawa K, Arata N, Ogihara A, Horikawa R, Sakamoto N. Association between low maternal low-density lipoprotein cholesterol levels in the second trimester and delivery of small for gestational age infants at term: a case-control study of the national center for child health and development birth cohort. J Maternal-Fetal Neonat Med, 2016; 30(12): 1383–1387.