DOI: https://doi.org/10.4314/njbmb.v40i1.12 NJBMB (2025) 40(1) 90-95

Nigerian Journal of Biochemistry and Molecular Biology

The Official Publication of the Nigerian Society of Biochemistry & Molecular Biology (NSBMB). Journal homepage: https://www.nsbmb.org.ng/journals/

e-ISSN: 2659-0042

Research Article

Association of Maternal Lipid Profile, Nutritional Status, and Gestational Diabetes Mellitus in Pregnant Women Attending General Hospital, Dutse, Jigawa State, Nigeria

Hadiza Abubakar[1,*], Danladi A. Ameh[1], Ismaila A. Umar[1].

[1] *Department of Biochemistry, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria*

OPEN ACCESS

***CORRESPONDENCE**
Abubakar, H.
hadizaabubakar378@gmail.com

ARTICLE HISTORY
Received: 08/04/2025
Reviewed: 28/08/2025
Revised: 12/09/2025
Accepted: 02/10/2025
Published: 31/10/2025

CITATION
Abubakar H., Ameh D. A. and Umar I.A(2025). Association of maternal lipid profile, nutritional status, and gestational diabetes mellitus in pregnant women attending general hospital, Dutse, Jigawa state, Nigeria. *Nigerian Journal of Biochemistry and Molecular Biology*. 40(1), 90-95, https://doi.org/10.4314/njbmb.v40i1.12

ABSTRACT

Gestational Diabetes is one of the most prevalent metabolic disorder during pregnancy that affects about 25% of pregnancies in some countries and associated with changes in lipid profile of pregnant women. This study analyzes the changes in lipid profile in patients with GDM. An oral glucose tolerance test (OGTT) was used to determine the existence of GDM among the study participants. Serum iron, zinc, calcium, albumin and lipid profile markers including total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) were determined. The study revealed elevated levels of TC (80.0% high TC as against 2.2% with normal TC), TG (41.4% high TG as against 2.3% with normal TG), HDL (55.6% high HDL as against 7.1% with normal HDL), and LDL (91.7% high LDL as against 4.2% with normal LDL) in patients with GDM. The participants demonstrated variations in key health indicators, with mid-upper arm circumference (MUAC) (69.6%) and albumin (71.7%) within the normal range. The calcium (2.22 mmol/l) level slightly exceeded the normal range. However, iron (117.76mg/dl) and zinc (77.00 mg/dl) levels remained within normal levels. The study underscored relationships between lipid profile, zinc, albumin and GDM status ($p<0.05$). Conclusively, pregnancies affected by GDM are characterized by dyslipidaemia, thus advanced lipid testing may indicate disturbed lipid homeostasis in GDM.

Keywords: *Diabetes, Gestational Diabetes, Hyperglycemia, Pregnancy, Metabolic Diseases*

INTRODUCTION

Gestational Diabetes Mellitus (GDM) is the most prevalent metabolic disorder during pregnancy, however, the association between dyslipidaemia and GDM remains unclear. GDM occurs by the increased severity of insulin resistance as well as an impairment of the compensatory increase in insulin secretion during pregnancy. It causes a diverse range of adverse maternal and neonatal outcomes and it is a threat to maternal and child health (Muche et al., 2019). Women diagnosed with GDM experience higher rates of gestational hypertension and pre-eclampsia, pre-term delivery, caesarean section, and later, type 2 diabetes. Adverse maternal and infant outcomes are directly related to maternal hyperglycaemia as reported by "Hyperglycaemia and Adverse Pregnancy Outcomes (HAPO)" trial and the Indian Gestational Diabetes Prevention and Control Project (Stewart, 2019). Screening for GDM is usually done at 24-28 weeks of gestation because insulin resistance increases during the second trimester and glucose levels rise in women who do not have the ability to produce enough insulin to adapt to this resistance (Reddi -Rani and Begum, 2016).

However, the prevalence of gestational diabetes is increasing worldwide and is estimated to affect more than 20 million live births (about one in six) (Saravanan et al., 2020). The global prevalence of GDM varies widely from 1-28% depending on population characteristics, screening methods, and diagnostic criteria (Azeez et al., 2021). Development of GDM, on the other hand, indicates a severe disorder of glucose metabolism, and it is therefore associated with an increased risk of complications for both mother and newborn (Kampmann et al., 2019).

Among others, women with GDM are at higher risk of hypertensive disorders of pregnancy, such as preeclampsia or eclampsia (Benhalima et al., 2019). Alterations of lipid profile during the course of normal pregnancy are transient and include increase in triglycerides (TG), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) levels (Born and Adeli, 2022; Yang and Wu, 2022). Since glucose metabolism disorders are intimately associated with dyslipidaemia, impaired glucose tolerance in GDM further affects lipoprotein metabolism. Evidence suggests that the increase in pro-atherogenic lipid parameters, predominantly TG level, is more prominent in early pregnancy of women who developed GDM, as compared to controls, while the data for LDL-C concentration are less conclusive (Habibi et al., 2022).

In addition, GDM is characterized by changes of apolipoproteins levels. Recently, it has been demonstrated that serum and placental levels of apolipoprotein E (apoE) were decreased in pregnant women with GDM, and that this apolipoprotein's concentrations negatively correlated with oxidative stress parameters in GDM (Li et al., 2022).Moreover, GDM is also a serious concern for many systems with increasing use of health and care resources and adverse outcomes, many of which can be mitigated by early diagnosis and treatment (Hodet al., 2015). GDM is associated with physiological changes in the lipid profile of pregnant women (Wang et al., 2019). The lipid profile is a direct measure of total cholesterol (TC), TG, HDL-C, LDL-C, and very low-density lipoprotein cholesterol (VLDL-C) (Antwi-Baffour et al., 2018). During early pregnancy, the increase in maternal fat depots is facilitated by insulin, followed by increased adipose tissue breakdown, and subsequent hypertriglyceridemia, mainly due to insulin resistance and estrogen effects (Herrera and Desoye, 2016). It is known that many factors affect lipid levels in GDM because carbohydrate metabolism directly affects lipid metabolism. There is still controversy over the association between lipid profile and GDM (Aghaie et al., 2018). Although lipid levels have been extensively studied during pregnancy, there are conflicting results in this regard. There are also few studies on whether fat patterns are different in women with GDM in the first trimester of pregnancy (Wang et al., 2019). Since changes in fat metabolism during pregnancy can be associated with adverse pregnancy outcomes such as GDM, therefore, this study aimed to investigate the association of lipid profile, nutritional status and GDM in pregnant women attending General Hospital, Dutse, Jigawa state, Nigeria.

MATERIALS AND METHODS

Study participants

This study enrolled 120 pregnant women attending antenatal care at General Hospital, Dutse, Jigawa State. Initially, about 25 pregnant women were selected on each booking day (Tuesdays and Thursdays) for 5 weeks and a total of 120 pregnant women were recruited. Maternal characteristics, general obstetrics and medical history were assessed through a semi-structured questionnaire. The participants were informed in detail about the aim and protocol of the study, which was approved by the Ahmadu Bello University Committee on Use of Human Subjects for Research (ABUCUHSR) (Approval Number: ABUCUHSR/2023/002) and Jigawa State Health Research Ethics Committee (Research Committee Assigned Number: JGHREC/2023/151). Participants' data were also protected. Helsinki Declaration of using human participants was followed accordingly. Informed consent was sought from the pregnant women and the Hospital Management before inclusion into the study.

Study design

This study was designed as a cross-sectional study. Simple random sampling was used for selection; targeting pregnant women at 24-28 weeks of gestation visiting the antenatal care unit, General Hospital, Dutse, Jigawa State. Dutse (Latitude: 11° 43' 59.99" N Longitude: 9° 17' 15.00" E) is a city located in North Western Nigeria. It is the capital city of Jigawa State, Nigeria.

Blood collection and oral glucose tolerance test (OGTT)

Blood samples were obtained using standard procedures as reported by Oguizu (2015). Exactly 5ml of venous blood was collected and transferred into plain bottles. The blood was allowed to clot and centrifuged for 15 minutes at 3000 rpm and the serum was collected and stored at -20^{0}C for subsequent assays. An oral glucose tolerance test (OGTT) was used to determine the existence of gestational diabetes. Blood glucose level was measured at specific time intervals by the use of glucometer using Accu-check glucose strips. The interpretation of the OGTT according to International Association of Diabetes and Pregnancy Study Group (IADPSG) guidelines is that pregnant women are considered to have GDM if fasting blood glucose is ⩾92 mg/dl (5.1 mmol/l), 1hblood glucose is ⩾180 mg/dl (10 mmol/l), and/or 2h blood glucose is ⩾153 mg/dL (⩾8.5 mmol/L).

Analysis of lipid profile and biochemical parameters

Total cholesterol (TC) (Allain *et al.,* 1974), tryglycerides (TG) (Jacobs and VanDemark, 1960), high-density lipoprotein cholesterol (HDL) (Allain *et al.,* 1974), low-density lipoprotein cholesterol (Friedwald *et al.,* 1972) and very low-density lipoprotein (Crook, 2006) were determined using Randox reagent kit. Serum albumin(Doumas *et al.,* 1972), calcium (Clark *et al.,* 1974), zinc, and iron(Makino *et al.,* 1988) were determined using bromocresol-green (BCG) method, O-cresolphtalein complexone (CPC) method, 2- (5-Bromo-2-pyridylazo)-5-(N-Propyl- N-sulfopropylamino) phenol (5-Br-PAPS) method and commercial Centronic GmbH assay kits, respectively. Mid-upper arm circumference (MUAC) measurement was obtained using the guidelines as described in the Food and Nutrition Technical Assistance Guide (Cogill, 2003).

Data analysis

Data collected were stored, managed, and analyzed using SPSS version 25.0 and Microsoft excel. Frequency, percentage and mean ± standard deviation were used to present the data. Chi square test was used to determine the relationship between variables. P < 0.05 was considered statistically significant.

RESULTS

Data from this study shows that pregnant women that were diagnosed with gestational diabestes mellitus (GDM) have higher fasting blood glucose (FBG)(83.46±18.76 mg/dL) than those not having GDM (72.62±14.00).

The TC, TG, HDL, LDL, VLDL levels and atherogenic index (AI) were significantly (P <0.05) higher in patients with GDM compared with patients without GDM (Table 1)

The majority (75%) of the pregnant women had normal tTC level, while 25% had high TC level. About 51.7% of the women had normal TG level, while 48.3% had high TG level. In addition, 70% of the women had normal HDL level, while 30% had low HDL level. Furthermore, 80% of the women had normal LDL level, while 20% had high LDL level. Moreover, 91.7% of the women had normal VLDL level, 8.2% had low VLDL level and 0.1% had low VLDL. Finally, 61.8% of the women had low AI, 23.6% had medium AI and 14.5% had high AI (Figure 1).

Table 1. Lipid Profile of the Pregnant Women Attending General Hospital, Dutse, Nigeria.

Parameter (mmol/l)	GDM(Positive)	GDM(Negative)	P-Value
TC	6.4 ± 0.5	4.2 ± 0.8	0.0001*
TG	2.2 ± 0.3	1.6 ± 0.4	0.026*
HDL	1.1 ± 0.2	1.7 ± 0.3	0.032*
LDL	4.2 ± 0.62	1.7 ± 0.7	0.0001*
VLDL	1.0 ± 0.2	0.7 ± 0.2	0.015*
AI	0.3 ± 0.1	-0.3 ± 0.02	0.0001*

Values are expressed as means ± SD. *Significant at p<0.05(Independent t-test comparing GDM and Non GDM women). n=120

TC: Total cholesterol, TG: Total triglycerides, LDL:Low density lipoprotein cholesterol, HDL:High density lipoprotein cholesterol, VLDL:Very low-density lipoprotein cholesterol, AI: Atherogenic index 1

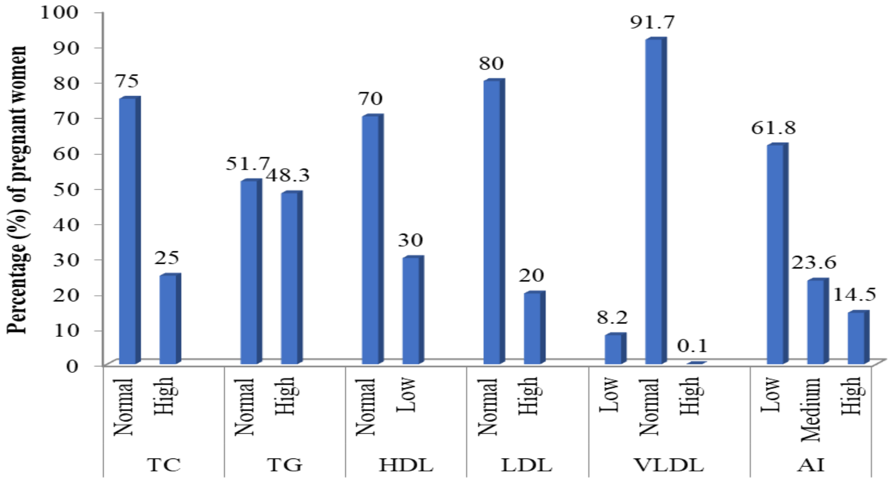

Figure 1: Percentage Distribution of Lipid Profile of Pregnant Women Attending General Hospital, Dutse, Jigawa State, Nigeria
Values are expressed as percentages of pregnant women with low or high levels of lipid profile parameters

A significantly (p<0.05) higher percentage of women with GDM had high levels of TC, TG, and LDL and low level of HDL compared to those without GDM. In particular, 80% of women with GDM had high level of TC, while only 20% of those without GDM had high level. Similarly, 41.4% of women with GDM had high level of TG, while only 34% of those without GDM had high level. Also, 91.7% of women with GDM had high level of LDL, while only 8.3% of those without GDM had high level. On the other hand, a significantly (p<0.05) higher percentage of women without GDM had normal levels of HDL and VLDL compared to those with GDM. Fifty percent of the pregnant women with GDM had high risk of dyslipidemia, 38.5% had medium risk while 12.5% had low risk based on the atherogenic index.

Table 2: Relationships between GDM Status and Lipid Profile of the Pregnant Women Attending General Hospital Dutse, Nigeria.

Variables		GDM	No GDM	Chi-square (p-value)
		n (%)		
TC	Normal	2(2.2)	88(97.8)	0.002*
	High**	24(80)	6(20)	
TG	Normal	2(3.2)	60(96.8)	0.001*
	High**	24(41.4)	34(58.6)	
HDL	Normal	6(7.1)	78(92.9)	0.042*
	Low**	20(55.6)	16(44.4)	
LDL	Normal	4(4.2)	92(95.8)	0.002*
	High	22(91.7)	2(8.3)	
VLDL	Low	2(20)	8(80)	0.894
	Normal	24(21.8)	86(78.2)	
AI	Low	3(12.5)	65(50.0)	0.01*
	Medium	10(38.5)	16(61.5)	
	High**	13(50.0)	13(87.5)	

*Significant at p<0.05(chi-square test)** At risk of dyslipidemia. TC: Total cholesterol, TG: Total triglycerides, LDL: Low density lipoprotein cholesterol, HDL: High density lipoprotein cholesterol, VLDL: Very low-density lipoproteincholesterol, AI: Atherogenic index.

The mid-upper arm circumference (MUAC), calcium and iron levels of pregnant women with GDM were insignificantly (p>0.05) reduced compared to the pregnant women without GDM. However, albumin and zinc levels of pregnant women with GDM were significantly (p<0.05) elevated compared to the pregnant women without GDM (Table 3).

Figure 2 shows that 71.7% of women had a normal albumin level (3.1-5.1 g/dL), while 28.3% had hypoalbuminemia (less than 3.1 g/dL). About two-third (69.5%) of women had a normal MUAC (>22cm), while 28.8% were classified as mildly to moderately undernourished (MUAC 19cm-22cm), and only 1.7% were classified as severely undernourished (MUAC <19cm).

Table 3: Relationships between GDM Status, Mid-upper arm Circumference and Biochemical Parameters of the Pregnant Women Attending General Hospital, Dutse, Nigeria.

	GDM	No GDM	p-value
MUAC (cm)	23.85 ± 2.93	23.86 ± 2.77	0.84
Albumin (g/dl)	2.95 ± 0.24	3.67 ± 0.39	0.038*
Calcium (mmol/l)	1.99 ± 0.29	2.28 ± 0.32	0.883
Iron (mg/dL)	102.58±10.12	122.00 ± 9.57	0.726
Zinc(μg/dl)	63.48 ± 4.61	80.77 ± 4.35	0.008*

*Significant at p<0.05(Independent t-test comparing GDM and Non GDM women).

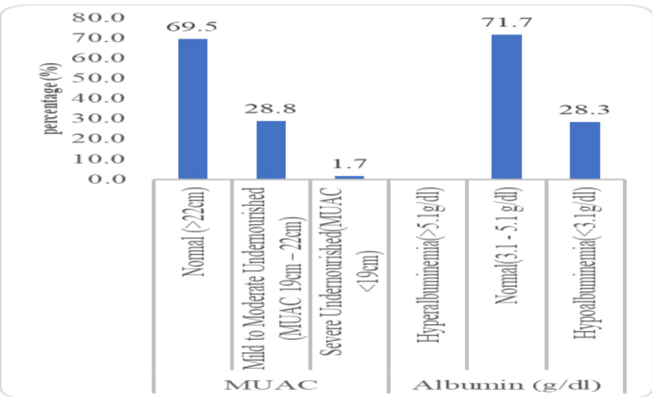

Figure 2: MUAC and Albumin Status of Pregnant Women Attending General Hospital Dutse, Jigawa State, Nigeria.

DISCUSSION

GDM is one of the leading pregnancy complications with possible adverse effects on pregnancy outcome, but also on long-term cardiometabolic health of both mother and child (Yang *et al.,* 2021). It is well known that metabolic adaptation to pregnancy is associated with the development of insulin resistance to ensure an adequate fetal supply of glucose. Hypertriglyceridemia is a common consequence of insulin resistance, but this relationship is bi-directional, since the evidence accumulated suggested that dyslipidemia can contribute to insulin resistance development as well (Li *et al.,* 2014).

GDM is associated with physiological changes in the lipid profile of pregnant women. It is known that many factors affect lipid levels in GDM because carbohydrate metabolism directly affects lipid metabolism. The lipid profile indicators in this study were total cholesterol (TC), triglycerides (TG), high density lipoproteins (HDL), low density lipoproteins (LDL) and very low-density lipoproteins (VLDL) and atherogenic index (AI). Compared to other studies, Adegbija and Adegbija (2020) in Nigeria reported similar results, where the prevalence of hypercholesterolemia in pregnant women was 26.4%. Another study by Alavi*et al.* (2018) reported in Iran that 42.5% of pregnant women had elevated serum triglyceride level. This is higher than the percentage found in this study. Furthermore, a study by Celik *et al.* (2015) reported a prevalence of low HDL cholesterol of 12.7% in Turkey, lower than the rate found in this study. This difference may be due to differences in study populations, dietary habits, and lifestyle factors. Relationships with lipid profiles from the present study indicate that a significantly higher percentage of women with GDM had elevated levels of TC, TG, and LDL compared to women without GDM. On the other hand, a proportion of women without GDM had normal HDL levels compared to women with GDM. These results are consistent with previous studies that showed a positive association between GDM and an unfavorable lipid profile, including high TC, TG, LDL and low HDL levels (Mirzamoradi *et al.,* 2017; Farren *et al.,* 2019; Elsayed *et al.,* 2021). Elevated lipid levels during pregnancy are associated with an increased risk of adverse pregnancy outcomes such as preeclampsia, prematurity, and fetal growth restriction (Farren *et al.,* 2019). Therefore, monitoring and treating lipid levels in pregnant women with GDM may be necessary to reduce the risk of adverse pregnancy outcomes.

Pregnancy outcome in women with GDM is affected by many indices. One of the vital indices in assessing this outcome is the nutritional status of a pregnant woman. Generally, the nutritional status of pregnant women with GDM is low. The average calcium level observed in this study was low when compared with the normal range for pregnant women. Adequate calcium intake during pregnancy is important in improving fetal bone development and preventing maternal bone loss.

The average iron level observed was within the normal range for pregnant women and this may be due to the fact that pregnant women that attend antennal clinics are placed on iron supplements. The mean zinc level observed in this study was also within the normal range (70-120µg/dl) for pregnant women. Adequate zinc intake is important for fetal growth and development during pregnancy, and deficiency can lead to undesirable consequences such as low birth weight and impaired immune function. This study is consistent with previous studies using MUAC and albumin as indicators of nutritional status in pregnant women. Kumar *et al.* (2016) reported that majority of the pregnant women in their study were having normal MUAC status. In the present study, a significant percentage of the pregnant women were mild to moderately malnourished. This could be as result of their low dietary diversity as observed in an earlier study (unpublished data). This result suggests that there may be regional differences in the prevalence of malnutrition and undernutrition in pregnant women. Interventions to improve maternal nutrition, such as dietary diversification and fortification, may be necessary to reduce the prevalence of malnutrition and improve pregnancy outcomes in these populations.

CONCLUSION

In conclusion, the results presented herein demonstrated variations in lipid profile in pregnancies affected by GDM. Serum levels of albumin and Zinc are significantly lower in women with GDM. This study shows the relationship between GDM, MUAC, and the analysed biochemical parameters.

Data availability

The laboratory data used to support the findings of this study are available from the corresponding author upon request.

AUTHORS' CONTRIBUTIONS

Conceptualization, Hadiza Abubakar, Prof. I.A. Umar and Prof. D.A Ameh; methodology, Hadiza Abubakar and Prof. I.A. Umar; validation, Prof. I.A. Umar and Prof. D.A Ameh; formal analysis, Hadiza Abubakar; investigation, Hadiza Abubakar; resources, Hadiza Abubakar; data curation, Hadiza Abubakar and Prof. I.A. Umar; writing—original draft preparation, Hadiza Abubakar; writing—review and editing, Prof. I.A. Umar and Prof. D.A Ameh; supervision, Prof. I.A. Umar and Prof. D.A Ameh; project administration, Hadiza Abubakar, funding acquisition, Hadiza Abubakar.All authors have read and agreed to the published version of the manuscript.

FUNDING STATEMENT

Funding for the research was strictly private.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGEMENT

We specially thank the participants, management of General Hospital Dutse, and the entire Ahmadu Bello University community for their support throughout the period this study was conducted.

REFERENCES

Adegbija, O. E., and Adegbija, O. J. (2020). Evaluation of Lipid Profile and Cardiometabolic Risk among Pregnant Women Attending Antenatal Clinics in Osogbo, Nigeria. *Nigerian Medical Journal*, 61(3): 125.

Aghaie, Z., Hajian, S. and Abdi, F. (2018). The relationship between lipid profiles in pregnancy and preterm delivery: A systematic review. *Biomedical Research and Therapy*, 5(8):2590–609. [Google Scholar]

Alavi, N. M., Alijahan, R., and Ahmadi, M. (2018). Prevalence of dyslipidemia in Iranian pregnant women: a systematic review and meta-analysis. *BMC Pregnancy and Childbirth*, 18(1):1-13.

Allain, C. C., Poon, L. S., Chan, C. S., Richmond, W. F. P. C., and Fu, P. C. (1974). Enzymatic determination of total serum cholesterol. *Clinical Chemistry*, 20(4): 470-475.

Antwi-Baffour, S., Kyeremeh, R., Boateng, S.O., Annison, L. and Seidu, M.A. (2018). Haematological parameters and lipid profile abnormalities among patients with Type-2 diabetes mellitus in Ghana. *Lipids in health and Disease*, 17(1):1–9.

Azeez, T. A., Briggs, T. A., and Adeyanju, A. S. (2021). A systematic review and meta - analysis of the prevalence and determinants of gestational diabetes mellitus in Nigeria. *The New Indian Journal of OBGYN,*9(2): 194-203. doi.org/10.21276/0bgyn.2023.9.2.2

Benhalima, K., Van Crombrugge, P., Moyson, C., Verhaeghe, J., Vandeginste, S., Verlaenen, H., Vercammen, C., Maes, T., Dufraimont, E. and De Block, C. (2019) Characteristics and pregnancy outcomes across gestational diabetes mellitus subtypes based on insulin resistance. *Diabetologia* 62: 2118–2128.

Bohn, M.K. Adeli, K. (2022). Physiological and metabolic adaptations in pregnancy: Importance of trimester-specific reference intervals to investigate maternal health and complications. *Critical Reviews in Clinical Laboratory Sciences*, 59: 76–92.

Celik, H., Avci, E. M., Atalay, A., and Yildirim, G. (2015). Evaluation of dyslipidemia and lipid peroxidation status in pregnant women. *International Medical Journal*, 4(1):1826-1835.

Clark, W.L, Baginski E.L, Marie S.S. and Zak B. (1974). Spectrometric study of direct determination of serum calcium. *Microchemical journal,* 20:22-32

Cogill, Bruce (2003). Anthropometric Indicators Measurement Guide. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, FHI 360.

Doumas B. T., Arends R. L. and Pinto P. C. (1972). Standard Methods of Clinical Chemistry. *Academic Press of Chicago,*7:175-189

Elsayed, E. T., Aly, H. A., Khafagy, A. A. and Elsayed, G. M. (2021). Dyslipidemia in pregnancy-induced hypertension and gestational diabetes mellitus: A pilot study. *Egyptian Journal of Basic and Applied Sciences*, 8(1): 17.

Farren, M., Daly, N., O'Higgins, A. C. and McKeating, A. (2019). The association between maternal lipids and perinatal outcomes in women with gestational diabetes mellitus (GDM). *Journal of Perinatology*, 39(11):1544-1550.

Friedewald, W. T., Levy, R. I. and Fredrickson, D. S. (1972). Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clinical Chemistry*, 18: 499–502.

Habibi, N., Mousa, A., Tay, C.T., Khomami, M.B., Patten, R.K., Andraweera, P.H., Wassie, M., Vandersluys, J., Aflatounian, A. andBianco-Miotto, T., (2022). Maternal metabolic factors and the association with gestational diabetes: A systematic review and meta-analysis. *Diabetes Metabolism Research and Review*, 38: e3532.

Herrera, E. andDesoye, G. (2016). Maternal and fetal lipid metabolism under normal and gestational diabetic conditions. *Hormone Molecular Biology and Clinical investigation*, 26(2):109–27.

Hod, M., Kapur, A., Sacks, D.A., Hadar, E., Agarwal, M. and Di Renzo, G.C. (2015). The international federation of gynecology and obstetrics (FIGO) initiative on gestational diabetes mellitus: a pragmatic guide for diagnosis, management, and care. *International Journal of Gynecology and Obstetrics,* 131: S173–211.

Homsher, R., Zak, B. (1985). Spectrophotometric investigation of sensitive complexing agents for the determination of zinc in serum. *Clinical Chemistry*, *31*(8): 1310–1313

Jacobs, N.J., and Vandemark, P.J. (1960). The purification and properties of the αglycerophosphate-oxidizing enzyme of Streptococcus faecalis 10C1. *Archives of Biochemistry and Biophysics*, 88(2): 250-255.

Kampmann, U., Knorr, S., Fuglsang, J. and Ovesen, P. (2019) Determinants of maternal insulin resistance during pregnancy: An updated overview. *Journal of Diabetes Research*, 2019, 5320156.

Kumar, N., Singh, A. K. and Rai, A. K. (2016). Dietary diversity and its relationship with nutritional status among pregnant women in Patiala, Punjab. *Indian Journal of Community Health*, 28(2):184-189.

Li, M., Hou, X., Zhang, R., Zheng, X. and Dang, W. (2022). Role of apolipoprotein E in suppressing oxidative stress in gestational diabetes mellitus patients and mouse model. *International Journal of Gynecology and Obstetrics*, 159: 204–212.

Li, N., Fu, J., Koonen, D.P., Kuivenhoven, J.A., Snieder, H. and Hofker, M.H. (2014). Are hypertriglyceridemia and low HDL causal factors in the development of insulin resistance? *Atherosclerosis*, 233: 130–138.

Makino, T., Kiyonaga, M. and Kina, K. (1988). A sensitive, direct colorimetric assay of serum iron using the chromogen, nitro-PAPS. *Clinica Chimica Acta*, 171(1): 19-27.

Mirzamoradi, M., Asemi, Z. and Esmaillzadeh, A. (2017). Soy intake, cardiometabolic risk factors and gestational diabetes. *Journal of Clinical Endocrinology and Metabolism*, 101(2): 465-472.

Muche, A. A., Olayemi, O. O. and Gete, Y. K. (2019). Prevalence and determinants of gestational diabetes mellitus in Africa based on the updated international diagnostic criteria: A systematic review and meta-analysis. *Archives of public health*, 77(36):1–20.

Oguizu, A. D. (2015). Assessment of Iron Selenium and Zinc Status of Pregnant Women in ObioAkpor Local Government Area, Rivers State. *Pakistan Journal of Nutrition*. 14(1): 1-5.

Reddi Rani, P. and Begum, J. (2016). Screening and diagnosis of gestational diabetes mellitus, where do we stand. *Journal of Clinical and Diagnostic Research*, 10(4): QE01–QE04. https://doi.org/10.7860/JCDR/2016/17588.7689

Saravanan, P., Magee, L. A., Banerjee, A., Coleman, M. A., Von Dadelszen, P., Denison, F., Farmer, A., Finer, S., Fox-Rushby, J., Holt, R., Lindsay, R. S., MacKillop, L., Maresh, M., McAuliffe, F. M., McCance, D., McCarthy, F. P., Meek, C. L., Murphy, H. R., Myers, J. and Williamson, C. (2020). Gestational diabetes: opportunities for improving maternal and child health. *The Lancet Diabetes and Endocrinology*, 8(9):793–800

Association of the atherogenic index of plasma and oxidative stress status with weight gain during non-complicated pregnancy. *Clinical Chemistry and Laboratory Medicine*, 50: 2019–2025.

Stewart, Z. A. (2019). Gestational diabetes. *Obstetrics, Gynaecology and Reproductive Medicine*, 30(3): 79–83. https://doi.org/10.1016/j.ogrm.2019.12.005.

Wang, J., Li, Z. and Lin, L. (2019). Maternal lipid profiles in women with and without gestational diabetes mellitus. *International Journal of Medicine*. 98(16):15320.

Yang, X., Leng, J., Liu, H., Wang, L., Li, W., Li, W., Yang, X., Liu, M. and Hu, G. (2021). Maternal gestational diabetes and childhood hyperlipidemia. *Diabetic Medicine*, 38: e14606.

Yang, Y. and Wu, N. (2022). Gestational diabetes mellitus and preeclampsia: Correlation and influencing factors. *Cardiovascular Medicine*, 9: 831297.