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Original Research Article

A Study to Determine the Correlation Between HbA1c and Lipid Profile in Patients with Type 2 Diabetes Mellitus

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Abstract:

Background: Type 2 diabetes mellitus (T2DM) is frequently associated with dyslipidemia, which substantially increases the risk of cardiovascular complications. Glycated hemoglobin (HbA1c) reflects long-term glycemic control and may serve as an indicator of lipid abnormalities.

Aim: To determine the correlation between HbA1c and lipid profile parameters in patients with T2DM.

Methodology: A hospital-based cross-sectional study was conducted among 100 patients with T2DM aged 40–60 years at a tertiary care center in Bihar, India. Demographic and clinical data were recorded using a pre-designed proforma. Fasting blood sugar (FBS), post-prandial blood sugar (PPBS), HbA1c, and lipid profile parameters including total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL) were measured using standard biochemical methods. Pearson's correlation analysis was performed to assess the association between HbA1c and lipid profile parameters, with $p < 0.05$ considered statistically significant.

Results: The mean age of the participants was 52.46 ± 6.18 years, and 58.0% were male. The mean HbA1c level was 8.14 ± 1.21%, indicating poor glycemic control. The study population demonstrated an atherogenic lipid profile, with mean TC, TG, LDL, HDL, and VLDL levels of 199.58 ± 34.16 mg/dL, 179.60 ± 46.22 mg/dL, 124.34 ± 29.15 mg/dL, 38.89 ± 6.84 mg/dL, and 35.92 ± 9.24 mg/dL, respectively. HbA1c showed significant positive correlations with TC ($r = 0.48$, $p < 0.001$), TG ($r = 0.55$, $p < 0.001$), LDL ($r = 0.51$, $p < 0.001$), and VLDL ($r = 0.44$, $p < 0.001$), while a significant inverse correlation was observed with HDL ($r = -0.39$, $p < 0.001$). Lipid abnormalities progressively worsened with increasing HbA1c levels.

Conclusion: Poor glycemic control is strongly associated with an atherogenic lipid profile in patients with T2DM. HbA1c may serve as a useful surrogate marker for identifying dyslipidemia and assessing cardiovascular risk in this population.

Keywords: Type 2 Diabetes Mellitus; HbA1c; Dyslipidemia; Lipid Profile; Cardiovascular Risk; Glycemic Control.

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Introduction

Diabetes mellitus (DM) is a heterogeneous cluster of metabolic conditions that is mainly characterized by chronic hyperglycemia, caused by impairment of insulin secretion, insulin activity or both. The disease is acquired through complicated interactions between genetic predisposition and the environmental factors. Insulin is a very important hormone in carbohydrates, lipid and protein metabolism and thus any impairment of its production or action causes extensive metabolic disorders. Chronic hyperglycemia in diabetes mellitus leads to extensive biochemical changes and secondary pathophysiology that ensures the impact of multi myogenous organ systems. Therefore, diabetes is a significant health liability not only to the patient, but also to the health care systems of most countries across the globe.

Diabetes mellitus can be categorized into two broad types: Type 1 diabetes mellitus and Type 2 diabetes mellitus. Type 2 diabetes mellitus (T2DM) is more

prevalent and represents the majority of the worldwide cases of diabetes. The rapidly growing diabetics in India has made India to be known as the diabetic capital of the world. It is important to note that Type 2 diabetes mellitus in the Indians is more likely to develop at a younger age and lesser body mass index as compared to the western population. Also, microvascular and macrovascular complications seem to occur earlier and in more severe forms in Indian diabetic patients in comparison to other ethnic groups. Recent research shows that the prevalence of coronary heart disease (CHD) among the Indian diabetics is similar to the prevalence found in migrant populations, which points to the high-cardiovascular risk in this population. [1]

Change in the lipid metabolism is one of the most significant metabolic effects of diabetes mellitus. The ensuing result of the disregulation of carbohydrate metabolism has a direct impact on the lipid metabolism leading to abnormalities in lipid synthesis, transport and clearance. The resulting changes bring about both qualitative and quantitative changes in lipid fractions, and thus collectively called diabetic dyslipidemia. Various research investigations that compared cardiovascular risk factors among diabetic patients have continually recorded high levels of fasting blood sugar (FBS) and post prandial body sugar (PPBS), high levels of total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), and triglyceride (TG) levels with low levels of high density lipoprotein cholesterol (HDL-C) levels when compared to non-diabetic control groups. [2]

Glycemic control during the management of diabetes mellitus is important to be evaluated. The gold standard measure of long-term glycemic status is glycated hemoglobin (HbA1c) since it indicates the average level of glucose in the blood in the last 8 - 12 weeks. HbA1c is a non-enzymatic glycation of hemoglobin in circulating erythrocytes, and the level is in relation to the duration and severity of hyperglycemia. Notably, HbA1c was found more useful in predicting coronary heart disease as compared to fasting glucose or two hours of post-load glucose. [3]

Moreover, HbA1c has been linked with atherosclerosis by measuring carotid intima-media thickness (IMT) as a surrogate measure of initial vascular injury and cardiovascular risk, which is strongly recommended by American Diabetes Association (ADA) whether in Type 1 or Type 2 diabetes patients as a measure of initial level of glycemic control and further in monitoring and therapeutic decisions. [4,5] The degree of diabetes mellitus, as measured by the level of HbA1c, has also been strongly associated with the changes in parameters of lipid profile.

Dyslipidemia is a frequent metabolic defect in Type 2 diabetes mellitus and is typified by an elevation of triglycerides, total cholesterol, LDL and VLDL levels as well as low HDL levels. This is a dyslipidemic pattern that is strongly related with insulin resistance, hyperinsulinemia, hypertension, and obesity that form the metabolic syndrome or Reavens syndrome. These defects promote atherosclerosis at a very rapid pace and are a cause of high cardiovascular morbidity and mortality that is witnessed in diabetic patients.

Different atherogenic indices are used in order to assess cardiovascular risk in diabetic patients. The proportion of total cholesterol to HDL-C (TC/HDL-C) of less than 5, the proportion of LDL-C to HDL-C of less than 3.5 are taken as significant signs of cardiovascular diseases. Moreover, the ratio of triglyceride to the HDL-C (TG/HDL-C) is also considered a good surrogate marker of insulin resistance and has been deemed equal to the level of insulin in fasting serum to evaluate insulin resistance in Type 2 diabetes mellitus. [7]

One of the most common conditions that accompany diabetes mellitus is dyslipidemia, especially increased levels of LDL cholesterol which is closely linked with inappropriate glycemic control. The parameter of long-term glycemic control that is most commonly used and reliable in the diagnosis of diabetic patients is glycated hemoglobin (HbA1c) [8]. Since HbA1c is the mean of blood glucose levels over the period of time, it is also regarded as a significant predeterminer of the appearance of diabetic complications, such as cardiovascular disease.

Given that poor glycemic control and lipid abnormalities have an independent role in causing vascular complications in diabetes mellitus, it would be important to define the relationship between HbA1c and lipid profile. By establishing this kind of relationship, clinicians would be able to utilize HbA1c as not just a glycemic control indicator, but as a possible indicator of dyslipidemia and cardiovascular risk, as well. The detection of lipid abnormalities in patients with poor glycemic control at an early stage may be used to help start prevention measures in time and minimize the cardiovascular complications burden.

Consequently, the current research was done to assess and establish the relationship between HbA1c and lipid profile parameters in Type 2 diabetes mellitus patients. Through this association, the study will help in enhancing risk stratification and management of diabetic patients to eventually help in curbing morbidity and mortality related to cardiovascular complications.

Methodology

Study Design: This study was a hospital-based cross-sectional observational study conducted to determine the correlation between glycated hemoglo-

bin (HbA1c) and lipid profile parameters in patients with Type 2 Diabetes Mellitus (T2DM).

Study Area: The study was carried out in the Department of Biochemistry, Anugrah Narayan Magadh Medical College, Gaya Ji, Bihar, India, in collaboration with the Department of Medicine.

Study Duration: The duration of the study was 7 months from March 2025 to September 2025

Sample Size: A total of 100 confirmed cases of Type 2 Diabetes Mellitus were included in the study.

Study Population: The study population consisted of male and female patients aged between 40 and 60 years, who were clinically diagnosed with Type 2 Diabetes Mellitus and attending the outpatient or inpatient services of the Medicine Department.

Data Collection: After explaining the purpose of the study, written informed consent was obtained from each participant. Demographic details and clinical history were recorded in a pre-designed proforma. Following an overnight fast of 8–10 hours, approximately 5 mL of venous blood was collected aseptically using a disposable syringe. The samples were allowed to clot and were centrifuged at 3000 rpm for 10 minutes to separate serum. Fasting blood glucose was estimated within 30 minutes to 1 hour of sample collection, and post-prandial blood glucose was measured as per standard clinical protocol.

Inclusion Criteria

- Patients diagnosed with Type 2 Diabetes Mellitus
- Age group between 40–60 years
- Both male and female patients
- Patients willing to participate and providing written informed consent

Exclusion Criteria

- Patients with Type 1 Diabetes Mellitus
- Patients with known liver disease, renal disease, thyroid disorders, or acute infections
- Patients on lipid-lowering drugs
- Pregnant women
- Patients unwilling to give informed consent

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of Anugrah Narayan Magadh Medical College, Gaya. All participants provided written informed consent prior to participation. Confidentiality of patient identity and laboratory findings was strictly maintained throughout the study.

Procedure: Venous blood samples collected after overnight fasting were processed immediately for biochemical analysis. Fasting and post-prandial blood glucose levels were measured by standard enzymatic methods. Lipid profile parameters including total cholesterol, triglycerides, and high-density lipoprotein cholesterol were analyzed using an automated biochemical analyzer (Cobas c111) according to manufacturer instructions. Low-density lipoprotein and very low-density lipoprotein levels were calculated using Friedewald's formula. Glycated hemoglobin (HbA1c) was estimated using a radioimmunoassay method with the HbA1c LD-500 analyzer. All analyses were performed under standardized laboratory conditions.

Statistical Analysis: All data were entered into Microsoft Excel and analyzed using SPSS version 20.0. Quantitative variables were expressed as mean ± standard deviation. Pearson's correlation coefficient test was applied to assess the correlation between HbA1c and lipid profile parameters including total cholesterol, triglycerides, HDL, LDL, and VLDL. A p-value less than 0.05 was considered statistically significant.

Result

Table 1 presents the demographic characteristics of the study population comprising 100 patients with type 2 diabetes mellitus. The mean age of the participants was 52.46 ± 6.18 years, indicating that the majority of patients belonged to the middle-aged group. Of the total participants, 58 (58.0%) were males and 42 (42.0%) were females, demonstrating a slight male predominance in the study cohort. The mean duration of diabetes was 6.2 ± 2.7 years, suggesting a moderately long disease history among the participants. Additionally, the mean body mass index (BMI) was 25.34 ± 3.21 kg/m², which falls within the overweight category according to standard BMI classifications. Overall, the study population consisted predominantly of middle-aged, overweight individuals with a moderate duration of type 2 diabetes mellitus.

Table 1: Demographic Characteristics of Study Population (N = 100)

Parameter	Value
Age (years)	52.46 ± 6.18
Male, n (%)	58 (58.0)
Female, n (%)	42 (42.0)
Duration of Diabetes (years)	6.2 ± 2.7
BMI (kg/m²)	25.34 ± 3.21

Table 2 presents the glycemic parameters of the study subjects with type 2 diabetes mellitus (N = 100). The mean fasting blood sugar (FBS) level was 182.64 ± 38.52 mg/dL, which is substantially higher than the recommended fasting glucose targets, indicating poor fasting glycemic control among the participants. Similarly, the mean post-prandial blood sugar (PPBS) level was 256.18 ± 52.74 mg/dL, reflecting significant postprandial hyperglycemia. The mean glycated hemoglobin (HbA1c) level was 8.14 ± 1.21%, exceeding the recommended target value of less than 7%, and suggesting inadequate long-term glycemic control over the preceding 8–12 weeks. Overall, these findings demonstrate persistent hyperglycemia and suboptimal diabetes management in the study population, which may contribute to an increased risk of microvascular and macrovascular complications.

Table 2: Glycemic Parameters of Study Subjects (N = 100)

Parameter	Mean ± SD
FBS (mg/dL)	182.64 ± 38.52
PPBS (mg/dL)	256.18 ± 52.74
HbA1c (%)	8.14 ± 1.21

Table 3 presents the lipid profile characteristics of the study subjects with type 2 diabetes mellitus (N = 100). The mean total cholesterol (TC) level was 199.58 ± 34.16 mg/dL, indicating borderline high cholesterol levels among the participants. The mean triglyceride (TG) concentration was 179.60 ± 46.22 mg/dL, reflecting elevated triglyceride levels commonly associated with diabetic dyslipidemia. The mean low-density lipoprotein (LDL) cholesterol level was 124.34 ± 29.15 mg/dL, which exceeds the recommended target values for patients with diabetes and suggests an increased risk of atherosclerotic cardiovascular disease. In contrast, the mean high-density lipoprotein (HDL) cholesterol level was relatively low at 38.89 ± 6.84 mg/dL, indicating reduced cardioprotective effects. The mean very low-density lipoprotein (VLDL) level was 35.92 ± 9.24 mg/dL, which was also elevated. Overall, the lipid profile demonstrates a characteristic atherogenic dyslipidemic pattern marked by increased TC, TG, LDL, and VLDL levels along with reduced HDL concentrations among patients with type 2 diabetes mellitus.

Table 3: Lipid Profile of Study Subjects (N = 100)

Lipid Parameter	Mean ± SD
Total Cholesterol (mg/dL)	199.58 ± 34.16
Triglycerides (mg/dL)	179.60 ± 46.22
HDL (mg/dL)	38.89 ± 6.84
LDL (mg/dL)	124.34 ± 29.15
VLDL (mg/dL)	35.92 ± 9.24

Table 4 demonstrates a significant association between glycated hemoglobin (HbA1c) levels and lipid profile parameters among patients with type 2 diabetes mellitus (N = 100). HbA1c showed moderate positive correlations with total cholesterol ($r = 0.48$, $p < 0.001$), triglycerides ($r = 0.55$, $p < 0.001$), low-density lipoprotein (LDL) cholesterol ($r = 0.51$, $p < 0.001$), and very low-density lipoprotein (VLDL) cholesterol ($r = 0.44$, $p < 0.001$), indicating that worsening glycemic control is associated with increasing levels of atherogenic lipids. The strongest positive correlation was observed between HbA1c and triglycerides ($r = 0.55$). Conversely, HbA1c exhibited a moderate negative correlation with high-density lipoprotein (HDL) cholesterol ($r = −0.39$, $p < 0.001$), suggesting that higher HbA1c levels are associated with lower concentrations of protective HDL cholesterol. Overall, these findings indicate that poor glycemic control is significantly linked with an unfavorable lipid profile and an increased risk of cardiovascular complications in patients with type 2 diabetes mellitus.

Table 4: Correlation Between HbA1c and Lipid Profile (Pearson Correlation) (N = 100)

Parameter	Correlation Coefficient (r)	P value	Significance
Total Cholesterol	0.48	<0.001	Highly Significant
Triglycerides	0.55	<0.001	Highly Significant
LDL	0.51	<0.001	Highly Significant
VLDL	0.44	<0.001	Highly Significant
HDL	−0.39	<0.001	Highly Significant (Inverse)

Table 5 presents the comparison of lipid profile parameters across different HbA1c categories among patients with type 2 diabetes mellitus (N = 100). Of the total participants, 24 (24.0%) had HbA1c levels <7%, 46 (46.0%) had HbA1c levels between 7–9%, and 30 (30.0%) had HbA1c levels >9%. A progressive deterioration in lipid parameters was observed with increasing HbA1c levels. Patients with HbA1c <7% exhibited the most favorable lipid profile, with mean total cholesterol (TC) of 168.2 ± 22.6 mg/dL, triglycerides (TG) of 142.1 ± 28.5 mg/dL, low-density lipoprotein (LDL) of 98.4 ± 18.7 mg/dL, and high-density lipoprotein (HDL) of 44.8 ± 5.3 mg/dL. In contrast, patients with HbA1c >9% demonstrated the most adverse lipid profile, with markedly elevated TC (226.5 ± 31.4 mg/dL), TG (214.2 ± 41.6 mg/dL), and LDL (149.3 ± 26.8 mg/dL), along with the lowest HDL levels (33.7 ± 5.1 mg/dL). These findings indicate a strong association between worsening glycemic control and increasing dyslipidemia.

Table 5: HbA1c Category-wise Lipid Profile Comparison (N = 100)

HbA1c Category	n (%)	TC (mg/dL)	TG (mg/dL)	LDL (mg/dL)	HDL (mg/dL)
<7%	24 (24.0)	168.2 ± 22.6	142.1 ± 28.5	98.4 ± 18.7	44.8 ± 5.3
7–9%	46 (46.0)	198.4 ± 29.7	176.6 ± 35.2	121.6 ± 21.9	39.2 ± 4.8
>9%	30 (30.0)	226.5 ± 31.4	214.2 ± 41.6	149.3 ± 26.8	33.7± 5.1

Discussion

The present study evaluated the relationship between glycemic control and lipid profile parameters among 100 patients with type 2 diabetes mellitus. The findings demonstrated significantly elevated fasting blood sugar (182.64 ± 38.52 mg/dL), postprandial blood sugar (256.18 ± 52.74 mg/dL), and mean HbA1c levels (8.14 ± 1.21%), indicating inadequate glycemic control among the study participants. HbA1c reflects average blood glucose levels over the preceding 8–12 weeks and is closely associated with the development of diabetic complications. Previous studies have shown that elevated HbA1c levels are associated with an increased risk of both microvascular and macrovascular complications (McCarter et al., 2004) [9]. The persistently high glycemic indices observed in our study suggest an increased future risk of vascular complications. Similar findings have been reported by Surekha Rani et al. [10], whereas community-based studies involving newly diagnosed patients have documented lower HbA1c levels. The relatively longer duration of diabetes observed in our study population (6.2 ± 2.7 years) may have contributed to the poor glycemic control."

The lipid profile analysis revealed a typical pattern of diabetic dyslipidemia characterized by elevated total cholesterol (199.58 ± 34.16 mg/dL), triglycerides (179.60 ± 46.22 mg/dL), low-density lipoprotein cholesterol (124.34 ± 29.15 mg/dL), and very low-density lipoprotein cholesterol (35.92 ± 9.24 mg/dL), along with reduced high-density lipoprotein cholesterol (38.89 ± 6.84 mg/dL). These findings are consistent with previous studies by Surekha Rani et al. [10] and Wexler et al. [11], which reported increased levels of atherogenic lipids and reduced HDL cholesterol among patients with type 2 diabetes mellitus. Although some population-based studies have reported normal LDL levels with increased concentrations of small dense LDL particles, our findings indicate that overt quantitative dyslipidemia remains common in patients with inadequately controlled diabetes.

In the present study, HbA1c showed moderate positive correlations with total cholesterol ($r = 0.48$, $p < 0.001$), triglycerides ($r = 0.55$, $p < 0.001$), LDL cholesterol ($r = 0.51$, $p < 0.001$), and VLDL cholesterol ($r = 0.44$, $p < 0.001$), whereas an inverse correlation was observed with HDL cholesterol ($r = -0.39$, $p < 0.001$). The strongest association was found between HbA1c and triglyceride levels. These findings are in agreement with those reported by Selvin et al. [12], Jayaram et al. [13], Rosmee and Koley [14], and Erciyas et al. [15], who demonstrated significant associations between poor glycemic control and adverse lipid parameters. Studies conducted among patients with better glycemic control have reported weaker correlations, suggesting that the severity of hyperglycemia may influence the strength of these associations.

Subgroup analysis demonstrated a progressive deterioration in lipid parameters with increasing HbA1c levels. Patients with HbA1c levels below 7% exhibited relatively favorable lipid profiles, whereas those with HbA1c levels greater than 9% had the highest total cholesterol, triglyceride, and LDL levels and the lowest HDL concentrations. These findings are consistent with previous evidence indicating that HbA1c levels above 7% are associated with an increased risk of dyslipidemia and cardiovascular complications (Rohlfling et al., 2002) [16]. Khaw et al. [17] further demonstrated that even modest reductions in HbA1c are associated with lower mortality risk. Therefore, HbA1c may serve not only as an indicator of long-term glycemic control but also as an indirect marker of lipid abnormalities and cardiovascular risk.

The pathophysiological basis for this association is multifactorial. Insulin resistance enhances lipolysis and increases the release of free fatty acids into the circulation, promoting hepatic triglyceride synthesis and increased VLDL production (Boden, 1997)

[18]. This process contributes to elevated triglyceride levels, reduced HDL concentrations, and the formation of small dense LDL particles. Chronic hyperglycemia also promotes glycation of apolipoproteins, thereby disrupting normal lipoprotein metabolism (Carmena, 2008) [19]. The coexistence of insulin resistance, hypertension, and dyslipidemia substantially increases cardiovascular risk in patients with type 2 diabetes mellitus (Mgonda et al., 1998) [20].

Overall, the findings of the present study support previous evidence demonstrating a strong relationship between poor glycemic control and atherogenic dyslipidemia. The observed correlations suggest that HbA1c may serve as a convenient surrogate marker for identifying patients at increased risk of lipid abnormalities and cardiovascular complications. Therefore, comprehensive management strategies targeting both glycemic control and lipid abnormalities are essential for reducing the burden of cardiovascular disease among patients with type 2 diabetes mellitus.

Conclusion

The present study demonstrates a significant association between poor glycemic control and an unfavorable lipid profile among patients with type 2 diabetes mellitus. Higher HbA1c levels were positively correlated with atherogenic lipid parameters, including total cholesterol, triglycerides, LDL cholesterol, and VLDL cholesterol, while an inverse correlation was observed with HDL cholesterol. Furthermore, worsening glycemic status was associated with progressive deterioration in lipid profile parameters across HbA1c categories, indicating that dyslipidemia intensifies with poor glycemic control. These findings suggest that HbA1c may serve not only as a reliable indicator of long-term glycemic status but also as a useful surrogate marker for identifying patients at increased cardiovascular risk. Early detection and effective management of both hyperglycemia and dyslipidemia may help reduce the risk of cardiovascular complications in patients with type 2 diabetes mellitus.

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