International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Comparative Evaluation of Glycosylated Haemoglobin and Lipid Profile in Gestational Diabetes Mellitus and Normoglycemic Pregnant Women

Jitendra Kumar[1], Ranjana Kumari[2]

[1]Professor and Head, Department of Biochemistry, Birsa Institute of Medical Sciences and Research, Khunti, Jiyarappa, Jharkhand (India).

[2]Deputy Chief Medical Officer (CMO), Burnpur Hospital, ISP, Steel Authority of India Limited (SAIL), Burnpur, West Bengal (India).

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Corresponding Author:

Jitendra Kumar
Professor and Head, Department of Biochemistry, Birsa Institute of Medical Sciences and Research, Khunti, Jiarapa, Jharkhand (India).
Email: jitendrarimsks@gmail.com

Received: 20-04-2026
Accepted: 10-05-2026
Available online: 13-06-2026

ABSTRACT

Background: Gestational diabetes mellitus (GDM) is a common metabolic disorder of pregnancy associated with disturbances in glucose and lipid metabolism, leading to adverse maternal and fetal outcomes. Identification of metabolic abnormalities during pregnancy may facilitate early intervention and improved disease management.

Objective: To evaluate glycated haemoglobin (HbA1c) and lipid profile parameters in women with gestational diabetes mellitus and compare them with normoglycaemic pregnant women.

Materials and Methods: This comparative case-control study was conducted in the Department of Biochemistry, Birsa Institute of Medical Sciences and Research, Khunti, Jharkhand, India. A total of 100 antenatal women in the third trimester of pregnancy were enrolled, including 50 women with GDM and 50 normoglycaemic pregnant controls. Fasting blood glucose, oral glucose tolerance test (OGTT) parameters, glycated haemoglobin (HbA1c), serum triglycerides, total cholesterol, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were assessed using standard biochemical methods. Data were analysed using Student's t-test, and a p-value <0.05 was considered statistically significant.

Results: Women with GDM exhibited significantly higher serum triglyceride levels (188.6 ± 15.2 mg/dL vs. 151.4 ± 14.1 mg/dL; $p<0.001$) and total cholesterol levels (206.8 ± 18.5 mg/dL vs. 170.2 ± 16.9 mg/dL; $p<0.001$) compared with controls. No significant differences were observed in HDL-C and LDL-C levels between the groups ($p>0.05$). Fasting blood glucose (118.4 ± 10.8 mg/dL vs. 91.2 ± 6.7 mg/dL; $p<0.001$) and 2-hour post-glucose blood glucose levels (201.6 ± 15.3 mg/dL vs. 161.8 ± 10.9 mg/dL; $p<0.001$) were significantly elevated in women with GDM. Mean HbA1c levels were also significantly higher among GDM cases ($8.24 \pm 1.18\%$) compared with controls ($5.84 \pm 0.42\%$) ($p<0.001$).

Conclusion: Gestational diabetes mellitus is associated with significant alterations in glucose metabolism and lipid profile, particularly elevated triglyceride and total cholesterol levels. Increased HbA1c levels in women with GDM reflect poor glycaemic control and may be useful for monitoring metabolic disturbances during pregnancy. Early detection and appropriate management of GDM may help reduce maternal and fetal complications.

Keywords*:* Gestational diabetes mellitus, glycated haemoglobin, HbA1c, lipid profile, triglycerides, cholesterol, oral glucose tolerance test.

INTRODUCTION

Gestational diabetes mellitus (GDM) is one of the most common metabolic disorders complicating pregnancy and has emerged as a major public health concern worldwide. Over the past few decades, the prevalence of GDM has increased considerably, largely due to rising maternal age, obesity, sedentary lifestyle, and changes in dietary habits. GDM is defined as glucose intolerance of variable severity with onset or first recognition during pregnancy, resulting in hyperglycaemia that may adversely affect both maternal and fetal outcomes [1]. Beyond abnormalities in glucose homeostasis, GDM is characterised by profound metabolic alterations involving carbohydrate, lipid, and protein metabolism. Pregnancy itself is associated with significant physiological and hormonal adaptations that ensure an adequate supply of nutrients to the developing fetus. These adaptations include progressive insulin resistance, enhanced lipolysis, and alterations in carbohydrate and lipid metabolism. Even in healthy pregnancies, substantial changes in the metabolism of carbohydrates, lipids, and amino acids occur, primarily due to hormonal influences and physiological insulin resistance [2]. However, women with limited pancreatic β-cell reserve may be unable to compensate for the increased insulin demand during pregnancy, leading to the development of GDM. Genetic variations affecting insulin secretion and glucose utilisation further contribute to the susceptibility of certain women to gestational diabetes [3]. Lipid metabolism undergoes marked physiological modifications during pregnancy. Plasma triglyceride (TG) concentrations normally increase two- to three-fold during the second and third trimesters, reflecting enhanced hepatic lipogenesis and reduced lipid clearance. Total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) also rise, although to a lesser extent. Following delivery, most lipid parameters gradually return to pre-pregnancy levels, while LDL-C may remain relatively unchanged [4-6]. Although these changes are considered adaptive, excessive lipid accumulation and dysregulation may contribute to adverse pregnancy outcomes. Emerging evidence suggests that maternal dyslipidaemia is closely associated with impaired glucose tolerance, endothelial dysfunction, and an increased risk of cardiovascular disease. Elevated serum triglyceride concentrations, particularly during early pregnancy, have been reported as useful predictors of abnormal glucose tolerance later in gestation [5]. Furthermore, pregnancy-related oxidative stress and inflammation may amplify cardiovascular risk, especially among women with additional metabolic predispositions [7]. Therefore, understanding the interplay between glucose metabolism and lipid abnormalities during pregnancy is essential for early risk stratification and preventive interventions. Glycated haemoglobin (HbA1c) is a well-established marker of long-term glycaemic control and reflects the average plasma glucose concentration over the preceding 8–10 weeks [8]. In addition to providing an estimate of glycaemic status, HbA1c has been recognised as a valuable predictor of diabetic complications and cardiovascular risk [8]. Elevated HbA1c levels have been associated with adverse lipid alterations and are considered an independent risk factor for coronary artery disease and stroke, irrespective of diabetic status [9]. Consequently, higher HbA1c levels are frequently accompanied by an atherogenic lipid profile. This association may be particularly relevant during pregnancy, where the coexistence of diabetes and physiological metabolic adaptations can further aggravate lipid abnormalities. Diabetes-associated dyslipidaemia is characterised by increased triglycerides and LDL cholesterol along with reduced HDL cholesterol, largely driven by insulin resistance and altered lipid metabolism. Studies have demonstrated that each 1% rise in HbA1c is associated with a substantial increase in cardiovascular risk. Moreover, HbA1c has been positively linked with cardiovascular morbidity even among individuals without diabetes whose HbA1c values fall within the normal range [10]. These findings highlight the potential role of HbA1c not only as a marker of glycaemic control but also as an indicator of broader metabolic disturbances. Several studies have reported significant alterations in lipid parameters among women with GDM [11]. Maternal dyslipidaemia, particularly elevated total cholesterol and triglyceride concentrations, has been associated with an increased risk of adverse obstetric outcomes, including preterm birth [12]. Prematurity remains a leading cause of neonatal morbidity and mortality worldwide and is further associated with long-term metabolic and developmental consequences [13]. Therefore, identification of metabolic abnormalities during pregnancy is important for improving maternal and neonatal health outcomes. Despite the growing burden of GDM in India, data exploring the relationship between HbA1c and lipid profile parameters among pregnant women remain limited, particularly in eastern India. Understanding this association may facilitate early identification of women at increased risk of metabolic complications and provide valuable insights into disease monitoring. Therefore, the present study was conducted to evaluate glycosylated haemoglobin and lipid profile parameters in women with gestational diabetes mellitus and compare them with normoglycaemic pregnant women.

MATERIALS AND METHODS

Study Design and Setting

This comparative case-control study was conducted in the Department of Biochemistry, Birsa Institute of Medical Sciences and Research, Khunti, Jiarapa, Jharkhand, India. The study aimed to compare glycosylated haemoglobin (HbA1c) and lipid profile parameters between pregnant women diagnosed with gestational diabetes mellitus (GDM) and normoglycaemic pregnant women. Written informed consent was obtained from all participants before enrolment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Sample Size Calculation

The sample size was estimated using G*Power software version 3.1.9.7 (Heinrich-Heine-University, Düsseldorf, Germany). Assuming a moderate effect size (d = 0.60), a significance level (α) of 0.05, and a statistical power (1−β) of 80% for comparison between two independent groups, the minimum required sample size was calculated to be 90 participants. To compensate for possible incomplete data and improve the statistical robustness of the study, a total of 100 participants were enrolled, comprising 50 women with GDM and 50 normoglycaemic pregnant women.

Study Participants
A total of 100 antenatal women aged 20–45 years in the third trimester of pregnancy were included in the study. The case group consisted of 50 pregnant women diagnosed with gestational diabetes mellitus, while the control group comprised 50 healthy normoglycaemic pregnant women without any pregnancy-related complications.

Detailed demographic information, obstetric history, and clinical examination findings were recorded using a predesigned proforma. Medical history regarding diabetes mellitus, hypertension, endocrine disorders, systemic illnesses, medication use, and previous obstetric complications was obtained from all participants.

Inclusion Criteria
Cases (GDM Group)
1. Pregnant women aged between 20 and 45 years.
2. Singleton pregnancy in the third trimester.
3. Diagnosed with gestational diabetes mellitus based on the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria.
4. Willingness to participate in the study and provide informed consent.

Controls (Normoglycaemic Group)
1. Pregnant women aged between 20 and 45 years.
2. Singleton pregnancy in the third trimester.
3. Normal glucose tolerance without evidence of gestational diabetes mellitus.
4. Absence of obstetric or medical complications.
5. Willingness to participate in the study and provide informed consent.

Exclusion Criteria
Participants were excluded if they had:
1. Pre-existing Type 1 or Type 2 diabetes mellitus.
2. Pregnancy-induced hypertension or chronic hypertension.
3. Thyroid disorders or other endocrine diseases.
4. Renal, hepatic, cardiovascular, or systemic illnesses.
5. Multiple gestation pregnancies.
6. Urinary tract infection, jaundice, or any active infectious disease.
7. Known dyslipidaemia before pregnancy.
8. Use of medications affecting glucose or lipid metabolism.
9. Any obstetric complication other than gestational diabetes mellitus.

Sample Collection and Processing
Following an overnight fast of 8–10 hours, approximately 5–10 mL of venous blood was collected aseptically from the antecubital vein of each participant. Blood samples were collected into appropriate vacutainers and transported immediately to the laboratory for analysis. Samples intended for serum analysis were allowed to clot at room temperature and subsequently centrifuged at 3000 rpm for 5 minutes. The separated serum was used for the estimation of lipid profile parameters, including total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). All specimens were labelled with unique identification codes to ensure confidentiality and accurate sample tracking throughout the study.

Biochemical Analysis
Gestational diabetes mellitus was diagnosed according to the International Association of Diabetes and Pregnancy Study Groups (IADPSG) recommendations using a 75-g oral glucose tolerance test (OGTT). Fasting and 2-hour plasma glucose levels were recorded. The oral glucose tolerance test was performed according to the conventional method described by Varley [14]. Plasma glucose concentrations were estimated using the glucose oxidase-peroxidase (GOD-POD) method on a Chemwell fully automated analyser [15]. Glycosylated haemoglobin (HbA1c) was measured according to the method described by Little and Goldstein [16] and expressed as a percentage (%). Serum total cholesterol and triglycerides were estimated using standard enzymatic colourimetric methods [17,18]. High-density lipoprotein cholesterol (HDL-C) was determined by phosphotungstic acid precipitation followed by enzymatic analysis of the supernatant fraction [19]. Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation [20].
The following biochemical parameters were evaluated:
- Fasting blood glucose (FBG)
- Two-hour post-glucose blood glucose
- Glycosylated haemoglobin (HbA1c)
- Serum total cholesterol (TC)
- Serum triglycerides (TG)

- High-density lipoprotein cholesterol (HDL-C)
- Low-density lipoprotein cholesterol (LDL-C)

Statistical Analysis

Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 24.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro–Wilk test. Comparisons between GDM cases and normoglycaemic controls were performed using the independent samples Student's t-test. A two-tailed p-value of less than 0.05 was considered statistically significant.

RESULTS

The comparison of serum lipid profile parameters between women with gestational diabetes mellitus (GDM) and normoglycaemic pregnant controls is presented in Table 1 and Figure 1. The mean serum triglyceride level was significantly higher in the GDM group (188.6 ± 15.2 mg/dL) compared to the control group (151.4 ± 14.1 mg/dL) ($p < 0.001$). Similarly, the mean serum total cholesterol level was significantly elevated among GDM cases (206.8 ± 18.5 mg/dL) compared with controls (170.2 ± 16.9 mg/dL) ($p < 0.001$). Although the mean serum HDL cholesterol level was slightly higher in the GDM group (56.9 ± 7.1 mg/dL) than in the control group (55.3 ± 6.8 mg/dL), the difference was not statistically significant ($p > 0.05$). Likewise, the mean serum LDL cholesterol level was higher among women with GDM (90.5 ± 14.2 mg/dL) compared to controls (86.8 ± 13.7 mg/dL); however, this difference did not reach statistical significance ($p > 0.05$). These findings indicate that gestational diabetes mellitus is associated with significantly increased serum triglyceride and total cholesterol concentrations, whereas HDL and LDL cholesterol levels remain comparable between GDM cases and normoglycaemic pregnant women.

Table 1: Comparison of serum lipid profile parameters between gestational diabetes mellitus (GDM) cases and normoglycaemic pregnant controls

Parameters	Cases (50) Mean±SD	Control (50) Mean±SD	P-value
Serum Triglycerides	188.6 ± 15.2	151.4 ± 14.1	<0.001
Serum Total Cholesterol	206.8 ± 18.5	170.2 ± 16.9	<0.001
Serum HDL Cholesterol	56.9 ± 7.1	55.3 ± 6.8	>0.05
Serum LDL Cholesterol	90.5 ± 14.2	86.8 ± 13.7	>0.05

All measurements were taken in mg/dL.

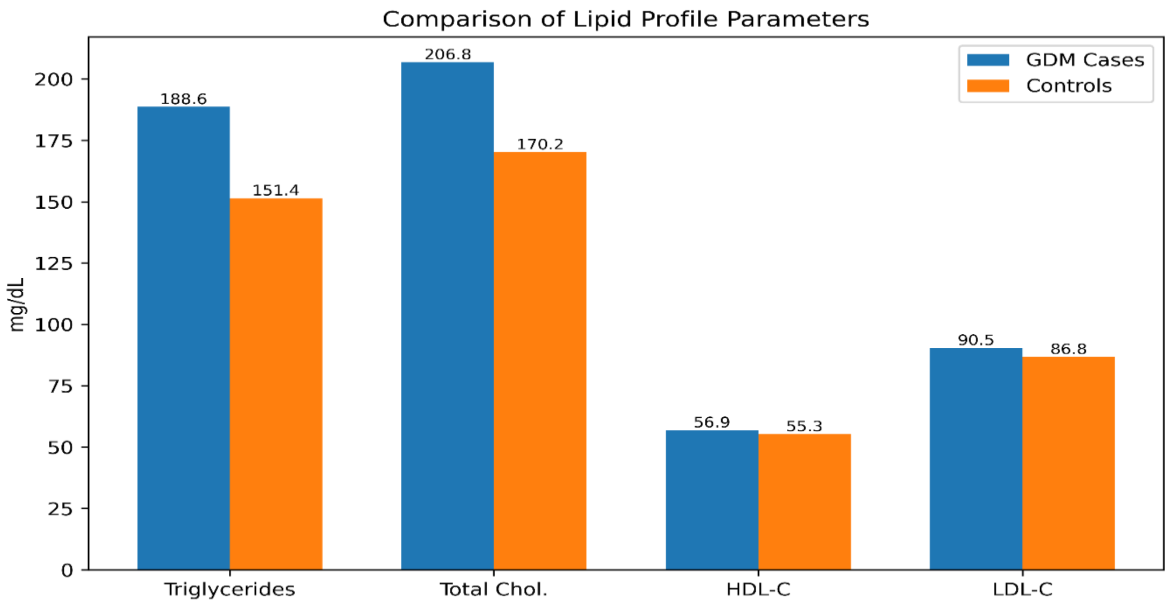

Figure 1: Comparison of serum lipid profile parameters between gestational diabetes mellitus (GDM) cases and normoglycaemic pregnant controls.

The oral glucose tolerance test (OGTT) parameters were significantly elevated among women with gestational diabetes mellitus (GDM) compared with normoglycaemic pregnant controls (Table 2 and Figure 2). The mean fasting blood glucose level was 118.4 ± 10.8 mg/dL in the GDM group, which was significantly higher than that observed in the control group (91.2 ± 6.7 mg/dL) ($p < 0.001$). Similarly, the mean 2-hour post-glucose blood glucose level was markedly increased among women with GDM (201.6 ± 15.3 mg/dL) compared to controls (161.8 ± 10.9 mg/dL), and the difference was statistically highly significant ($p < 0.001$). These findings demonstrate significantly impaired glucose tolerance and poorer glycaemic status among pregnant women with gestational diabetes mellitus compared with normoglycaemic pregnant women.

Table 2: Comparison of oral glucose tolerance test (OGTT) parameters between gestational diabetes mellitus (GDM) cases and normoglycaemic pregnant controls

Parameters	Cases (50) Mean±SD	Control (50) Mean±SD	P-value
Fasting Blood Glucose	118.4 ± 10.8	91.2 ± 6.7	<0.001
2-Hour Post-Glucose Blood Glucose	201.6 ± 15.3	161.8 ± 10.9	<0.001

All measurements were taken in mg/dL.

The comparison of glycated haemoglobin (HbA1c) levels between women with gestational diabetes mellitus (GDM) and normoglycaemic pregnant controls is presented in Table 3 and Figure 2. The mean HbA1c level was significantly higher among women with GDM (8.24 ± 1.18%) compared to the control group (5.84 ± 0.42%). The observed difference was statistically highly significant ($p < 0.001$). These findings indicate that women with gestational diabetes mellitus had markedly poorer long-term glycaemic control than normoglycaemic pregnant women, as reflected by the significantly elevated HbA1c levels.

Table 3: Comparison of glycated haemoglobin (HbA1c) levels between gestational diabetes mellitus (GDM) cases and normoglycaemic pregnant controls

Parameters	Cases (50) Mean±SD	Control (50) Mean±SD	P-value
Glycosylated Haemoglobin	8.24 ± 1.18	5.84 ± 0.42	<0.001

HbA1c values are expressed as a percentage (%).

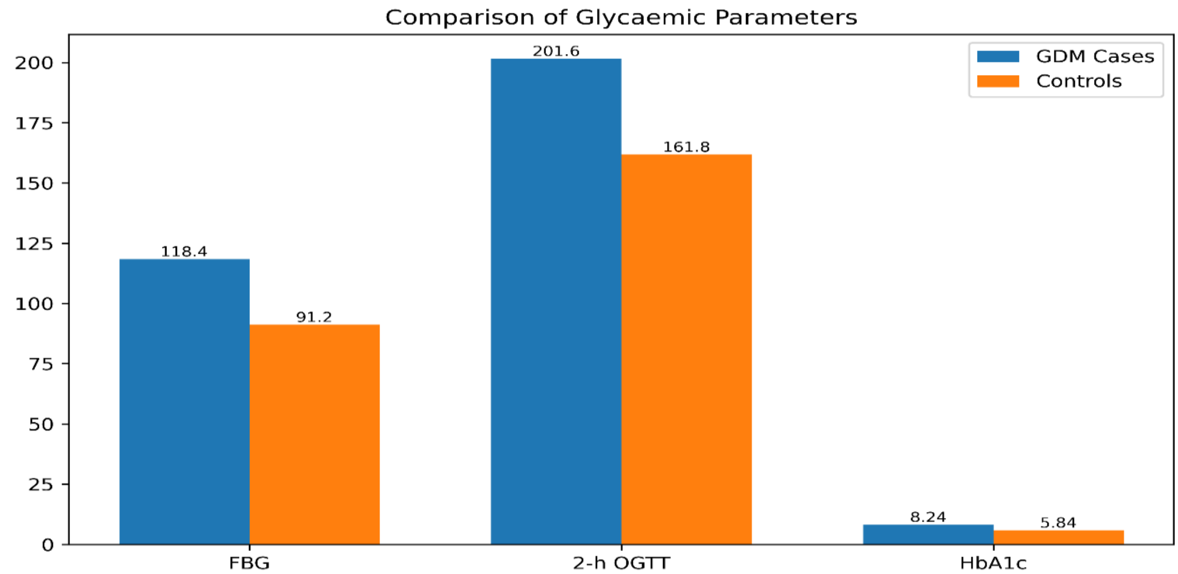

Figure 2. Comparison of fasting blood glucose (FBG), 2-hour post-glucose blood glucose, and glycated haemoglobin (HbA1c) levels between gestational diabetes mellitus (GDM) cases and normoglycaemic pregnant controls.

DISCUSSION

Gestational diabetes mellitus (GDM) is one of the most common metabolic complications of pregnancy and is associated with significant short- and long-term consequences for both the mother and the fetus. Maternal hyperglycaemia during pregnancy increases the risk of adverse obstetric outcomes, including pre-eclampsia, preterm delivery, operative delivery, and the subsequent development of type 2 diabetes mellitus. In addition, the altered intrauterine metabolic environment predisposes the fetus to excessive growth, resulting in macrosomia and an increased risk of neonatal complications such as respiratory distress syndrome, hypoglycaemia, and hyperbilirubinaemia [21]. Beyond disturbances in glucose homeostasis, GDM is characterised by complex alterations in lipid metabolism that may contribute to endothelial dysfunction, oxidative stress, and future cardiovascular risk. Although physiological hyperlipidaemia is a normal adaptation of pregnancy, exaggerated lipid abnormalities in women with GDM may further aggravate metabolic dysfunction and adversely affect maternal and fetal health. Abnormalities in carbohydrate metabolism are closely linked with alterations in lipid metabolism, and the coexistence of these metabolic disturbances may increase the risk of hypertension, dyslipidaemia, and cardiovascular disease later in life [22]. Therefore, assessment of lipid profile and glycaemic parameters in women with GDM is important for identifying individuals at increased risk and facilitating timely therapeutic intervention. In the present study, women with gestational diabetes mellitus exhibited significantly higher serum triglyceride and total cholesterol levels compared with normoglycaemic pregnant controls. The mean serum triglyceride concentration was 188.6 ± 15.2 mg/dL in women with GDM compared with 151.4 ± 14.1 mg/dL among controls, while total cholesterol levels were 206.8 ± 18.5 mg/dL and 170.2 ± 16.9 mg/dL, respectively. These findings indicate the presence of significant dyslipidaemia in women with GDM and support the concept that insulin resistance plays a central role in the alteration of lipid metabolism during pregnancy. Increased insulin resistance promotes enhanced lipolysis, increased free fatty acid flux to the liver, and increased hepatic synthesis of triglyceride-rich lipoproteins, thereby contributing to elevated circulating triglyceride concentrations. However, Sobki SH et al. [23] reported lower triglyceride levels in women with GDM compared with controls, which contrasts with the findings of the present study. Such differences may be attributable to variations in study design, ethnic background, nutritional status, sample size, and gestational age at assessment. In contrast, the present study did not demonstrate statistically significant differences in HDL cholesterol and LDL cholesterol levels between women with GDM and normoglycaemic pregnant women. Although both HDL-C and LDL-C values were slightly higher in the GDM group, the differences did not reach statistical significance. These observations suggest that triglycerides and total cholesterol may be more sensitive indicators of metabolic alterations associated with gestational diabetes than HDL-C and LDL-C in the studied population. Similar findings have also been reported by Kjos et al. [11], who observed alterations in lipid parameters among women with gestational diabetes mellitus. The oral glucose tolerance test remains the cornerstone for the diagnosis and assessment of gestational diabetes mellitus. In the present study, fasting blood glucose and 2-hour post-glucose blood glucose levels were significantly elevated in women with GDM compared with controls. These findings reflect impaired glucose tolerance and the inability of pancreatic β-cells to compensate adequately for the increased insulin resistance that develops during pregnancy. Persistent hyperglycaemia contributes substantially to maternal and fetal morbidity by promoting excessive fetal growth, metabolic derangements, and obstetric complications. Therefore, early identification of abnormal glucose tolerance through routine antenatal screening is essential for timely management and prevention of adverse pregnancy outcomes. Similar elevations in blood glucose levels among women with gestational diabetes have been reported by Taricco et al. [24], supporting the observations of the present study. Glycated haemoglobin (HbA1c) reflects the average blood glucose concentration over the preceding 8–12 weeks and serves as a reliable indicator of long-term glycaemic control. In the present study, HbA1c levels were significantly higher among women with GDM than among normoglycaemic pregnant women. The elevated HbA1c values observed in the GDM group indicate sustained hyperglycaemia and poorer metabolic control throughout pregnancy. As HbA1c reflects chronic glycaemic exposure, it may provide additional information beyond single-point glucose measurements and may help identify women at greater risk of adverse maternal and fetal outcomes. Our findings are in agreement with those reported by Baxi et al. [25] and Bacigalupo et al. [26], who also documented significantly higher HbA1c levels among women with gestational diabetes mellitus. The observed elevation in HbA1c further supports its usefulness as a complementary biomarker for monitoring glycaemic status and assessing metabolic disturbances during pregnancy. Overall, the findings of the present study highlight the close association between gestational diabetes mellitus, impaired glucose regulation, and abnormalities in lipid metabolism. The significant elevations in serum triglycerides, total cholesterol, fasting blood glucose, 2-hour postprandial blood glucose, and HbA1c levels observed among women with GDM emphasise the importance of comprehensive metabolic assessment during pregnancy. Early recognition and appropriate management of these abnormalities may contribute to improved maternal and neonatal outcomes while reducing the long-term risk of metabolic and cardiovascular complications.

Limitations of the study:

The present study has certain limitations that should be considered while interpreting the findings. First, the study was conducted at a single tertiary care centre with a relatively modest sample size, which may limit the generalisability of the results to the broader population. Second, the cross-sectional design precluded assessment of temporal changes in lipid profile and glycaemic parameters throughout pregnancy and their impact on maternal and neonatal outcomes. Third, potential confounding factors such as dietary habits, physical activity, body mass index, and socioeconomic status were not evaluated. Despite these limitations, the study provides valuable insights into the alterations in glycaemic and lipid parameters among women with gestational diabetes mellitus and highlights the importance of metabolic monitoring during pregnancy.

CONCLUSIONS

The present study demonstrated that gestational diabetes mellitus is associated with significant alterations in both glycaemic and lipid parameters during pregnancy. Women with GDM exhibited significantly higher fasting blood glucose, 2-hour post-glucose blood glucose, glycated haemoglobin (HbA1c), serum triglyceride, and total cholesterol levels compared with normoglycaemic pregnant women. However, no significant differences were observed in HDL cholesterol and LDL cholesterol levels between the two groups. These findings suggest that disturbances in glucose metabolism in GDM are accompanied by selective alterations in lipid metabolism, particularly elevated triglyceride and total cholesterol concentrations. Assessment of HbA1c together with routine lipid profile evaluation may aid in the early identification and monitoring of metabolic abnormalities among pregnant women with GDM. Early diagnosis and appropriate management of these metabolic disturbances may contribute to improved maternal and fetal outcomes.

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