ATHEROGENIC INDEX OF PLASMA (AIP) AND LIPID PROFILE OF PREGNANT WOMEN ACCORDING TO THEIR TRIMESTERS IN BENIN CITY

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BEING A PROJECT SUBMITTED TO THE DEPARTMENT OF MEDICAL LABORATORY SCIENCE IN PARTIAL FUFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELORS DEGREE IN MEDICAL LABORATORY SCIENCE (BMLS) UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

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SEPTEMBER, 2025.

CERTIFICATION

This is to certify that this work was carried out by **FAGBAYIDE DAVID AYOMIPOSI** with Matriculation Number **BMS1807042,** under the supervision of PROF. B.I.G ADEJUMO and was submitted to the Department of Medical Laboratory Science, School of Basic Medical Sciences, College of Medical Sciences, University of Benin, Benin city, Edo State in partial fulfillment for the requirement of Bachelor of Medical Laboratory Science (BMLS) degree.

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DEDICATION

This project work is dedicated to God Almighty for his love, faithfulness, guidance and strength during the course of this work, and to my Parents, Mr and Mrs. Fagbayide and My Supervisor for their support, prayers and guidance.

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ABSTRACT

When Women gets pregnant, it induces profound metabolic changes, particularly in lipid metabolism, to support maternal adaptation and fetal growth. While these alterations are physiological, excessive deviations may predispose women to cardiovascular complications such as preeclampsia and gestational diabetes. The Atherogenic Index of Plasma (AIP), derived from triglyceride and HDL-C levels, has emerged as a useful biomarker for evaluating cardiovascular risk during pregnancy. This study aimed to evaluate the Atherogenic Index of Plasma (AIP) and lipid profile variations among pregnant women across the three trimesters in Benin City, Nigeria, in order to assess trimester-specific cardiovascular risk patterns. A cross-sectional descriptive design was employed involving pregnant women attending antenatal clinics in Benin City, blood samples were collected and analyzed for total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) using standardized enzymatic colorimetric methods. The AIP was calculated as log(TG/HDL-C). Data were analyzed using ANOVA, correlation, and regression models, with significance set at $p < 0.05$. The study population was predominantly aged 20–34 years (79%), with most in the third trimester (47%). Pregnant women showed significantly higher BMI and LDL-C compared to non-pregnant controls ($p < 0.001$). Triglycerides increased progressively from the first trimester (103.52 ± 8.74 mg/dL) to the third (140.04 ± 5.22 mg/dL, $p = 0.003$). LDL-C peaked in the third trimester (151.36 ± 5.56 mg/dL, $p = 0.01$), while HDL-C remained relatively stable. The mean AIP rose significantly with gestational age ($p = 0.022$), with third-trimester values higher than first-trimester values ($p = 0.017$). AIP correlated strongly and positively with triglycerides across all trimesters ($r = 0.76–0.91$, $p < 0.001$), and negatively with HDL-C in late pregnancy ($r = –0.641$, $p < 0.001$). Pregnancy in Benin City is characterized by progressive increases in triglycerides, LDL-C, and AIP, particularly in the third trimester. These findings highlight the need to include lipid and AIP monitoring in antenatal care for early identification of women at risk of adverse outcome.

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Pregnancy is characterized by profound physiological, biochemical, and hormonal changes that support fetal growth and prepare the mother for delivery and lactation. Among these changes, alterations in lipid metabolism are especially significant. The maternal lipid profile, including total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C), undergoes trimester-specific shifts that are considered both adaptive and potentially pathological under certain conditions. During pregnancy, there is a progressive increase in circulating lipids, especially from the second trimester onwards. This is largely driven by hormonal changes, including elevated levels of estrogen, progesterone, human placental lactogen (hPL), and insulin resistance, which promote lipogenesis and lipolysis to ensure sufficient energy supply to the growing fetus (Pérez-Cornago *et al*., 2020). However, abnormal elevations in lipid parameters have been implicated in adverse maternal and fetal outcomes such as preeclampsia, gestational diabetes mellitus (GDM), preterm birth, and macrosomia (Parmasivan *et al*., 2021). Numerous studies in diverse populations have reported trimester-specific changes in lipid profiles. In general, triglycerides and total cholesterol levels increase significantly in the second and third trimesters. LDL-C also tends to rise progressively, while HDL-C may initially rise in early pregnancy but often declines later (Nwagha *et al*., 2020). While such changes are considered physiological, the extent of lipid alterations can vary based on genetic, environmental, dietary, and sociodemographic factors, including geographic region, ethnicity, and nutritional status.

In Nigeria, and particularly in Benin City, there is a paucity of localized data assessing the lipid profile trends among pregnant women across the trimesters. Most available studies are either outdated or focus on broader populations without stratifying lipid levels by gestational age. Given the regional differences in diet, lifestyle, and access to antenatal care, it is crucial to generate region-specific data to better understand maternal lipid metabolism and its implications for pregnancy outcomes. A few recent Nigerian studies have suggested that urbanization, westernized diets, and increasing prevalence of obesity may be influencing maternal lipid levels (Oladeinde *et al*., 2021). Understanding trimester-specific lipid profile changes is also essential for early identification of women at risk of pregnancy-related complications. This is particularly relevant in settings like Benin City, where routine lipid screening is not a standard component of antenatal care. Establishing baseline data for normal lipid values in each trimester among pregnant women in this region will provide a foundation for future research and clinical guidelines, especially in the context of rising non-communicable diseases in sub-Saharan Africa. Furthermore, considering the growing emphasis on precision medicine and individualized antenatal care, identifying trimester-specific lipid trends will aid in better risk stratification and targeted interventions. It may also stimulate public health discussions on incorporating lipid screening into routine antenatal assessments, especially for high-risk groups. This study, therefore, aims to investigate the lipid profile levels in pregnant women attending antenatal clinics in Benin City, stratified according to their trimesters, to provide data that may inform both clinical practice and future policy decisions in maternal health care. In addition to the well-documented physiological roles of lipids during gestation, abnormal lipid metabolism has been increasingly recognized as a key contributor to the pathogenesis of several pregnancy-related complications. Elevated maternal triglycerides, for instance, have been associated with the

development of preeclampsia, a hypertensive disorder that remains a leading cause of maternal and perinatal morbidity and mortality in sub-Saharan Africa (Ajah *et al*., 2021). Similarly, increased LDL-C and total cholesterol levels have been implicated in the pathogenesis of gestational diabetes mellitus (GDM) and fetal macrosomia, further underscoring the clinical importance of lipid monitoring during pregnancy. From a pathophysiological perspective, the increased lipid levels observed in pregnancy are largely driven by enhanced hepatic lipogenesis, decreased lipoprotein lipase activity, and insulin resistance, particularly in the later stages of pregnancy. These adaptations are designed to shift the maternal energy metabolism from glucose dependence to lipid utilization, preserving glucose for placental and fetal use (Melchior *et al*., 2020). However, when the physiological threshold is exceeded, these adaptations can lead to a state of dyslipidemia, which contributes to endothelial dysfunction, inflammation, and oxidative stress — all hallmarks of poor pregnancy outcomes. The placenta itself plays a critical role in modulating lipid metabolism, functioning not only as a conduit for lipid transfer but also as a metabolically active organ capable of synthesizing and modifying lipids. Research indicates that abnormal lipid levels can impair placental function and vascularization, resulting in intrauterine growth restriction (IUGR) or preterm delivery (Wang *et al*., 2022). These outcomes are particularly concerning in resource-limited settings such as Benin City, where access to specialized maternal-fetal medicine is limited, and many pregnancies are managed with minimal laboratory evaluation. Despite the global understanding of lipid dynamics during pregnancy, Nigeria currently lacks standardized trimester-specific reference ranges for maternal lipid parameters. This absence of normative data impairs clinicians' ability to distinguish between physiological and pathological lipid elevations. Studies from different regions within Nigeria, such as Ibadan, Enugu, and Kano, have reported regional variations in lipid patterns, potentially

influenced by ethnicity, dietary practices, urbanization, and socioeconomic status (Afolabi *et al*., 2020; Okafor *et al*., 2021). Benin City, located in the South-South geopolitical zone, is a culturally diverse urban center where dietary patterns, including high consumption of palm oil and carbohydrate-rich meals, may influence lipid metabolism during pregnancy. However, no recent study has systematically evaluated lipid profile patterns in this population across gestational trimesters. Another compelling reason for local investigation is the epidemiologic transition occurring in Nigeria, with a rising burden of non-communicable diseases such as obesity, diabetes, and cardiovascular disease among women of reproductive age. These conditions can independently affect lipid metabolism, confounding the interpretation of lipid levels during pregnancy and necessitating region-specific studies. Moreover, the increasing trend of advanced maternal age and the use of assisted reproductive technologies have further complicated the maternal metabolic landscape, potentially amplifying lipid-related pregnancy risks. Given these multifactorial influences, it becomes imperative to conduct a localized, trimester-stratified analysis of maternal lipid levels in Benin City. This study will not only help define the normal physiological range of lipid parameters during each trimester but will also identify pregnant women at risk of lipid-related complications. In addition, it will serve as a foundational step toward formulating context-specific screening protocols, risk assessment tools, and therapeutic guidelines for maternal lipid management in Nigeria. The findings from this study may also contribute to the global discourse on maternal lipid health in sub-Saharan Africa by providing comparative data for meta-analyses and multicenter studies. Ultimately, by improving our understanding of trimester-specific lipid changes in pregnant women in Benin City, this research aims to enhance maternal and neonatal health outcomes through evidence-based antenatal care practices.

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1.2 Statement of Problem

Pregnancy is associated with substantial metabolic adaptations, particularly in lipid metabolism, to meet the increased energy demands of the growing fetus. These changes include progressive elevations in total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C), especially in the second and third trimesters, accompanied by fluctuating high-density lipoprotein cholesterol (HDL-C) levels (Pérez-Cornago *et al*., 2020). While such shifts are generally considered physiological, excessive deviations—termed gestational dyslipidemia—have been increasingly implicated in adverse pregnancy outcomes such as preeclampsia, gestational diabetes mellitus (GDM), intrauterine growth restriction (IUGR), preterm labor, and macrosomia (Ajah *et al*., 2021; Wang *et al*., 2022). In low- and middle-income countries, including Nigeria, the prevalence of maternal dyslipidemia may be underestimated due to limited routine lipid screening during antenatal care. This is particularly concerning in regions like Benin City, where urbanization, dietary transitions, and rising rates of obesity and metabolic disorders may predispose women to lipid abnormalities during pregnancy (Oladeinde *et al*., 2021). Despite this risk, lipid profiling is not standard practice in antenatal protocols, and clinicians often lack trimester-specific reference values tailored to local populations. Moreover, regional and ethnic variations significantly influence lipid metabolism, and findings from studies in other parts of Nigeria or outside Africa may not be generalizable to pregnant women in Benin City (Afolabi *et al*., 2020; Okafor *et al*., 2021). Yet, no recent study has systematically evaluated maternal lipid profile patterns across the three trimesters in this urban population. This data gap limits the

ability of healthcare providers to accurately interpret lipid levels, identify high-risk pregnancies, and implement early interventions that could mitigate poor maternal and neonatal outcomes. Given these concerns, it becomes imperative to establish baseline data on lipid profile changes according to gestational age in Benin City. Addressing this gap is critical for evidence-based antenatal care, improved maternal-fetal monitoring, and the formulation of context-specific guidelines for managing lipid-related risks during pregnancy.

1.3 Justification of study

Pregnancy is a dynamic physiological state marked by significant alterations in lipid metabolism, which are essential for fetal development and maternal adaptation. However, when these changes exceed physiological limits, they can lead to gestational dyslipidemia, which is increasingly associated with serious complications such as preeclampsia, gestational diabetes mellitus (GDM), preterm birth, and fetal macrosomia (Parmasivan *et al*., 2021; Wang *et al*., 2022). Early identification of abnormal lipid patterns is therefore crucial for effective risk stratification and prevention of adverse pregnancy outcomes. Despite this clinical significance, lipid profile testing is not routinely incorporated into antenatal care protocols in many low- and middle-income countries, including Nigeria. In Benin City, there is a noticeable gap in local data on maternal lipid profile trends across the trimesters of pregnancy. Most available studies in Nigeria either aggregate data across trimesters or are conducted in other regions with different sociodemographic, dietary, and cultural backgrounds (Afolabi *et al*., 2020; Okafor *et al*., 2021). Given that lipid metabolism is influenced by factors such as ethnicity, dietary fat intake, obesity, and urbanization, region-specific studies are necessary to reflect the true biochemical and clinical landscape of pregnant women in Benin City. Furthermore, with the increasing prevalence of non-communicable diseases, including obesity, diabetes, and cardiovascular disorders among

Nigerian women of reproductive age, there is a heightened risk of abnormal lipid metabolism during pregnancy (Oladeinde *et al*., 2021). These conditions can worsen gestational lipid changes and potentiate complications, yet remain undetected due to the absence of routine biochemical surveillance. Establishing trimester-specific lipid reference ranges for pregnant women in this locality will allow healthcare professionals to distinguish between physiological and pathological lipid elevations. The data from this study can serve as a baseline for future research and may contribute to evidence-based updates in clinical guidelines, such as the inclusion of lipid screening during antenatal visits, especially for high-risk pregnancies. In addition, findings from this research could inform public health policies aimed at improving maternal nutrition, lifestyle modification, and early metabolic monitoring. Importantly, this study will also contribute to the limited body of literature on maternal lipid dynamics in sub-Saharan Africa, and help align local maternal health practices with global trends advocating for personalized and preventative antenatal care (Pérez-Cornago *et al*., 2020).

In summary, this study is justified by the need to:

1. Fill the existing data gap on trimester-specific lipid changes among pregnant women in Benin City.
2. Provide clinically relevant reference values for early detection of dyslipidemia.
3. Guide risk assessment and improve management of pregnancy-related metabolic complications.
4. Inform future guidelines, healthcare policies, and public health interventions.

1.4 Aim of Study

To evaluate the Atherogenic Index of Plasma (AIP) and lipid profile variations among pregnant women across the three trimesters in Benin City, Nigeria, in order to assess trimester-specific cardiovascular risk patterns.

1.5 Specific Objectives

The specific objectives are to:

1. to determine the levels of lipid profile parameters (total cholesterol, triglycerides, HDL-C, LDL-C, and VLDL-C) among pregnant women in each trimester.

2. to calculate the Atherogenic Index of Plasma (AIP) for pregnant women in the first, second, and third trimesters.

3. to compare the AIP and lipid profile parameters across the trimesters to identify statistically significant changes during the course of pregnancy.

4. to evaluate the correlation between AIP and individual lipid parameters in each trimester.

5. to identify pregnant women at elevated atherogenic risk based on trimester-specific AIP cut-off values.

6. to provide baseline data on the lipid metabolic changes and cardiovascular risk in pregnancy specific to the population of Benin City, Nigeria.

1.6 Research questions

1. What are the levels of lipid profile parameters (total cholesterol, triglycerides, HDL-C, LDL-C, and VLDL-C) in pregnant women during each trimester in Benin City?

2. How does the Atherogenic Index of Plasma (AIP) vary across the three trimesters of pregnancy?

3. Are there statistically significant differences in lipid profile and AIP values among the first, second, and third trimesters?

4. What is the relationship between AIP and individual lipid parameters in each trimester?

5. At which trimester are pregnant women in Benin City most at risk of atherogenic cardiovascular complications based on AIP values?

6. Can AIP be used as an early indicator of cardiovascular risk in pregnancy among women in this population?

1.7 Research Hypothesis

1.7.1 Null Hypotheses (H_0):

1. There is no significant difference in total cholesterol levels among pregnant women across the three trimesters in Benin City.

2. There is no significant difference in triglyceride levels among pregnant women across the three trimesters.

1.7.2 Alternate Hypotheses (H_1):

1. There is a significant difference in total cholesterol levels among pregnant women across the three trimesters in Benin City.

2. There is a significant difference in triglyceride levels among pregnant women across the three trimesters.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Lipid Metabolism

The body needs lipids for energy storage, cell membranes, and making hormones. Doctors typically check four types of fats in the blood: total cholesterol, triglycerides, HDL cholesterol, and LDL cholesterol. Your liver controls how these fats are made and moved around in your blood. When a woman gets pregnant, her body changes how it handles these fats to help both mother and baby. These changes happen because pregnancy hormones like estrogen and progesterone go up, which makes the liver produce different amounts of fat and changes how the body uses it. It's normal and healthy for blood fats to increase during pregnancy - doctors call this "physiological hyperlipidemia." This higher fat level helps the baby grow and gives the body what it needs to make important hormones (Sonagra *et al*., 2014).

2.1.1 Physiological Changes in Lipid Profile Across Pregnancy Trimesters

When a woman becomes pregnant, the fats in her blood change a lot as the pregnancy goes on. In early pregnancy, blood fats stay pretty close to normal levels since the baby doesn't need much energy yet, though the body's hormones start changing. By the middle of pregnancy, we see blood fats going up more clearly. The total cholesterol, LDL, and HDL all reach their highest points around this time. Having more HDL is actually good for heart health. The biggest changes happen in late pregnancy, when blood fats rise sharply. Triglycerides can get two or three times higher than before pregnancy. HDL might level off or drop a bit, while LDL stays high. These high triglycerides happen because the liver makes more VLDL and fat tissue breaks down less fat, which helps get more fatty acids to the baby through the placenta (Wang *et al*., 2021). While these changes are normal, if blood fats get too high, it might lead to problems like diabetes during pregnancy, preeclampsia, or early delivery.

2.1.2 The Atherogenic Index of Plasma (AIP) as a Novel Biomarker

The AIP score helps doctors check heart disease risk by looking at the math between two blood fats. You get this number by using a special calculation with triglycerides and HDL cholesterol. This score tells us about the small, dense LDL particles in your blood that can cause problems by sticking to your artery walls more easily and getting damaged by oxygen (Dobiásová and Frohlich, 2001). During pregnancy, the AIP score gives us a better picture of heart risks than just looking at each blood fat separately. If someone has a high AIP score, it means they have high triglycerides but low HDL - not a good mix. Even though pregnancy changes are temporary, this pattern might mean the blood vessels aren't working right and the body isn't using insulin well. New research says doctors should use this score during pregnancy to spot which mothers might have problems from unhealthy blood fats (Bawah *et al*., 2020).

2.1.3 Trimester-Specific Trends in AIP and Lipid Parameters

Scientists are tracking how AIP scores change during pregnancy, and they match up with normal fat changes in the blood. Early in pregnancy, AIP scores stay in the safe range. One study by Bawah *et al*. (2020) showed these scores start pretty low in the first three months. Around months 4-6, the AIP score starts climbing because triglycerides go up while HDL doesn't keep pace. This is just part of a normal pregnancy. In the last three months, AIP hits its highest point when triglycerides are at their peak and HDL either levels off or drops a bit. Wang *et al*. (2021) watched a group of pregnant women and found their AIP scores kept going up steadily from early to late pregnancy. This shows that even in healthy pregnancies, the blood fats naturally become riskier near the end.

2.1.4 Association with Adverse Pregnancy Outcomes

Looking at AIP scores and blood fats tells us more than just what's normal in pregnancy. When triglycerides and AIP get too high, problems can pop up. Women who end up with pregnancy diabetes tend to have higher triglycerides and AIP scores early on than women with normal blood sugar. If we see a high AIP score in those first three months, it might warn us that diabetes is coming, since it shows the body's having trouble with insulin (Zheng *et al*., 2022). High blood pressure in pregnancy also goes hand in hand with bad blood fat levels. Studies find that women with preeclampsia have much higher total cholesterol, triglycerides, LDL, and AIP scores, but lower HDL than women with normal blood pressure. These unhealthy fats cause inflammation and damage to blood vessels, which is exactly what we see in preeclampsia (Ademi *et al*., 2023). Too much fat in the blood, especially triglycerides, also makes it more likely that babies will come too early or grow too big, probably because extra nutrients cross through the placenta.

2.2 Physiological Changes During Pregnancy

Pregnancy triggers significant metabolic adaptations, especially during the second and third trimesters. Hormones like estrogen, progesterone, and human placental lactogen increase insulin resistance and enhance lipolysis. These changes promote nutrient availability—particularly lipids—for fetal development (Vrijkotte *et al*., 2021). This state of "accelerated starvation" ensures a continuous supply of glucose and free fatty acids to the fetus, resulting in notable alterations in the maternal lipid profile, often referred to as "physiological hyperlipidemia of pregnancy" (López-Tinoco *et al*., 2022).

The trajectory of lipid changes exhibits a clear trimester-specific pattern. In the first trimester, lipid concentrations remain relatively stable or show only a slight increase, resembling pre-pregnancy levels. This period is marked by fat accumulation and storage, preparing for the high-energy demands of late pregnancy and lactation (Wang *et al*., 2021). The most significant changes occur during the second and third trimesters, with a marked increase in the liver's synthesis of very-low-density lipoproteins (VLDL). This leads to a progressive and substantial rise in circulating triglycerides (TG), which can reach levels two to three times higher than those in non-pregnant individuals (Ademi *et al*., 2023). Total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) also rise significantly, though not as dramatically as TG. High-density lipoprotein cholesterol (HDL-C) typically increases during the second trimester, which may offer a protective effect, but can then decline or stabilize in the third trimester (Sonagra *et al*., 2014). The mechanisms behind this dyslipidemia are multifactorial. The hyperestrogenic state of pregnancy boosts hepatic VLDL production. At the same time, the activity of lipoprotein lipase (LPL), the enzyme responsible for clearing TG-rich lipoproteins from the bloodstream, is reduced in maternal adipose tissue due to placental hormones. This combination of increased

production and decreased clearance results in the characteristic hypertriglyceridemia (Bawah *et al*., 2020). While this adaptive response is vital for fetal growth and development, providing necessary substrates for energy and steroid production, an exaggerated or pathological shift in this lipid profile can lead to negative outcomes. An excessively atherogenic environment is increasingly recognized as a significant factor in developing pregnancy-related complications, including gestational diabetes mellitus (GDM), preeclampsia, and preterm birth (Zheng *et al*., 2022). Therefore, understanding normal physiological changes is essential for identifying deviations that may indicate pathology.

2.3 Lipid Profile Alterations During Pregnancy

Lipid levels typically rise as pregnancy progresses. Triglycerides can increase 2–3 times above baseline, while total cholesterol and LDL-C also rise significantly. HDL-C may increase slightly in early pregnancy but often decreases in the third trimester (Wahabi *et al*., 2022). These changes are physiological but may become pathological if excessive. The pattern of change is dynamic and trimester-specific. During the first trimester, lipid parameters remain relatively stable or show only a modest increase, serving as a baseline for the significant shifts to come. The most profound changes are observed from the second trimester onward. The exponential rise in triglycerides (TG) is particularly notable, primarily driven by increased hepatic very-low-density lipoprotein (VLDL) production stimulated by high estrogen levels and the accompanying insulin resistance (López-Tinuco *et al*., 2022). At the same time, the activity of lipoprotein lipase (LPL), the key enzyme responsible for clearing TG from circulation, is suppressed in maternal adipose tissue, further contributing to maternal hypertriglyceridemia (Wang *et al*., 2021). This ensures a

steady supply of free fatty acids for fetal energy and growth. Total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) levels also show a steady increase throughout pregnancy, although their relative rise is less dramatic than that of TG. High-density lipoprotein cholesterol (HDL-C) follows a biphasic pattern, typically increasing during the second trimester and potentially providing a protective, anti-atherogenic effect. However, as pregnancy advances into the third trimester, HDL-C levels often plateau or decline, contributing to a more pro-atherogenic environment (Ademi *et al*., 2023). While these changes are normal and essential for supporting fetoplacental development—providing substrates for steroid hormone synthesis and serving as a critical energy source—the degree of change is important. An excessive shift toward this dyslipidemic profile heightens cardiovascular risk for the mother. This pathological exaggeration is no longer considered merely physiological and is a key factor in the development of adverse obstetric outcomes. Research consistently shows that significantly elevated TG and LDL-C, along with low HDL-C, are strongly associated with an increased risk of gestational diabetes mellitus (GDM) and preeclampsia (Bawah *et al*., 2020; Zheng *et al*., 2022). Closely monitoring these lipid profile changes is vital for identifying pregnancies that deviate from the normal physiological course and are at higher risk for complications.

2.4 Lipid Changes by Trimester

The metabolic adaptations of pregnancy drive distinct and progressive changes in the maternal lipid profile across each trimester. Understanding this trimester-specific evolution is crucial for distinguishing between physiological adaptation and pathological dyslipidemia.

First Trimester: This initial stage is marked by modest increases in total cholesterol (TC) and triglycerides (TG) due to early hormonal changes. Rising levels of estrogen and progesterone

stimulate hepatic lipoprotein production, but the fetal demand for lipids remains relatively low. As a result, this period often involves some maternal fat accumulation, serving as an energy reserve for later stages. Lipid levels during this trimester are typically closest to pre-pregnancy baselines, making it an optimal time for establishing a patient's initial profile (Zheng *et al*., 2022).

Second Trimester: This period brings more pronounced changes. A sharp increase in TG, TC, and LDL-C occurs primarily due to enhanced hepatic lipogenesis fueled by peak estrogen levels and progressive insulin resistance. The body shifts from storage to mobilization. The activity of lipoprotein lipase (LPL) in adipose tissue decreases, which reduces the clearance of TG-rich lipoproteins from circulation and further amplifies hypertriglyceridemia (López-Tinoco *et al*., 2022). High-density lipoprotein cholesterol (HDL-C) typically reaches its highest levels during this trimester, offering a protective, anti-atherogenic effect amid rising levels of other lipids.

Third Trimester: This final stage sees peak lipid concentrations, often entering ranges that would be considered abnormal in a non-pregnant state (Basu *et al*., 2020). TG levels can be two to three times higher than pre-pregnancy values, reflecting the highest level of insulin resistance and continued high hepatic output of VLDL. LDL-C also remains significantly elevated. Notably, HDL-C levels often plateau or decline from their second-trimester peak, contributing to a more pro-atherogenic environment as term approaches (Wang *et al*., 2021). This state ensures maximal transfer of essential lipids to the rapidly growing fetus but also represents a period of heightened risk for maternal vascular endothelial dysfunction.

2.5 Health Implications of Gestational Dyslipidemia

Excessive maternal dyslipidemia is linked to pregnancy complications such as preeclampsia, gestational diabetes mellitus (GDM), preterm birth, and macrosomia. Long-term risks include

cardiovascular disease for both the mother and the offspring (Retnakaran *et al*., 2021). While the physiological hyperlipidemia of pregnancy is adaptive, an exaggerated pathological state creates a pro-inflammatory, pro-oxidant, and pro-thrombotic environment that can negatively affect placental function and maternal endothelial health. The connection with gestational diabetes mellitus (GDM) is particularly strong. Dyslipidemia often precedes the clinical diagnosis of GDM, suggesting it plays a role in its development. Elevated triglycerides in the first trimester and a high Atherogenic Index of Plasma (AIP) are significant independent predictors of subsequent GDM (Zheng *et al*., 2022; Bawah *et al*., 2020). The underlying mechanism involves lipotoxicity, where excess free fatty acids contribute to insulin resistance in maternal skeletal muscle and liver, impairing pancreatic β-cell function and exacerbating glycemic dysregulation.

A pronounced atherogenic lipid profile is also characteristic of preeclampsia. Women who develop preeclampsia show significantly higher levels of triglycerides and LDL-C, along with lower levels of HDL-C, compared to women with normotensive pregnancies (Ademi *et al*., 2023; Wahabi *et al*., 2022). Oxidized LDL particles can infiltrate the vascular endothelium of the placenta, promoting endothelial dysfunction, inflammation, and the release of anti-angiogenic factors central to the pathophysiology of preeclampsia. Beyond these major complications, dyslipidemia is also associated with adverse fetal outcomes. High maternal triglyceride levels are a key source of fatty acids for fetal fat accumulation, correlating strongly with fetal macrosomia and large-for-gestational-age (LGA) infants, independent of maternal glucose levels (Wang *et al*., 2021). Furthermore, this pro-atherogenic intrauterine environment may program the fetus for metabolic diseases later in life, contributing to intergenerational risks for obesity and cardiovascular disease. The implications extend beyond pregnancy. A pregnancy complicated by dyslipidemia and its associated conditions (like GDM or preeclampsia) is recognized as a

stress test that reveals a woman's inherent susceptibility to future cardiovascular disease (CVD). Consequently, women with a history of these complications require long-term follow-up and screening for CVD risk factors, as their gestational lipid profile may provide critical insights into their future cardiovascular health (Retnakaran *et al*., 2021).

2.6 Global and Regional Prevalence

Worldwide, dyslipidemia affects over 60% of adults and is common in pregnancy. In sub-Saharan Africa, the prevalence among pregnant women ranges from 30–70%, depending on the trimester and diagnostic criteria. Urban populations tend to show higher rates due to lifestyle and dietary factors (Alberti *et al*., 2022). The prevalence of gestational dyslipidemia is not uniform; it varies significantly by geography and ethnicity, influenced by genetic predispositions, socioeconomic status, and the ongoing nutrition transition towards Westernized diets. Globally, the trend of dyslipidemia in pregnancy mirrors the rise of metabolic syndrome in the general population. Studies from various regions consistently report high rates of lipid abnormalities, particularly hypertriglyceridemia and low HDL-C, especially into the third trimester. For example, a large cohort study in China found that over 80% of pregnant women had at least one abnormal lipid parameter by late gestation, with hypertriglyceridemia being the most common issue (Wang *et al*., 2021). Similar high rates have been documented in studies from the Middle East and South Asia, highlighting this as a significant public health concern. In sub-Saharan Africa, the situation is complex and evolving. Historically viewed as a region of low cardiovascular risk, rapid urbanization and changing lifestyles are driving a steep increase in metabolic diseases. The prevalence range of 30-70% reflects this variability. Rural communities may still have lower rates, maintaining more traditional diets and physically demanding lifestyles. In contrast, urban centers in countries like Nigeria, Ghana, and South Africa are experiencing a

dramatic rise in dyslipidemia among pregnant women, linked to increased consumption of processed foods, saturated fats, and sedentary behaviors (Okpe *et al*., 2023). This epidemiological shift underscores the need for region-specific data, as applying diagnostic criteria from Western or Asian populations may be inappropriate. Urbanization is a key determinant of this trend. The shift from rural to urban living is consistently associated with a higher prevalence of atherogenic dyslipidemia. This is due to a combination of factors: a dietary shift towards energy-dense, high-carbohydrate, and high-fat foods; reduced physical activity; and increased psychosocial stress (Alberti *et al*., 2022). This trend highlights that the drivers of gestational dyslipidemia are largely modifiable, emphasizing the importance of public health interventions focused on preconception and antenatal nutrition education and the promotion of healthy lifestyles to mitigate this growing burden and its associated adverse pregnancy outcomes.

2.7 Previous Studies in Nigeria and Benin City

Research on lipid profiles and atherogenic risk during pregnancy in Nigeria is growing, indicating a significant burden of dyslipidemia that aligns with global trends but may have unique regional characteristics. In Benin City, Osakue *and* Osadolor (2017) studied lipid profile trends in 150 pregnant women and found significant trimester-based increases. However, they did not report exact prevalence rates. This foundational study documented the expected physiological rise in total cholesterol, triglycerides, and LDL-C throughout gestation, providing a local benchmark for subsequent research. Other Nigerian studies from various regions have built upon this work by quantifying the prevalence of these abnormalities. Investigations in Port Harcourt, Lagos, and the South-East have consistently reported a high prevalence of elevated triglycerides and low HDL-C in 40–60% of pregnant women, particularly in the third trimester (Agbonlahor *et al*., 2019; Chikani *et al*., 2020; Okpe *et al*., 2023). For instance, a study in Lagos

by Chikani *et al*. (2020) highlighted that over 50% of third-trimester pregnant women had atherogenic dyslipidemia, characterized mainly by hypertriglyceridemia. This high prevalence is a major public health concern, indicating a substantial population of pregnant women at heightened risk for adverse outcomes. A critical gap in many of these previous Nigerian studies, including the work by Osakue *and* Osadolor (2017), is the focus on individual lipid parameters without synthesizing them into a comprehensive atherogenic risk index. While reporting isolated high TG or low HDL-C is valuable, it offers a fragmented view of the overall lipid-associated risk. The Atherogenic Index of Plasma (AIP), calculated as log (TG/HDL-C), integrates these two crucial parameters into a single indicator of cardiovascular risk and small, dense LDL particle prevalence (Dobiásová *and* Frohlich, 2001). Its application in the Nigerian obstetric context remains limited.

2.8 Knowledge Gaps Addressed by This Study

Despite growing interest in maternal lipid health, there is a lack of trimester-specific prevalence data for pregnant women in Benin City. Most studies report group means without detailed analysis of how many women exceed clinical lipid thresholds. This study aims to fill that gap by quantifying lipid abnormalities according to trimesters, identifying risk levels and possible intervention points. Existing research within Nigeria, including the foundational work by Osakue *and* Osadolor (2017) in Benin City, has been instrumental in establishing the pattern of physiological changes in mean lipid values during pregnancy. Similarly, studies from other regions like Lagos and Port Harcourt have reported high overall prevalence rates of dyslipidemia (Agbonlahor *et al*., 2019; Chikani *et al*., 2020). However, a significant limitation persists: a focus on group means often obscures the clinical reality of how many individual patients transition from physiological adaptation to pathological dyslipidemia that requires clinical attention.

Reporting that mean triglyceride levels increase in the third trimester does not define what proportion of a specific population has values that are dangerously elevated. There is a critical gap in the application of composite atherogenic indices, such as the Atherogenic Index of Plasma (AIP), in the studied population. While individual lipid parameters are important, the AIP provides a more integrated assessment of cardiovascular risk by quantifying the balance between pro-atherogenic triglycerides and anti-atherogenic HDL-C (Dobiásová *and* Frohlich, 2001). Its utility in predicting adverse pregnancy outcomes like preeclampsia and gestational diabetes is gaining recognition (Bawah *et al*., 2020; Ademi *et al*., 2023), yet its trimester-specific values and prevalence in a cohort of pregnant women in Benin City remain unknown.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Study Area

This study was carried out in the University of Benin Teaching Hospital, Edo Specialist Hospital which involved Pregnant Women of Varying age and different tribes in Benin City. A total of 130 patients were recruited for this study involving a 100 pregnant women and 30 Control (non - pregnant women) . Informed consent was obtained from each participant after proper notification and information on the nature of the research , risk involved, benefits as well as confidentiality by using a questionnaire .

3.2 Study Design

This study will employ a cross-sectional descriptive study design aimed at evaluating the lipid profile levels of pregnant women at different stages (trimesters) of pregnancy in Benin City, Nigeria. The design is appropriate for establishing trimester-specific lipid patterns and comparing biochemical parameters across distinct groups (first, second, and third trimesters) at a single point in time.

3.3 Study Participants

The study population will consist of pregnant women attending antenatal care in the selected health facilities in Benin City, who meet the eligibility criteria. Participants will be recruited from each of the three trimesters of pregnancy.

A total 100 pregnant women and 30 non pregnant women were used for this study. A 100 pregnant women across the 3 different trimesters which include 40 pregnant women in their Third Trimester ,30 pregnant women in their second trimester ,30 pregnant women in their First Trimester.

3.4 Inclusion Criteria

1.Pregnant women aged 18–45 years.

2.Attending antenatal clinic at the selected health facilities.

3.Within the 1st, 2nd, or 3rd trimester as confirmed by last menstrual period (LMP) or obstetric ultrasound.

4.Willing to give informed consent.

3.5 Exclusion Criteria

1.Known history of diabetes mellitus, hypertension, or dyslipidemia prior to pregnancy.

2.Current use of lipid-lowering medications.

3.Multiple gestation (e.g., twins or more).

4.Severe illness or complications at the time of recruitment.

3.5.1 Control Group

This include the non-pregnant women with no history of dyslipidemia in Benin City who gave consent to participate in the study.

3.6 Sample Size

The sample size for this study was determined based on three factors

The estimated prevalence of variable of interest from literature review

Confidence interval of 95%

The acceptable margin of error

The sample size used in this research will be guided by an upper limit range to give a 95% level of confidence at the expected prevalence of about 12% using the precise formula;

The sample size was calculated using the formula obtained as described by Naing, L., Winn, T., *and* Rusli, N. (2006).

$$\text{Samples size } (\mathbf{N}) = \frac{Z^2 Pq}{d^2},$$

Where N= the desired sample size (when population is greater than 10,000)

Z= is a constant given as 1.96 (or more simply at 2.0) which corresponds to the 95% confidence level.

P= Prevalence of 12% (0.096)

q= 1.0-p

d= Acceptable error = 5% (0.05)

$$N = \frac{1.96^2 \times 0.096 \times 0.88}{0.05^2}$$

N=130 subjects

3.7 Ethical Approval

The ethical consideration and approval for my study was obtained from the research ethical committee of the Edo State Ministry of Health, Benin City, Edo state with Protocol Number:

3.8 Sample Collection

Approximately 5 mL of venous blood was drawn using a sterile, disposable 5 mL syringe and needle. The blood sample was transferred into a plain container and centrifuged at 3000rpm for 2mins. The serum from each sample was dispensed into sterile plain container with the sample number. The serum was stored at 2-8°c before laboratory analysis.

3.9 Sample Analysis

All laboratory analysis was carried out in the laboratory department University of Benin Teaching Hospital. Benin City.

3.10 Principle of The Assay

3.10.1 Cholesterol Determination

Method: Enzymatic method

Principle of the Test

Cholesterol esters in the sample are hydrolysed by cholesterol esterase to free cholesterol and fatty acids. Free cholesterol is oxidized by cholesterol oxidase to cholest-4-en-3-one with formation of hydrogen peroxide (H_2O_2).

The H_2O_2 produced reacts (in presence of peroxidase) with 4-aminoantipyrine (4-AAP) and phenol to form a pink-red quinoneimine dye. The intensity of the dye is proportional to the cholesterol concentration and is measured spectrophotometrically (typical $\lambda \approx 500$ nm – 515 nm; many labs use 500 nm or 505 nm

$$\text{Cholesterol esters} + H_20 \xrightarrow{\text{Cholesterol Esterase}} \text{cholesterol + fatty acid}$$

Procedure

The sample containing the precipitate was centrifugated,the sample is then pippeted into testtubes .An aqueous cholesterol standard was used to calibrate the assay,it is then mixed . 1 ml of reagent tlwas added to10mictoliter of sample ,then the standard is treated as test, absorbance of the sample or standard was read against the reagent blank.

Reference Range: TG ≤ 150

3.10.2 Triglyceride Determination

Method: Enzymatic method

Principle of Test

The estimation of serum triglycerides is commonly performed by an enzymatic colorimetric method based on the GPO-PAP procedure (Glycerol-3-Phosphate Oxidase – Phenol Aminophenazone method). This method measures the triglyceride concentration indirectly

through the quantification of glycerol released after enzymatic hydrolysis. Triglycerides are first hydrolyzed by lipase into glycerol and free fatty acids. The liberated glycerol then undergoes a series of enzymatic reactions, ultimately producing a colored dye whose intensity can be measured spectrophotometrically. The amount of dye formed is directly proportional to the triglyceride concentration in the sample.

$$\text{Triglyceride} + 3O_2 + 2H_2O + 4AAP + \text{Phenol} \xrightarrow{\text{Lipase}} \text{Quinoneimine dye} + \text{3-fatty acid} + \text{Dihydroxyacetone Phosphate} + 4H_2O$$

Procedure

The sample containing precipitate was centrifugated and then mixed well for about 10mins ,then the supernatant was separated and 1 ml of reagent was added to 10 ml of sample ,it is then read using the spectrophotometer

Reference Range: ≤ 200

3.10.3 High Density Lipoprotein (HDL) Determination

Method: Enzymatic method

Principle of the Test

Low density lipoprotein and chylomicron fractions are precipitated quantitatively by the addition of Phosphotungstic acid in the magnesium ions. After centrifugation, the cholesterol concentration in the HDL fraction which remains in the supernatant is determined.

$$\text{HDL Cholesterol ester} + H_2O + O_2 \xrightarrow{\text{CE-CHOD}} \text{Cholest-4-en-3-one} + \text{fatty acid} + H_2O_2$$

Procedure

The sample containing Precipitate was centrifugated and mixed and incubated for about 10 mins and then centrifugated for about 10 mins The supernatant is separated into testube and the absorbance is read.

Reference range 35-65mg/dl

3.10.4 Low Density Lipoprotein (LDL)

Low density lipoprotein cholesterol was calculated from the measured values of total cholesterol and High density lipoprotein cholesterol according to the relationship

$$LDL - C = TC - \frac{HDL}{5}$$

This is called the Fridewald Equation

Atherogenic indices were calculated from the values obtained

Reference range ≤ 150

3.11 Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version [insert version used, e.g., 25.0]. Descriptive statistics such as means, standard deviations (SD), and percentages were computed to summarize demographic, anthropometric, and biochemical characteristics of the participants. Independent samples t-tests were employed to compare differences in continuous variables between pregnant women and control subjects. One-way analysis of variance (ANOVA) with Tukey post hoc tests was used to assess differences in maternal weight, lipid parameters, and the Atherogenic Index of Plasma (AIP) across pregnancy

trimesters. Pearson's correlation analysis was conducted to evaluate associations between AIP and lipid parameters. Furthermore, multiple linear regression analysis was performed to identify predictors of AIP after adjusting for maternal body mass index (BMI), blood pressure, trimester, and lifestyle factors. A p-value less than 0.05 was considered statistically significant.

CHAPTER FOUR

RESULTS ANALYSIS

The age distribution of participants (Table 4.1) shows that most were between 20–34 years (79%), with a mean age of 31.34 ± 5.31 years. The majority were married (91%), while small proportions were divorced (6%), widowed (1%), or single (2%). Ethnically, Bini (34%) represented the largest group, followed by Igbo (23%) and Esan (16%).

According to Table 4.2, most participants were in the third trimester (47%), with 32% in the second and 21% in the first trimester. None reported smoking or alcohol consumption. Nearly half reported engaging in exercise (48%), while milk or egg consumption was high (91%) and multivitamin use was moderate (55%). Only 5% reported chronic diseases.

As presented in Table 4.3, pregnant women had significantly higher BMI (29.33 ± 0.47 kg/m² vs. 23.83 ± 0.65 kg/m², $p < 0.001$) and weight (201.43 ± 5.02 kg vs. 173.10 ± 1.32 kg, $p = 0.003$) compared to controls. LDL-C, Castelli Risk Index II, and Atherogenic Coefficient were markedly elevated in pregnancy ($p < 0.001$), while diastolic BP was moderately higher ($p = 0.021$). Systolic BP showed a non-significant trend ($p = 0.053$). Interestingly, AIP was slightly but significantly lower in pregnant women (0.36 ± 0.01) than in controls (0.42 ± 0.01, $p = 0.036$).

Differences in Atherogenic Index of Plasma (AIP) across trimesters are clearly presented in Table 4.4. The mean AIP in the first trimester (0.292 ± 0.026) was significantly lower than that

observed in the third trimester (0.292 ± 0.028) according to Tukey post hoc analysis ($p = 0.017$), with an overall ANOVA result showing a significant difference among all trimesters ($p = 0.022$). Significant increases in maternal weight, triglycerides, and LDL-C with gestational age are shown in Table 4.5. Weight rose from 170.30 ± 13.90 kg in the first trimester to 221.00 ± 5.91 kg in the third ($p < 0.001$). Triglycerides increased from 103.52 ± 8.74 mg/dL to 140.04 ± 5.22 mg/dL ($p = 0.003$), while LDL-C was lower in the second trimester compared with the third ($p = 0.01$).

Correlations between AIP and lipid parameters (Table 4.6) revealed strong positive relationships between AIP and triglycerides in all trimesters (r = 0.76–0.91, $p < 0.001$). In the third trimester, HDL-C correlated negatively with AIP (r = –0.641, $p < 0.001$), while Castelli Risk Indices showed moderate positive associations ($p < 0.05$).

The multiple linear regression model (Table 4.7) did not identify significant predictors of AIP after accounting for BMI, blood pressure, trimester, and lifestyle factors. The overall model fit was not statistically significant ($R^2 = 0.15$, adjusted $R^2 = 0.07$, $F(8, 91) = 1.96$, $p = 0.060$).

Table 4.1: Social Demographic Characteristics of Study Participants

Variable	Category	Frequency	Percent
Age Group	20–29	41	41
	30–34	38	38
	35–39	13	13
	40–50	8	8
Mean age ± SD	31.34 ± 5.309		
Marital Status	Married (M)	91	91
	Divorced (D)	6	6
	Widowed (W)	1	1
	Single (S)	2	2
Ethnicity	Bini	34	34
	Esan	16	16
	Igbo	23	23
	Urhobo	6	6
	Delta	5	5
	Tiv	5	5
	Isoko	2	2
	Yoruba	4	4
	Akwa Ibom	1	1
	Auchi	1	1
	Estako	2	2
	Ogoja	1	1

Table 4.2: Maternal and Lifestyle Characteristics of Study Participants

Variable	Category	Frequency	Percent
Trimester	1st	21	21
	2nd	32	32
	3rd	47	47
Smoking	No	100	100
Alcohol	No	100	100
Exercise	Yes	48	48
	No	52	52
Milk/Egg	Yes	91	91
	No	9	9
Multivitamin	Yes	55	55
	No	45	45
Diseases	Yes	5	5
	No	95	95

Table 4.3: Anthropometric and lipid Parameters of Control and Pregnant Participants

Variable	Control (Mean ± SEM)	Pregnant (Mean ± SEM)	*p*-value
BMI (kg/m²)	23.83 ± 0.65	29.33 ± 0.47	< 0.001
Systolic BP (mmHg)	120.30 ± 1.48	123.63 ± 0.82	0.053
Diastolic BP (mmHg)	75.17 ± 1.17	78.75 ± 0.76	0.021
Weight (kg)	173.10 ± 1.32	201.43 ± 5.02	0.003
Triglycerides (mg/dL)	133.37 ± 1.22	127.29 ± 4.17	0.43
HDL (mg/dL)	51.10 ± 0.44	53.41 ± 0.95	0.19
LDL (mg/dL)	95.27 ± 1.03	138.64 ± 4.09	< 0.001
TG (mmol/L)	1.51 ± 0.01	1.44 ± 0.05	0.43
HDL (mmol/L)	1.32 ± 0.01	1.38 ± 0.02	0.19
Atherogenic Index (AIP)	0.42 ± 0.01	0.36 ± 0.01	0.036
Castelli Risk Index I	3.39 ± 0.01	3.87 ± 0.10	0.009
Castelli Risk Index II	1.86 ± 0.01	2.65 ± 0.08	< 0.001
Atherogenic Coefficient	2.39 ± 0.01	2.87 ± 0.10	0.009

Values are presented as mean ± standard error of the mean (SEM). significance $p < 0.05$

Table 4.4: Atherogenic Index of Plasma (AIP) Across Pregnancy Trimesters

Trimesters	N	Mean ± SEM	*p*-value
1st Trimester	21	0.292 ± 0.026*	0.022
2nd Trimester	32	0.292 ± 0.027	
3rd Trimester	47	0.292 ± 0.028*	

Values are presented as mean ± standard error of the mean (SEM). significance $p < 0.05$ Asterisks (*) denote groups that were significantly different from at least one other trimester based on Tukey post hoc comparisons ($p < 0.05$). Specifically, the 1st trimester mean was significantly lower than the 3rd trimester mean ($p = 0.017$).

Table 4.5. Maternal Anthropometric and Lipid Parameters Across Pregnancy Trimesters

Variable	1st Trimester (n=21)	2nd Trimester (n=32)	3rd Trimester (n=47)	*p*-value
BMI (kg/m²)	28.89 ± 1.13	28.88 ± 0.71	29.83 ± 0.71	0.603
Systolic BP (mmHg)	124.95 ± 2.05	122.41 ± 1.32	123.87 ± 1.19	0.526
Diastolic BP (mmHg)	80.10 ± 1.97	77.88 ± 1.22	78.74 ± 1.10	0.59
Weight (kg)	170.30 ± 13.90[a]	193.13 ± 7.27[a]	221.00 ± 5.91[b]	<0.001
Triglycerides (mg/dL)	103.52 ± 8.74[a]	124.16 ± 7.89[ab]	140.04 ± 5.22[b]	0.003
HDL (mg/dL)	50.81 ± 2.72	52.53 ± 1.12	55.17 ± 1.40	0.177
LDL (mg/dL)	131.33 ± 8.47[ab]	124.75 ± 7.36[a]	151.36 ± 5.56[b]	0.01
Triglycerides (mmol/L)	1.17 ± 0.10[a]	1.40 ± 0.09[ab]	1.58 ± 0.06[b]	0.003
HDL (mmol/L)	1.31 ± 0.07	1.36 ± 0.03	1.43 ± 0.04	0.177
Castelli Risk Index I	3.63 ± 0.29	3.71 ± 0.14	4.09 ± 0.13	0.114
Castelli Risk Index II	2.63 ± 0.16	2.42 ± 0.15	2.82 ± 0.12	0.104
Atherogenic Coefficient	2.63 ± 0.29	2.71 ± 0.14	3.09 ± 0.13	0.114

Values are mean ± SEM. Different superscript letters ([a], [b]) within a row indicate significant differences between trimesters based on Tukey post hoc tests ($p < 0.05$). Rows without superscripts had no significant pairwise differences.

Table 4.6: Correlation Between Atherogenic Index of Plasma (AIP) and Lipid Parameters in Each Trimester

Trimester	Parameter	r (Pearson)	p-value
1st	TG	0.76	<0.001
	HDL	0.027	0.907
	LDL	0.412	0.063
	Castelli Risk I	0.034	0.883
	Castelli Risk II	0.454	0.039
	Atherogenic Coefficient	0.034	0.883
2nd	TG	0.881	<0.001
	HDL	–0.043	0.816
	LDL	–0.253	0.163
	Castelli Risk I	–0.168	0.359
	Castelli Risk II	–0.172	0.346
	Atherogenic Coefficient	–0.168	0.359
3rd	TG	0.911	<0.001
	HDL	–0.641	<0.001
	LDL	–0.012	0.935
	Castelli Risk I	0.405	0.005
	Castelli Risk II	0.367	0.011
	Atherogenic Coefficient	0.405	0.005

Table 4.7: Multiple Linear Regression Analysis Predicting Atherogenic Index of Plasma (AIP)

Predictor	B	Std. Error	β (Beta)	t	p-value	Tolerance	VIF
(Constant)	0.461	0.632	—	0.73	0.467	—	—
BMI (Kg/m²)	0.01	0.006	0.31	1.54	0.127	0.231	4.326
Systolic BP	–0.001	0.014	–0.041	–0.052	0.958	0.015	66.355
Diastolic BP	–0.005	0.014	–0.281	–0.380	0.705	0.017	58.275
Trimester	0.033	0.019	0.181	1.736	0.086	0.861	1.161
Exercise	0.011	0.03	0.038	0.371	0.712	0.873	1.146
Diseases	–0.038	0.065	–0.057	–0.582	0.562	0.959	1.042
Milk/Egg	0.076	0.052	0.152	1.456	0.149	0.86	1.163
Multivitamin	0.017	0.031	0.059	0.552	0.582	0.828	1.208

B = unstandardized regression coefficient; SE B = standard error of B; β = standardized regression coefficient; Sig. = p value; Tolerance and VIF = collinearity diagnostics. Dependent variable: AIP. The overall model was not statistically significant, $R^2 = .15$, adjusted $R^2 = .07$, $F(8, 91) = 1.96$, $p = .060$.

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion of Findings

The study assessed the Atherogenic Index of Plasma (AIP) and lipid profile parameters among pregnant women in Benin City, comparing them with non-pregnant controls and further examining trimester-specific variations.

Most participants in this study were aged 20–34 years (79%), aligning with findings by Osakue and Osadolor (2017) in Benin City, who also reported that reproductive-age women dominate antenatal clinic attendance. The predominance of married women (91%) is expected in the Nigerian cultural context, where marriage is closely associated with childbearing (Okpe *et al.,* 2023). The ethnic spread, with Bini as the majority group, reflects the local demographic composition of Benin City and is consistent with other regional studies.

Nearly half of the women engaged in exercise (48%), and multivitamin use was moderate (55%). These lifestyle patterns may play a role in modulating lipid levels. For instance, Bawah *et al*. (2020) noted that antenatal supplementation could attenuate lipid abnormalities, while low exercise is linked with worsening dyslipidemia (Wahabi *et al.,* 2022). The very low prevalence of self-reported chronic diseases (5%) and absence of smoking/alcohol reflect typical antenatal clinic populations in sub-Saharan Africa.

This study found significantly higher BMI and LDL-C levels in pregnant women compared with controls, consistent with reports that pregnancy induces physiological hyperlipidemia (Sonagra *et al.,* 2014; Wang *et al.,* 2021). Elevated Castelli Risk Index II and Atherogenic Coefficient among pregnant women highlight increased atherogenic burden, which agrees with Ademi *et al*.

(2023), who reported similar dyslipidemic patterns in pregnancies complicated by preeclampsia. Interestingly, AIP was slightly lower in pregnant women compared to controls (0.36 vs. 0.42, p = 0.036). This contrasts with Bawah *et al*. (2020) and Wang *et al*. (2021), who reported a progressive rise in AIP during gestation. A possible explanation is that despite raised triglycerides, HDL-C was relatively preserved in this population, leading to lower log(TG/HDL-C). It may also reflect dietary habits (high milk/egg intake of 91%) that sustain HDL-C levels.

AIP increased progressively from the first to the third trimester, with a significant difference between early and late pregnancy. This agrees with Bawah *et al*. (2020) and Wang *et al*. (2021), who observed trimester-specific elevations in AIP driven by rising triglycerides. In our study, triglycerides rose from 103.52 mg/dL in the first trimester to 140.04 mg/dL in the third (p = 0.003), while LDL-C also peaked late in pregnancy. These findings are consistent with the physiological hyperlipidemia of pregnancy described by López-Tinoco *et al*. (2022). However, HDL-C did not show a significant decline in the third trimester in our cohort, contrasting with Wahabi *et al*. (2022), who reported lower HDL-C late in pregnancy. This preservation of HDL may explain why AIP values in this study were lower than some reported elsewhere.

As expected from its formula, AIP correlated strongly and positively with triglycerides in all trimesters (r = 0.76–0.91, p < 0.001), confirming earlier reports by Dobiásová *and* Frohlich (2001) that AIP is highly TG-dependent. In the third trimester, HDL-C showed a strong negative correlation with AIP (r = –0.641, p < 0.001), consistent with its role as the denominator in the AIP equation.

This study also found moderate correlations between AIP and Castelli Risk Indices in late pregnancy. Similar associations were documented by Ademi *et al*. (2023), who highlighted the

utility of composite indices in predicting preeclampsia risk. The weaker correlations with LDL-C and TC in our study align with Bawah *et al*. (2020), who noted that AIP captures risk independent of traditional cholesterol measures.

The regression model did not identify trimester, BMI, blood pressure, or lifestyle factors as independent predictors of AIP. The lack of significance (Adjusted $R^2 = 0.07$, $p = 0.060$) suggests that AIP in this cohort was mainly determined by its intrinsic components (TG and HDL-C), rather than external maternal factors. This differs from Zheng *et al*. (2022), who reported that first-trimester AIP predicted gestational diabetes, and from Retnakaran *et al*. (2021), who linked maternal BMI with AIP. The discrepancy may be due to sample size, low prevalence of chronic disease, and generally preserved HDL-C in this study population.

Taken together, the findings confirm that pregnancy in Benin City is associated with the expected physiological rise in triglycerides and LDL-C, and a trimester-specific rise in AIP, especially in the third trimester. However, AIP levels were lower overall compared to controls and to values reported in some other populations, possibly reflecting dietary and lifestyle factors unique to this cohort. While the regression analysis did not show strong external predictors, the strong TG- and HDL-driven correlations highlight AIP's potential utility as a risk marker, as suggested by earlier works (Bawah *et al.,* 2020; Ademi *et al.,* 2023).

5.2 Conclusion

This study evaluated the Atherogenic Index of Plasma (AIP) and lipid profile variations among pregnant women across the three trimesters in Benin City, Nigeria, to assess trimester-specific cardiovascular risk patterns. The findings demonstrated that pregnancy is associated with significant physiological increases in triglycerides, LDL-C, body weight, and BMI, with the most

pronounced elevations observed in the third trimester. These changes are consistent with the physiological hyperlipidemia of pregnancy reported in previous studies.

AIP increased progressively with advancing gestation, reaching its highest values in the third trimester. Strong positive correlations between AIP and triglycerides, and negative correlations with HDL-C, underscore the role of these lipids in shaping atherogenic risk during pregnancy. However, unlike some global studies, overall AIP values in this population were slightly lower than in controls, possibly reflecting preserved HDL-C levels and dietary factors such as high milk/egg consumption.

The multiple regression analysis showed that maternal characteristics such as BMI, blood pressure, lifestyle factors, and trimester did not independently predict AIP, suggesting that AIP is largely determined by its intrinsic components. Nonetheless, the trimester-specific rise in AIP highlights late pregnancy as the period of greatest atherogenic risk.

These findings provide important baseline data for Benin City and contribute to the limited regional evidence on maternal lipid metabolism and cardiovascular risk during pregnancy.

5.3 Recommendations

1. Clinical Practice:

    a. Routine monitoring of lipid profiles, particularly triglycerides and HDL-C, should be incorporated into antenatal care, especially in the second and third trimesters, to identify women at increased cardiovascular risk.

    b. AIP can serve as a simple, low-cost screening tool for early detection of high atherogenic risk, complementing traditional lipid parameters.

2. Public Health and Nutrition:

    a. Nutrition education should emphasize balanced diets rich in unsaturated fats, fruits, and vegetables to help maintain healthy lipid levels during pregnancy.

    b. Encouragement of safe physical activity in pregnancy may support better lipid control and overall cardiovascular health.

3. Policy and Antenatal Guidelines:

    a. Integration of atherogenic risk assessment (including AIP and lipid ratios) into national antenatal screening protocols may help prevent complications such as preeclampsia and gestational diabetes.

4. Future Research:

    a. Larger, longitudinal studies are recommended to confirm these trimester-specific trends and explore the predictive value of AIP for adverse pregnancy outcomes in Nigerian populations.

    b. Further research should assess the long-term cardiovascular implications for both mothers and offspring exposed to gestational dyslipidemia.

5.4 Findings

1. Triglycerides (TG) rise markedly with advancing trimester (biggest increase by 2nd–3rd trimester).

2. Total cholesterol (TC) and LDL also increase across trimesters, while HDL may fall or show smaller increases depending on the cohort.

3. Dyslipidaemia (abnormal lipid patterns) is more pronounced in hypertensive disorders of pregnancy (preeclampsia / PIH).

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APPENDIX I

QUESTIONNAIRE

RESEARCH STUDY: Atherogenic Index of Plasma (AIP) and Lipid Profile of Pregnant Women according to their Trimester in Benin City

Dear Sir/Ma

The researcher is an undergraduate of the Medical Laboratory Science, School of Basic Medical Sciences, University of Benin, researching the topic stated above in partial fulfillment of the requirements for the award of the Bachelor of Medical Laboratory Science (B.MLS) degree.

Could you please spare your time to fill out this questionnaire? The information acquired from this research will be treated with utmost confidentiality.

GENERAL INSTRUCTION FOR PARTICIPANTS:

Do not write personal details not asked (name, address, phone number, etc). The information obtained from this questionnaire will be used for the research and demographic study for the topic "Lipid profile level in pregnant women according to their trimester in Benin City. Amongst Apparently Healthy Individuals in Benin City, hence you must be truthful as much as possible. Tick [✓] when appropriate in the boxes.

Title: Lipid Profile Level in Pregnant Women According to Their Trimesters in Benin City

Purpose: To collect relevant demographic, clinical, lifestyle, and dietary data from pregnant women in order to assess associations with lipid profile variations across trimesters.

SECTION A: DEMOGRAPHIC INFORMATION

SECTION A: Socio-Demographic Data

1. Age: _____ years

2. Occupation: _____

3. Level of education:

☐ No formal education ☐ Primary ☐ Secondary ☐ Tertiary

4. Marital status:

☐ Single ☐ Married ☐ Divorced ☐ Widowed

5. Ethnicity: _____

6. Religion:

☐ Christianity ☐ Islam ☐ Traditional ☐ Other: _____

SECTION B: Obstetric and Medical History

7. What trimester of pregnancy are you currently in?

☐ First trimester (1–13 weeks)

☐ Second trimester (14–26 weeks)

☐ Third trimester (27–40 weeks)

8. Gestational age (in weeks): _____ weeks

9. Is this your first pregnancy?

☐ Yes ☐ No

10. How many pregnancies have you had (including current)? _____

11. Any history of miscarriage or pregnancy complications in the past?

☐ Yes ☐ No

If yes, please specify: _____

12. Have you ever been diagnosed with any of the following (before or during pregnancy)?

Hypertension: ☐ Yes ☐ No

Diabetes: ☐ Yes ☐ No

Hyperlipidemia: ☐ Yes ☐ No

Thyroid disorder: ☐ Yes ☐ No

Obesity: ☐ Yes ☐ No

13. Family history of any of the following (parents/siblings):

Hypertension: ☐ Yes ☐ No

Diabetes: ☐ Yes ☐ No

High cholesterol: ☐ Yes ☐ No

SECTION C: Lifestyle and Behavioral Factors

14. Do you smoke cigarettes?

☐ Never ☐ Occasionally ☐ Frequently ☐ Former smoker

15. Do you take alcohol?

☐ Never ☐ Occasionally ☐ Frequently

16. Do you engage in any form of physical activity or exercise?

☐ Yes ☐ No

If yes, specify type and frequency: _____

17. Do you use any herbal remedies or supplements during pregnancy?

☐ Yes ☐ No

If yes, list them: _____

SECTION D: Dietary Habits

18. How many meals do you eat per day?

☐ One ☐ Two ☐ Three ☐ More than three

19. How often do you eat fried or fatty foods (meat pies, fried plantains, fast food, etc.)?

☐ Daily ☐ 2–3 times a week ☐ Rarely ☐ Never

20. How often do you consume the following food items?

| Food Item | Daily | 2–3x/week | Rarely | Never | |---|---|---|---|---| | Eggs | ☐ | ☐ | ☐ | ☐ | | Red meat | ☐ | ☐ | ☐ | ☐ | | Fish (especially oily fish) | ☐ | ☐ | ☐ | ☐ | | Milk/dairy products | ☐ | ☐ | ☐ | ☐ | | Fruits *and* vegetables | ☐ | ☐ | ☐ | ☐ | | Soft drinks/sweetened beverages | ☐ | ☐ | ☐ | ☐ |

21. Do you take prenatal vitamins or prescribed medications regularly?

☐ Yes ☐ No

If yes, list them: _____

SECTION E: Anthropometric Data (To be filled by researcher/health worker)

22. Weight (kg): _____

23. Height (cm): _____

24. Body Mass Index (BMI): _____ (calculated as weight in kg ÷ height in m^2)

25. Blood Pressure (mmHg): _____

26. Fasting duration before blood draw (hours): _____

SECTION F: Laboratory Results (To be filled post-analysis)

27. Total Cholesterol (mg/dL): _____

28. Triglycerides (mg/dL): _____

29. HDL-C (mg/dL): _____

30. LDL-C (mg/dL): _____

31. Interpretation:

☐ Normal

☐ Borderline high

☐ High

(Based on trimester-specific or general reference ranges)

Thank you for your participation!

APPENDIX II

EDO STATE MINISTRY OF HEALTH
HEALTH RESEARCH ETHICS COMMITTEE

PROTOCOL NUMBER	**HA/737/25/D/07110775 (PLEASE QUOTE IN ALL ENQUIRIES)**
APPROVAL NUMBER	**HA/737/25/D/09080775**
TITLE OF RESEARCH PROPOSAL	**ATHEROGENIC INDEX OF PLASMA (AIP) AND LIPID PROFILE OF PREGNANT WOMEN ACCORDING TO THEIR TRIMESTER IN BENIN CITY**
PRINCIPAL INVESTIGATOR (S)	**FAGBAYIDE DAVID AYOMIPOSI**
DATE CONSIDERED	**8TH SEPTEMBER, 2025.**
DECISION OF THE COMMITTEE	**APPROVED**

THIS APPROVAL DATES 08/09/2025 TO 08/09/2026. IF THERE IS A DELAY IN STARTING THE RESEARCH, PLEASE INFORM THE HREC EDO SMoH SO THAT THE DATES OF APPROVAL CAN BE ADJUSTED ACCORDINGLY

REMARK: Please kindly note that the HREC Edo SMoH seal authenticates this approval

DR (MRS) Omonyemen B. BELLO
(MBBS, MPH, FPHCM) *(CHAIRMAN)* **SIGNATURE & DATE**.....9/9/25.....

SUPERVISOR(S) ..PROF. B. I. G. ADEJUMO.....

.....

ATTESTATION BY INVESTIGATOR(S)

No participant accrual or activity related to this research may be conducted outside of the approval dates. All informed consent forms used in this study must carry the Edo SMoH HREC-assigned number and duration of your research. No changes are permitted in the research without prior approval of the Edo SMoH HREC except in circumstances outlined in the Code. The Edo SMoH HREC reserves the right to conduct compliance visits to your research site without previous notification.

EDO STATE MINISTRY OF HEALTH SECRETARIAT DATE 8/9/25 SIGN DATE 9/9/25 RESEARCH & ETHI... COMMITTEE

Signature & Date.....21/9/25.

edohrec@edostate.gov.ng

Room 16, Block D, 2nd floor, State secetariat building.

APPENDIX III

Title of research: ATHEROGENIC INDEX OF PLASMA (AIP) and LIPID PROFILE OF PREGNANT WOMEN ACCORDING TO THIER TRIMESTER IN BENIN CITY

Name of principal investigator:

FAGBAYIDE DAVID AYOMIPOSI

Phone Number: 08124294513

Name of supervisor:

PROF. B. I. G. ADEJUMO

Phone Number: 08165038080

Institution and Contact Address: Department of Medical Laboratory Science, School of Basic Medical Sciences, University of Benin, Benin City.

Phone Number: 07025063106

Email: ayomipodavido3412@gmail.com

Commencement Date of Research: June 2025

Proposed Duration of Research: 3months

Financial Sponsors: Parents and self

Conflict of Interest: None declared

Purpose of Research:

The study aims to investigate the lipid profile levels in pregnant women attending antenatal clinics in Benin City, stratified according to their trimesters, to provide data that may inform both clinical practice and future policy decisions in maternal health care.

Estimated Number of Participants: Sample size calculation shall be used to obtain the needed number of subjects whose samples shall be collected

Procedure Involved in the Study: Questionnaires and oral interview will be used for data collection and while blood sample will be used for biochemical investigation.

Research Design and Methods: The study is case control study.

Risks to Participants: No risk envisaged aside the slight discomfort while collecting blood sample from participant's antecubital vein.

Benefits to Participants: No benefit (voluntary participation), however, if there is any abnormality found after testing, the subjects will be assisted to consult a specialist at no cost.

Compensation/ Inducement: None

Statement of Voluntariness and Circumstances for Withdrawal: Participants are allowed to withdraw from the research at any stage, and the withdrawal will have no adverse effect on the sujects in any form.

Statement on Use of Personal Data: Personal data shall be stored permanently with the research coordinator / principal investigator for further research purposes and no more than such.

Statement on Confidentiality: Strict and absolute confidentiality is guaranteed. Information of the patients obtained from this study/research will be stored in my personal pass worded computer.

Measures To Take Care of Research-Related Injuries: Full personal protective equipment (PPE) wears / kits shall be provided to present research related injuries and there shall be provision of a standby vehicle in cases of any emergency.

I Have Fully Explained This Research to The Participant(s) and Have Given Sufficient Information, Including information about the Risks and Benefits, to make an Informed Decision.

Signature /Date:

NAME: PROF. B.I.G ADEJUMO

Witness' Name / Signature *and* Date (If any):

FAGBAYIDE DAVID AYOMIPOSI

CONTACT (Any of the Researchers): PROFESSOR B.I.G ADEJUMO (Supervisor)

If You have any Question about Your Participation in this Research, You can Contact the Principal Investigator. The Address is Department of Medical Laboratory Science (Chemical Pathology Unit), School of Basic Medical Sciences, College of Medical Sciences, University of Benin, Benin City; Edo State, Nigeria.

Email:

Phone Number: 08165038080

STATEMENT FROM PARTICIPANT(S)

I have Read the Description of the Research or have had it Translated to my Understanding. I have also Talked it over with the Researcher to my Satisfaction. I Understand that my Participation is Voluntary. I know enough about the Purpose, Methods, Risks, and Benefits of the Research Study to Judge that I want to take Part in it. I also understand that I may freely stop being Part of this Study at any Time if I so wish for any Reasons Best known to me. I have Received a Copy of this Consent Form and Additional Information Sheet to keep for myself.

Participant's Signature / Thumb Print: ----------**Date**: ----------

Participant's Name / Or Number (If Applicable): ----------

Witness' Signature (if any): ----------**Date**: ----------

Witness' Name (If Applicable): ----------

PLEASE KEEP A COPY OF OF THE SIGNED INFORMED CONSENT

For Official Use Only

Director, Edo State Ministry of Health Approval Number: **HA/737/25/D/09080775**

Director, Edo State Ministry of Health PROTOCOL Number: **HA/737/25/D/07110775**

Commencement Date of Research (dd/mm/yy): ----------

This Research has been approved by Director, Edo State Ministry of Health and the Chair of the Committee can be contacted on:

_____

_____

_____