

ISSN Print: 2708-2709
ISSN Online: 2708-2717

Journal of Diabetes, Metabolism and Endocrinology
https://jdmeonline.com/

Research Article

Association Between Glycated Haemoglobin and Serum Lipid Parameters in Patients with Type 2 Diabetes Mellitus: A Hospital-Based Cross-Sectional Study

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Article History
Received: 28.05.2026
Accepted: 21.08.2026
Published: 05.09.2026

doi: 10.61336/jdme.0704.21

Abstract: Background: Type 2 diabetes mellitus is frequently accompanied by dyslipidemia, increasing cardiovascular risk. Glycated hemoglobin (HbA1c) reflects long-term glycemic control, but its relationship with individual lipid parameters varies across studies. This study aimed to assess the association between HbA1c and serum lipid parameters in patients with type 2 diabetes mellitus. **Materials and Methods:** This hospital-based cross-sectional study was conducted in the Departments of Endocrinology and General Medicine, Patna Medical College and Hospital, from August 2025 to July 2026. This study included 100 patients, categorized into HbA1c <7% and ≥7% groups. Group differences, Pearson correlations and simple linear regression were examined, with $p<0.05$ considered statistically significant. **Results:** A total of 100 patients with type 2 diabetes mellitus were included, comprising 48 males (48%) and 52 females (52%). Of these, 45 patients (45%) had HbA1c <7%, while 55 (55%) had HbA1c ≥7%. Patients with HbA1c ≥7% showed higher mean triglyceride levels (172.42±60.90 vs. 132.00±59.50 mg/dL; $p = 0.001$) and significantly lower HDL-C levels (45.49±10.67 vs. 50.44±10.13 mg/dL; $p = 0.020$) compared with those with HbA1c <7%. Pearson's correlation analysis demonstrated significant positive correlations of HbA1c with triglycerides ($r = 0.349$, $p<0.001$) and VLDL-C ($r = 0.349$, $p<0.001$), whereas HDL-C showed a significant negative correlation ($r = -0.245$, $p = 0.014$). No statistically significant correlations were observed between HbA1c and total cholesterol or LDL-C ($p>0.05$). **Conclusion:** The findings suggest that poorer glycemic control is associated with higher triglycerides and VLDL-C and lower HDL-C. Concurrent assessment of HbA1c and lipid parameters may support cardiovascular risk evaluation and comprehensive diabetes care. The single-centre, cross-sectional design limits causal inference and generalizability. Confirmation using individual patient records and adjustment for age, sex, body mass index and treatment factors are necessary before journal submission.

Keywords: Type 2 Diabetes Mellitus, Glycated Hemoglobin, HbA1c, Dyslipidemia, Serum Lipid Profile, Glycaemic Control

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a common metabolic disorder characterized by persistent hyperglycemia resulting from insulin resistance and progressive impairment of insulin secretion. It is an important public health concern because of its increasing prevalence and associated vascular complications. India has experienced a substantial rise in the burden of diabetes over recent decades. The Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) study reported a national diabetes prevalence of 11.4%, corresponding to approximately 101 million affected individuals. The same study also highlighted the high prevalence of dyslipidemia and other metabolic risk factors in the Indian population [1]. Glycated hemoglobin (HbA1c) is an established indicator of long-term glycemic control in patients with diabetes mellitus. It is formed through the non-enzymatic binding of glucose to hemoglobin and reflects average blood glucose concentrations over the preceding two to three months [2]. Unlike fasting or postprandial blood glucose measurements, which indicate glycemic status at a particular time, HbA1c provides an assessment of glucose control over a longer period. An HbA1c level below 7% is generally recommended for many non-pregnant adults with diabetes, although treatment targets should be individualized according to clinical circumstances [3]. Dyslipidemia is a frequent metabolic abnormality in patients with T2DM and contributes significantly to the development of cardiovascular disease. The characteristic lipid disturbances include elevated triglycerides, reduced high-density lipoprotein cholesterol (HDL-C) and an increased proportion of small, dense Low-Density Lipoprotein (LDL) particles. These alterations are closely related to insulin resistance, which promotes increased hepatic production of Very-Low-Density Lipoproteins (VLDL) and reduces the clearance of triglyceride-rich lipoproteins [4]. Since both hyperglycemia and dyslipidemia contribute to cardiovascular risk, assessment of glycemic control together with serum lipid parameters is an important component of diabetes management [5].

Several Indian studies have examined the association between HbA1c and serum lipid abnormalities in patients with T2DM. Sheth *et al*. reported significant associations between HbA1c, dyslipidemia and obesity in a Western Indian

population [6]. A study conducted in Katihar, Bihar, by Kumar *et al*. demonstrated positive correlations of HbA1c with total cholesterol, triglycerides and LDL-C, along with an inverse correlation with HDL-C [7]. Similarly, a hospital-based study at AIIMS Patna observed that elevated triglyceride and VLDL-C levels were prominent lipid abnormalities among individuals with diabetes [8]. Lnu *et al*. also reported associations between HbA1c and certain lipid parameters, particularly LDL-C and atherogenic lipid ratios, among patients with T2DM [9]. More recently, Uddin *et al*. observed a weak positive correlation between HbA1c and triglyceride levels, whereas correlations with other lipid parameters were not statistically significant [10].

Although previous studies suggest an association between glycemic control and lipid abnormalities, the findings have not been entirely consistent across different populations. Variations in age, body mass index, duration of diabetes, treatment patterns and other metabolic factors may influence the relationship between HbA1c and serum lipid parameters. Further evaluation in different hospital settings is therefore relevant to understanding these associations and their possible clinical implications.

In this context, the present hospital-based cross-sectional study was undertaken to evaluate the association between glycated hemoglobin (HbA1c) and serum lipid parameters in patients with type 2 diabetes mellitus. The study aimed to assess the relationship of HbA1c with total cholesterol, triglycerides, HDL-C, LDL-C and VLDL-C and to compare lipid profiles among patients with different levels of glycemic control. The findings may contribute to a better understanding of the association between glycemic status and dyslipidemia and highlight the importance of monitoring lipid abnormalities in patients with type 2 diabetes mellitus.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based, observational, retrospective cross-sectional study was conducted in the Departments of Endocrinology and General Medicine at Patna Medical College and Hospital (PMCH), Patna, Bihar, India. Clinical and laboratory records of patients with an established diagnosis of type 2 diabetes mellitus attending the outpatient departments between August 2025 and July 2026 were reviewed. Patients were selected using a non-probability sampling method, based on predefined inclusion and exclusion criteria. A total of 172 patient records were screened, of which 72 were excluded and 100 eligible patients were included in the final analysis. The study was undertaken in accordance with the ethical principles outlined in the Declaration of Helsinki. Patient-related information was handled confidentially and personal identifiers were excluded from the final dataset used for statistical analysis.

Study Population

The study population comprised patients with an established diagnosis of T2DM attending the outpatient departments of Endocrinology and General Medicine during the study period. Patients were screened for eligibility based on their clinical history, diagnosis, treatment records and availability of laboratory investigations. Eligible patients with the required HbA1c and serum lipid profile reports were considered for inclusion in the study.

Sample Size Calculation

The sample size was calculated using G*Power software (version 3.1), considering an expected correlation coefficient (r) of 0.30 between glycated hemoglobin (HbA1c) and serum lipid parameters, a 95% confidence level, 80% statistical power and a 5% level of significance. Based on these assumptions, the minimum required sample size was estimated to be 85 patients. Considering an anticipated dropout or incomplete-data rate of 15%, the sample size was increased to 100 patients to ensure adequate statistical power and reliability in assessing the correlation between HbA1c and serum lipid parameters in a tertiary care hospital setting.

Inclusion Criteria

Patients fulfilling the following criteria were considered eligible for inclusion:

- Adult patients aged between 30 and 70 years, irrespective of sex
- Patients with an established clinical diagnosis of type 2 diabetes mellitus, as documented in their medical records.
- Patients attending the outpatient departments of Endocrinology or General Medicine during the specified study period
- Patients with available HbA1c reports for assessment of long-term glycemic control
- Patients with available serum lipid profile reports, including total cholesterol, triglycerides, HDL-C, LDL-C and VLDL-C
- Patients whose clinical records contained sufficient demographic, treatment-related and biochemical information for the required analysis
- Patients who were not receiving lipid-lowering medications at the time of biochemical assessment

Exclusion Criteria

Patients with conditions or treatment histories that could independently influence glycemic status or serum lipid metabolism were excluded to minimize potential confounding. The exclusion criteria included:

- Patients diagnosed with type 1 diabetes mellitus, as the underlying metabolic disturbances differ from those of T2DM
- Patients with documented cardiovascular disease, including established coronary artery disease or heart failure, which may influence lipid metabolism and treatment patterns
- Patients with known hypothyroidism, as thyroid hormone deficiency can independently cause abnormalities in serum cholesterol and triglyceride levels
- Patients with nephrotic syndrome or significant renal disease, which may alter lipid metabolism and serum lipoprotein concentrations
- Patients with cholestatic liver disease, because impaired hepatic function and bile excretion can affect lipid synthesis and clearance
- Patients receiving lipid-lowering medications, including statins, fibrates, or other hypolipidemic agents, which could modify the natural relationship between HbA1c and serum lipid parameters
- Patients receiving systemic corticosteroids, oral contraceptive pills, or thiazide diuretics, as these medications may influence glucose and lipid metabolism
- Patients with incomplete clinical records or unavailable HbA1c or serum lipid profile results required for the primary analysis

Data Collection

Demographic, clinical and biochemical information was collected retrospectively from hospital records using a structured data collection form. Recorded variables included age, sex, body mass index, duration of diabetes, treatment history, glycated haemoglobin (HbA1c), fasting plasma glucose and serum lipid parameters. HbA1c and lipid profile results were considered for analysis to ensure temporal comparability. When multiple eligible laboratory reports were available for the same patient, the most recent qualifying set of results within the study period was selected. Each patient was included only once in the final dataset to avoid duplication of observations.

Biochemical Assessment

HbA1c was used as the indicator of long-term glycemic control and was expressed as a percentage. The serum lipid profile included total cholesterol, triglycerides, HDL-C, LDL-C and VLDL-C, with all lipid parameters expressed in mg/dL. HbA1c values and lipid parameters were obtained from laboratory reports generated by the hospital laboratory.

Where LDL-C and VLDL-C were not directly measured, calculated values could be derived from the fasting lipid profile using the Friedwald equation, provided the laboratory's calculation criteria were satisfied:

$$\text{LDL-C (mg/dL)} = \text{Total cholesterol} - \text{HDL-C} - (\text{Triglycerides}/5)$$
$$\text{VLDL-C (mg/dL)} = \text{Triglycerides}/5$$

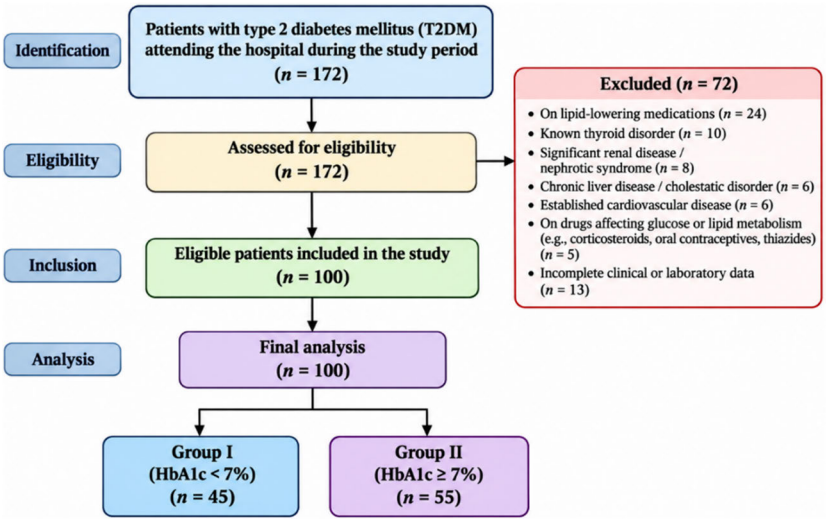


Figure 1: Flow Diagram Showing Patient Screening, Assessment of Eligibility, Inclusion and Grouping According to Glycated Hemoglobin Levels

The calculated LDL-C values were considered appropriate only when fasting triglyceride levels were below 400 mg/dL.

Assessment of Glycemic Control

Based on HbA1c levels, patients were categorized into two groups: Group A comprised patients with HbA1c below 7% (n = 45), representing relatively good glycemic control, while Group B included patients with HbA1c of 7% or above (n = 55), representing suboptimal glycemic control. The serum lipid parameters were compared between these two groups to assess differences in lipid profiles according to glycemic control. In addition, HbA1c was analyzed as a continuous variable to examine its correlation with individual lipid parameters.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 25.0. Continuous variables were expressed as mean±standard deviation (SD), while categorical variables were presented as frequencies and percentages. The Shapiro–Wilk test was used to assess normality. Differences between groups were evaluated using the independent samples t-test or Mann–Whitney U test, as appropriate. Pearson's or Spearman's correlation coefficient was used to assess the association between HbA1c and serum lipid parameters. Simple linear regression analysis was performed to evaluate the relationship between HbA1c and individual lipid parameters. A p-value of less than 0.05 was considered statistically significant (Figure 1).

RESULTS

A total of 100 patients with type 2 diabetes mellitus were included in the study, comprising 48 males (48%) and 52 females (52%). The overall mean age was 56.74±7.46 years, with no significant difference between males and females (p = 0.659). The mean Body Mass Index (BMI) was significantly higher among females (31.18±3.96 kg/m^2) compared with males (28.72±4.01 kg/m^2; p = 0.003). Similarly, females had significantly higher mean HbA1c levels than males (8.48±1.55% vs. 7.76±1.42%; p = 0.018). Although fasting plasma glucose was higher among males (173.13±48.66 mg/dL) than females (159.98±45.82 mg/dL), the difference was not statistically significant (p = 0.168) (Table 1).

The sex-wise comparison of serum lipid parameters showed significant differences in total cholesterol, HDL-C and LDL-C levels. Females had higher mean total cholesterol (192.83±31.18 mg/dL) than males (172.47±30.65 mg/dL; p = 0.001). Similarly, HDL-C (51.91±10.37 vs. 43.19±9.30 mg/dL; p<0.001) and LDL-C (110.20±25.34 vs. 98.30±25.37 mg/dL; p = 0.021) were significantly higher among females. However, triglyceride and VLDL-C levels were comparable between the two groups, with no statistically significant differences (p = 0.917 for both parameters) (Table 2).

Based on glycemic control, 45 patients (45%) had HbA1c levels below 7% (Group A), while 55 patients (55%) had HbA1c levels of 7% or above (Group B). The mean HbA1c was 6.45±0.36% in Group A and 9.51±1.17% in Group B (p<0.001). Patients with suboptimal glycemic control had significantly higher triglyceride levels (172.42±60.90 vs. 132.00±59.50 mg/dL; p = 0.001) and VLDL-C levels (34.48±12.18 vs. 26.40±11.90 mg/dL; p = 0.001). In contrast, HDL-C levels were significantly lower in Group B than in Group A (45.49±10.67 vs. 50.44±10.13 mg/dL; p = 0.020). Although total cholesterol and LDL-C levels were higher among patients with HbA1c ≥7%, the differences were not statistically significant (p = 0.098 and p = 0.145, respectively). Fasting plasma glucose was also significantly higher in Group B (182.00±45.20 mg/dL) compared with Group A (147.10±43.40 mg/dL; p<0.001) (Table 3, Figure 2).

Table 1: Sex-Wise Comparison of Demographic and Clinical Characteristics of Patients with Type 2 Diabetes Mellitus (N = 100)

Parameter	Male (n = 48) Mean±SD	Female (n = 52) Mean±SD	Overall (N = 100) Mean±SD	p-value
Age (years)	56.40±7.29	57.06±7.67	56.74±7.46	0.659
BMI (kg/m^2)	28.72±4.01	31.18±3.96	30.00±4.15	0.003*
HbA1c (%)	7.76±1.42	8.48±1.55	8.13±1.53	0.018*
FPG (mg/dL)	173.13±48.66	159.98±45.82	166.29±47.43	0.168

BMI: Body Mass Index, HbA1c: Glycated Hemoglobin, FPG: Fasting Plasma Glucose. p-values were calculated using Welch's independent samples t-test. *Statistically significant at p<0.05

Table 2: Sex-Wise Comparison of Serum Lipid Parameters among Patients with Type 2 Diabetes Mellitus (N = 100)

Parameter	Male (n = 48) Mean±SD	Female (n = 52) Mean±SD	Overall (N = 100) Mean±SD	p-value
Total cholesterol (mg/dL)	172.47±30.65	192.83±31.18	183.06±32.42	0.001*
HDL-C (mg/dL)	43.19±9.30	51.91±10.37	47.72±10.75	<0.001*
LDL-C (mg/dL)	98.30±25.37	110.20±25.34	104.49±25.92	0.021*
Triglycerides (mg/dL)	154.92±63.58	153.58±65.02	154.23±64.01	0.917
VLDL-C (mg/dL)	30.98±12.72	30.72±13.00	30.85±12.80	0.917

HDL-C: High-Density Lipoprotein Cholesterol, LDL-C: Low-Density Lipoprotein Cholesterol, VLDL-C: Very-Low-Density Lipoprotein Cholesterol. p-values were calculated using Welch's independent samples t-test. *Statistically significant at p<0.05

Table 3: Comparison of Serum Lipid Parameters According to Glycemic Control Among Patients with Type 2 Diabetes Mellitus (N = 100)

Parameters	Group A: HbA1c <7% (n = 45) Mean±SD	Group B: HbA1c ≥7% (n = 55) Mean±SD	p-value
HbA1c (%)	6.45±0.36	9.51±1.17	<0.001*
Total cholesterol (mg/dL)	177.20±31.50	187.86±32.10	0.098
HDL-C (mg/dL)	50.44±10.13	45.49±10.67	0.020*
LDL-C (mg/dL)	100.36±25.10	107.89±25.90	0.145
Triglycerides (mg/dL)	132.00±59.50	172.42±60.90	0.001*
FPG (mg/dL)	147.10±43.40	182.00±45.20	<0.001*
VLDL-C (mg/dL)	26.40±11.90	34.48±12.18	0.001*

HbA1c: Glycated Hemoglobin, HDL-C: High-Density Lipoprotein Cholesterol, LDL-C: Low-Density Lipoprotein Cholesterol, FPG: Fasting Plasma Glucose, VLDL-C: Very-Low-Density Lipoprotein Cholesterol. *p<0.05 indicates statistical significance. Illustrative p-values calculated using Welch's independent samples t-test

Table 4: Correlation Between Glycated Haemoglobin (HbA1c) and Individual Serum Lipid Parameters in Patients with Type 2 Diabetes Mellitus (N = 100)

Serum lipid parameters	Pearson's correlation coefficient (r)	p-value
Total cholesterol (mg/dL)	0.179	0.075
HDL-C (mg/dL)	−0.245	0.014*
LDL-C (mg/dL)	0.153	0.128
Triglycerides (mg/dL)	0.349	<0.001*
VLDL-C (mg/dL)	0.349	<0.001*

HbA1c: Glycated Haemoglobin, HDL-C: High-Density Lipoprotein Cholesterol, LDL-C: Low-Density Lipoprotein Cholesterol, VLDL-C: Very-Low-Density Lipoprotein Cholesterol. Pearson's correlation coefficient (r) indicates the direction and strength of association. *p<0.05 indicates statistical significance

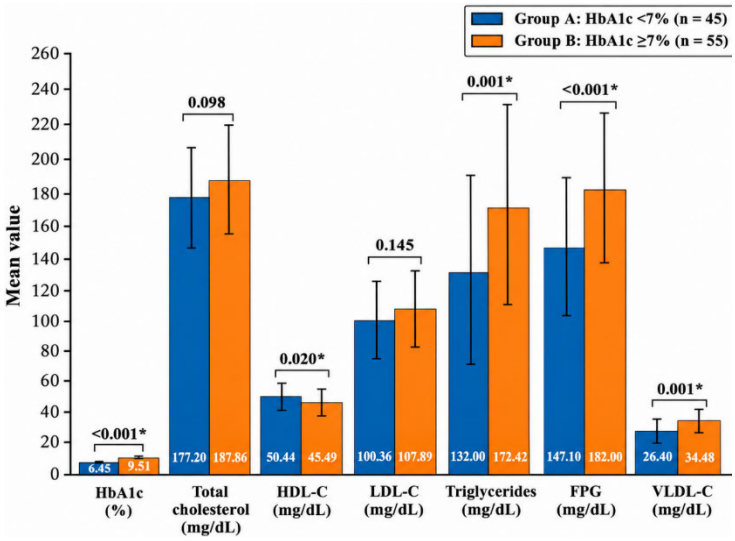


Figure 2: Comparison of HbA1c, Serum Lipid Parameters and Fasting Plasma Glucose Between Patients with HbA1c <7% (Group A) and HbA1c ≥7% (Group B)

Table 5: Simple Linear Regression Analysis of the Association Between HbA1c and Serum Lipid Parameters in Patients with Type 2 Diabetes Mellitus (N = 100)

Serum lipid parameters	Regression coefficient (B)	Standard error (SE)	Standardized β	R^2	p-value
Total cholesterol (mg/dL)	0.00845	0.00469	0.179	0.032	0.075
HDL-C (mg/dL)	−0.03487	0.01394	−0.245	0.060	0.014*
LDL-C (mg/dL)	0.00903	0.00589	0.153	0.023	0.129
Triglycerides (mg/dL)	0.00834	0.00226	0.349	0.122	<0.001*
VLDL-C (mg/dL)	0.04172	0.01132	0.349	0.122	<0.001*

HbA1c was the dependent variable and each serum lipid parameter was examined separately using simple linear regression. B: Unstandardized regression coefficient, SE: Standard Error, β: Standardized regression coefficient, R^2: Coefficient of determination. *p<0.05 indicates statistical significance

Correlation analysis showed a significant positive association of HbA1c with triglycerides (r = 0.349, p<0.001) and VLDL-C (r = 0.349, p<0.001). A significant negative correlation was observed between HbA1c and HDL-C (r = −0.245, p = 0.014). However, the correlations of HbA1c with total cholesterol (r = 0.179, p = 0.075) and LDL-C (r = 0.153, p = 0.128) were weak and statistically non-significant (Table 4).

Simple linear regression analysis demonstrated significant positive associations of HbA1c with triglycerides (β = 0.349, p<0.001) and VLDL-C (β = 0.349, p<0.001). Each parameter explained approximately 12.2% of the variation in HbA1c levels in its respective regression model. HDL-C showed a significant negative association with HbA1c (β = −0.245, p = 0.014), accounting for approximately 6.0% of the variation. In contrast, total cholesterol (β = 0.179, p = 0.075) and LDL-C (β = 0.153, p = 0.129) did not demonstrate statistically significant associations with HbA1c (Table 5).

DISCUSSION

The relationship between glycemic control and lipid abnormalities is of considerable clinical importance in patients with type 2 diabetes mellitus (T2DM), particularly because both disturbances contribute to cardiovascular risk. The present analysis suggests that Higher Glycated Hemoglobin (HbA1c) levels are associated mainly with increased triglycerides and Very-Low-Density Lipoprotein Cholesterol (VLDL-C), along with reduced high-density lipoprotein cholesterol (HDL-C). In contrast, the associations with total cholesterol and low-density lipoprotein cholesterol (LDL-C) were not statistically significant. This pattern is consistent with the characteristic dyslipidaemia associated with insulin resistance, in which triglyceride-rich lipoproteins and HDL metabolism are particularly affected [4]. These observations provide a basis for understanding the relationship between long-term glycaemic status and individual lipid parameters in patients with T2DM. Alterations in serum lipid profiles have also been documented in other chronic disorders, including β-thalassemia major. A study involving patients with β-thalassemia major demonstrated significantly reduced total cholesterol, LDL-C and HDL-C levels, alongside increased triglyceride concentrations compared with healthy controls. These findings further illustrate that lipid metabolism may be altered across different disease conditions, although the underlying mechanisms and patterns of dyslipidemia may vary according to the associated pathology [11].

The study population comprised 100 patients, with a nearly equal distribution of males and females. Female patients had significantly higher Body Mass Index (BMI) and HbA1c levels than males, suggesting differences in adiposity and glycaemic control between the sexes. Similar findings were reported by Uddin *et al*. [12] in a hospital-based Indian study, where HbA1c levels were significantly higher among females. Prabhavathi *et al*. [13] also observed higher HbA1c levels in female patients with T2DM. These differences may reflect variations in body composition, insulin sensitivity, hormonal status, lifestyle and treatment-related factors. However, the influence of these factors cannot be established without further evaluation. The absence of a significant sex-wise difference in fasting plasma glucose, despite differing HbA1c levels, also highlights that a single glucose measurement and long-term glycaemic assessment may not always show identical patterns.

Sex-wise comparison of lipid parameters revealed higher total cholesterol, LDL-C and HDL-C concentrations among females, while triglyceride and VLDL-C levels were comparable between the sexes. Kumar *et al*. [8], in a hospital-based study conducted at AIIMS Patna, reported greater dyslipidaemia among diabetic women than men. Sheth *et al*. [6] also demonstrated associations between obesity, dyslipidaemia and HbA1c in an Indian population. The higher BMI observed among females in the present analysis may have contributed to differences in lipid metabolism. Nevertheless, the simultaneous elevation of HDL-C indicates that the female lipid profile cannot be considered uniformly more adverse. Differences in individual lipid fractions should therefore be interpreted separately rather than treating dyslipidaemia as a single biochemical abnormality. When patients were categorised according to glycaemic control, those with HbA1c ≥7% had higher triglyceride and VLDL-C concentrations and lower HDL-C levels than patients with HbA1c <7%. The positive correlation between HbA1c and triglycerides was particularly relevant. Uddin *et al*. [11] similarly observed higher triglyceride concentrations among patients with poor glycaemic control and reported a weak positive correlation between HbA1c and triglycerides. Kumar *et al*. [8] also identified increased triglyceride and VLDL-C concentrations as prominent lipid abnormalities in patients with diabetes. In a study involving patients with T2DM from a rural tribal population in Jharkhand, Kumar S [13] reported positive correlations of HbA1c with several lipid parameters, including triglycerides and VLDL-C. These findings support a relationship between poor glycaemic control and disturbances in triglyceride metabolism across different Indian populations.

Similar observations have been reported internationally. AlZeer *et al*. [14], in a retrospective study involving 483 patients with newly diagnosed T2DM in Saudi Arabia, found significant associations between HbA1c and triglycerides and HDL-C, whereas total cholesterol and LDL-C were not significantly associated with glycaemic control. This pattern closely resembles the findings presented in the current analysis. Differences between studies may arise from variations in patient selection, age distribution, duration of diabetes, degree of obesity and antidiabetic treatment. Such variations are especially relevant when comparing patients attending tertiary care hospitals with those recruited from primary care or community settings.

The association between hyperglycaemia and increased triglyceride concentrations has a plausible metabolic explanation. Insulin resistance promotes the mobilisation of free fatty acids from adipose tissue and increases their delivery to the liver, contributing to hepatic triglyceride synthesis and VLDL production. At the same time, impaired insulin action reduces the clearance of triglyceride-rich lipoproteins, further increasing circulating triglyceride concentrations. Taskinen and Borén [4] described these abnormalities as central features of diabetic dyslipidaemia. Adiels *et al*. [15] also demonstrated that increased production of large VLDL1 particles is an important metabolic disturbance associated with hyperglycaemia in T2DM. Together, these mechanisms help explain why triglycerides may show a clearer association with HbA1c than some other lipid parameters.

An inverse association between HbA1c and HDL-C was another important finding in the tabulated analysis. This observation is consistent with the metabolic disturbances that accompany insulin resistance and

hypertriglyceridemia. Increased concentrations of triglyceride-rich lipoproteins promote the exchange of triglycerides and cholesterol esters between lipoprotein particles, resulting in triglyceride-enriched HDL particles that undergo more rapid catabolism. Consequently, HDL-C concentrations may decline as glycaemic control deteriorates. Hirano [16] described these alterations in HDL metabolism together with the increased production of small, dense LDL particles in diabetic dyslipidaemia. However, findings across clinical studies are not uniform. Lnu *et al*. [9] did not observe a significant correlation between HbA1c and HDL-C in their study, suggesting that the relationship may vary according to population characteristics and metabolic status.

Although total cholesterol and LDL-C concentrations were numerically higher among patients with HbA1c ≥7%, their associations with HbA1c were not statistically significant. Similar findings were reported by AlZeer *et al*. [14], whereas Lnu *et al*. [9] demonstrated a significant association between HbA1c and LDL-C. Kumar [13] also observed positive correlations involving total cholesterol and LDL-C in a rural Indian population. These differences may reflect variations in disease duration, metabolic characteristics and study methodology. Moreover, diabetic dyslipidaemia involves qualitative changes in LDL particles, including an increased proportion of small, dense LDL, even when conventional LDL-C concentrations are not markedly elevated [4,16]. Therefore, the absence of a significant association with LDL-C concentration does not necessarily indicate the absence of atherogenic lipid abnormalities.

Correlation and simple linear regression analyses further supported the observed relationships involving triglycerides, VLDL-C and HDL-C. The reported correlation between HbA1c and triglycerides was moderate in magnitude ($r = 0.349$), with a coefficient of determination of approximately 12.2%. This indicates that triglyceride concentration accounted for a relatively small proportion of the variation in HbA1c in the unadjusted regression model. The identical association observed with VLDL-C requires particular consideration because VLDL-C was calculated from triglycerides using a fixed relationship. Consequently, these results should not be regarded as two independent biological associations. Furthermore, simple regression does not account for potentially important confounding factors such as age, sex, BMI, diabetes duration and medication use. The findings therefore demonstrate statistical associations rather than independent effects or causal relationships.

From a clinical perspective, the observed pattern supports the value of assessing glycaemic control and lipid parameters together during routine diabetes management. Although HbA1c is an established indicator of long-term glucose control, it cannot replace direct lipid assessment, as different lipid fractions may respond differently to metabolic disturbances. The American Diabetes Association recommends comprehensive cardiovascular risk assessment and appropriate lipid management in patients with diabetes [5]. Recognition of elevated triglycerides and reduced HDL-C alongside suboptimal glycaemic control may help clinicians identify patients requiring closer metabolic evaluation. Overall, the present analysis adds to the existing literature by examining these relationships in a tertiary care setting in Bihar and reinforces the importance of considering glycaemic and lipid abnormalities as related but distinct components of diabetes care.

Limitations of the Study

The present study provides useful insights into the association between glycaemic control and serum lipid parameters in patients with type 2 diabetes mellitus. However, the relatively small sample size, single-center setting and cross-sectional design may limit the generalisability of the findings and prevent causal interpretation. Larger multicentre prospective studies with long-term follow-up may further strengthen these observations and their clinical relevance.

CONCLUSION

The present study suggests a significant association between glycaemic control and serum lipid abnormalities in patients with type 2 diabetes mellitus. Higher HbA1c levels were associated with increased triglyceride and VLDL-C levels and reduced HDL-C levels, whereas the associations with total cholesterol and LDL-C were not statistically significant. These findings highlight the relationship between glucose and lipid metabolism and support the importance of regular monitoring of both HbA1c and serum lipid profiles. An integrated approach to glycaemic and lipid management may help in the early identification of dyslipidaemia and reduction of cardiovascular risk in patients with type 2 diabetes mellitus.

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