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Association of Triglyceride Glucose Index (TYG Index) with Hba1c in Type 2 Diabetes Mellitus Patients

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Abstract

Background: Type 2 diabetes mellitus is a global health challenge associated with significant metabolic and cardiovascular risks. The Triglyceride-Glucose (TyG) index, a marker of insulin resistance and metabolic risk, has gained prominence as a tool to assess the interplay between glycemic control and lipid metabolism. Understanding its association with HbA1c levels may provide insights into better managing patients with type 2 diabetes.

Objectives: To assess HbA1c levels and lipid profiles in patients with type 2 diabetes mellitus, calculate the Triglyceride-Glucose (TyG) index, and study the association between the TyG index and HbA1c levels.

Methods: A cross-sectional study was conducted over 12 months, involving 50 patients with type 2 diabetes mellitus. Participants were aged above 18 years and diagnosed per ADA criteria. Following written informed consent, a detailed history, clinical examination, and laboratory investigations, including FBS, PPBS, HbA1c, lipid profile, RFT, and LFT, were conducted. Patients were categorized based on HbA1c levels (≤7.0% and >7.0%), and the TyG index was calculated using the formula: log [(fasting triglycerides) * (fasting plasma glucose) / 2]. Statistical analysis was performed using SPSS Version 26.0, with a significance level of $\alpha = 0.05$.

Results: The mean age of participants was 54.26 years (SD = 7.82). The mean FBS and triglyceride levels were 137.10 mg/dL (SD = 49.47) and 179.36 mg/dL (SD = 94.42), respectively, while the mean HbA1c was 8.62% (SD = 2.52), indicating poor glycemic control in many patients. Nearly 46% of participants had HbA1c levels above 8%. The TyG ratio demonstrated a significant increase with rising HbA1c levels, from a mean of 4.5980 in the <6% group to 5.3908 in the >10% group ($p < 0.001$). Hypertriglyceridemia was strongly associated with poor glycemic control ($p < 0.001$), while other lipid parameters showed minimal changes.

Conclusion: This study established a significant association between the Triglyceride-Glucose (TyG) index and HbA1c levels, emphasizing the role of metabolic dysregulation in poorly managed type 2 diabetes. These findings underscore the importance of effective glycemic control to mitigate metabolic and cardiovascular risks in this population.

Keywords: Diabetes Mellitus; Triglyceride Glucose index; Insulin resistance; Glycated hemoglobin; Lipid profile.

Introduction

Diabetes mellitus is among the oldest known disorders in the world. Infections, peripheral vascular disease, neuropathy, retinopathy, and nephropathy are all consequences of diabetes mellitus (DM), a metabolic disease that produces micro- and macroangiopathies. Globally, the prevalence of diabetes has been shockingly and consistently increasing due to changes in lifestyle, obesity, and physical inactivity. There are currently 78 million people with diabetes mellitus in Southeast Asia, and by 2040, that figure is expected to increase to 140 million. The WHO estimates that 69.2 million people (8.7%) in India had diabetes in 2015; more than 36 million of these people remained undiagnosed [1].

According to studies, there will likely be 10.2% (578 million) more diabetics worldwide in 2030 than there were in 2019 (9.3% or 463 million). Furthermore, the frequency was 10.8% in urban regions and 7.2% in rural areas. Between 85 and 90 percent of cases of diabetes are type 2. According to the 8th edition of the International Diabetes Federation's (IDF) Diabetes Atlas, the number of diabetics in India is expected to increase from the current 74 million to 134.3 million by 2045. Diabetes mellitus and its related complications are the leading cause of illness and mortality globally [2-4].

Obesity and atherogenic dyslipidemia are common in T2DM patients, significantly raising their risk of coronary artery disease. High levels of triacylglycerol, low density lipoprotein cholesterol (LDL-C), and TG/HDL, a measure of tiny dense LDL particles, have been linked to an increased risk of cardiovascular disease in people with diabetes, according to studies. Insulin resistance and its related consequences have been implicated in the increased incidence of lipid abnormalities in diabetes mellitus [5,6]. The gradual, non-enzymatic glycosylation of hemoglobin results in hemoglobin A1c (HbA1c), a measure of glucose tolerance and glucose control in diabetes. It is displayed in lab tests as the result of dividing HbA1c by total hemoglobin. These days, HbA1c is utilized to control blood sugar levels in diabetic patients and forecast the likelihood of complications from the disease [7].

Insulin resistance can also be shown by the triglyceride-glucose index (TyG index), which is determined using fasting blood glucose (FBG) and triglyceride (TG) readings. In patients with blood glucose levels below 100, it has been demonstrated that the TyG index is a more accurate indicator of diabetes risk than FPG and TG measurements. Low HbA1C levels were linked to a reduced TyG index when patients were compared based on their HbA1C levels. A person's chance of developing diabetes decreases with a lower TyG score. For men, this rise is doubled, and for women, it is quadrupled. According to all of these findings, diabetes individuals' HbA1c levels rise when their TG/HDL-C ratio and TyG index rise [8-11].

This study aims to determine the relationship between the Triglyceride Glucose Index (TyG Index) and HbA1c in Type 2 Diabetes Mellitus patients.

Objectives of The Study

This study was conducted to assess the Hba1C levels and lipid profile in patients with type 2 diabetes mellitus, to calculate Triglyceride-Glucose index (TyG index) and to assess association of Triglyceride-Glucose index (TyG index) with Hba1C levels in type 2 diabetes mellitus patients.

Methodology

We conducted a cross-sectional study in the Department of General Medicine at KIMS Bangalore over a period of 12 months on patients with type 2 diabetes mellitus receiving care at KIMS Hospital, where we included a sample size of 50 participants. We included patients aged above 18 years and who were diagnosed with type 2 diabetes mellitus according to the ADA criteria. The exclusion criteria of our study included patients with type 1 diabetes mellitus, a history of hypo- or hyperthyroidism, cardiovascular diseases, liver diseases, or those who were pregnant.

The study was conducted after obtaining written informed consent from the study subjects. An elaborate history was taken, and a thorough clinical examination of the participants was performed. The subjects were divided into two subgroups based on their HbA1c levels: HbA1c $\leq$ 7.0% (indicating good glycemic control) and HbA1c > 7.0% (indicating poor glycemic control). The following parameters were assessed in the patients: fasting blood sugar (FBS), postprandial blood sugar (PPBS), HbA1c, lipid profile, renal function tests (RFT), and liver function tests (LFT). The Triglyceride-Glucose (TyG) index was calculated using the formula: log [(fasting triglycerides) * (fasting plasma glucose) / 2]. The association between the TyG index and HbA1c levels was then studied.

The data was collected and compiled in MS Excel. Descriptive statistics has been used to present the data. To analyse the data SPSS (Version 26.0) was used. Significance level was fixed as 5% (α = 0.05). Qualitative variables were expressed as frequency and percentages and Quantitative variables are expressed as Mean and Standard Deviation. To assess the relationship between TYG with HbA1c, TYG-BMI and TYG-WC in type 2 diabetes mellitus, chi-square test was used. Mann Whitney Test was used to compare the mean age, duration of diabetes, mean values of anthropometric and biochemical parameters of subjects between well glycemic controlled and poorly glycemic controlled patients. Receiver operating characteristic (ROC) curve analyses was performed to derive the cut off value of all indexes with maximum sensitivity and specificity to assess the Glycemic control.

Results

The total sample size was 50 in the present study. The age distribution reveals that the majority of participants are in the middle-aged to early senior category as depicted in Table 1 & Figure 1. The 51–60 years age group constitutes the largest proportion at 42% (21 individuals), followed by the 40–50 years group at 36% (18 individuals). The 61–70 years age group accounts for 20% (10 individuals), and the 71–80 years group, the least represented, comprises only 2% (1 individual). The mean age of participants is 54.26 years (SD = 7.82).

As seen in Table 2 & Figure 2, the study findings revealed that the mean fasting blood sugar (FBS) level among participants was 137.10 mg/dL (SD = 49.47), while the mean triglycerides level was 179.36 mg/dL (SD = 94.42). The mean high-density lipoprotein (HDL) level was 37.56 mg/dL (SD = 11.99), and the mean total cholesterol level was 167.58 mg/dL (SD = 49.21). Low-

density lipoprotein (LDL) had a mean level of 104.28 mg/dL (SD = 42.04), and very low-density lipoprotein (VLDL) had a mean level of 29.48 mg/dL (SD = 15.35). The mean HbA1c level was 8.62% (SD = 2.52), indicating poor glycemic control in many patients. Additionally, the mean Triglyceride-Glucose (TyG) ratio was 4.97 (SD = 0.36), reflecting the interplay between triglycerides and glucose levels and suggesting a generally elevated cardiovascular risk profile in the study population.

Among participants, 10% have HbA1c levels below 6%, while 44% fall within the 6–8% range. Notably, 22% have levels between 8–10%, and 24% have levels exceeding 10%. This data indicates that nearly half the population (46%) has HbA1c levels above 8%, underscoring the prevalence of poorly managed diabetes within the group (Table 3 & Figure 3).

Analysis of lipid profiles across HbA1c categories reveals significant trends (Table 4 & Figures 4 [A-E]). Triglyceride levels increase markedly with rising HbA1c, from a mean of 100.80 mg/dL in the <6% group to 291.25 mg/dL in the >10% group ($p < 0.001$). HDL levels show a slight, non-significant decline as HbA1c rises ($p = 0.257$). Changes in total cholesterol, LDL, and VLDL across HbA1c groups are minimal and not statistically significant ($p > 0.05$). These findings suggest a strong association between poor glycemic control and hypertriglyceridemia, while other lipid parameters remain relatively unaffected.

The TyG ratio, an established marker of metabolic risk, demonstrates a significant increase with higher HbA1c levels. The mean TyG ratio rises from 4.5980 (SD = 0.13) in the <6% group to 5.3908 (SD = 0.19) in the >10% group ($p < 0.001$). This trend highlights the direct impact of poor glycemic control on metabolic dysregulation and insulin resistance. Overall, these findings emphasize the critical need for effective glycemic management to mitigate metabolic and cardiovascular risks in this population (Table 5 & Figure 5).

Discussion

Hyperglycemia results from changes in insulin secretion, action, or both in diabetes mellitus (DM), a group of metabolic disorders. Recurrent or chronic hyperglycemia is one of the symptoms that can be used to identify it: Fasting blood sugar (FBS) level at or above 126 mg/dL, random plasma glucose at or above 200 mg/dl, and plasma glucose at or above 200 mg/dl two hours after a 75 g oral glucose load as in a glucose tolerance test (GTT) (WHO report, 2006). Diabetes affects 2.4% of people in rural India and 4–11.6% of people in urban regions. The development of both microvascular and macrovascular complications is significantly influenced by insulin resistance and dyslipidemia [12-14].

Research has indicated that the triglyceride/HDL-C ratio is linked to cardiovascular risk, primarily because of insulin resistance. Lastly, they have demonstrated that HDL-C and triglycerides may be indicators of glycemic management, particularly in individuals with type 2 diabetes [20,21].

In the current study, we assessed the HbA1c levels and lipid profiles in patients with type 2 diabetes mellitus and calculated the Triglyceride-Glucose (TyG) index and studied the association between them. The present study, comprising a total sample size of 50 participants, predominantly involved middle-aged to early senior individuals. The age group 51–60 years represented the largest proportion of participants (42%), followed by the 40–50 years group (36%). The mean age of the participants was 54.26 years (SD = 7.82), suggesting a

population at higher risk for both diabetes-related complications and metabolic dysregulation due to aging. In our study, we included a larger and more diverse sample of participants with T2DM, allowing for subgroup analysis based on HbA1c levels and their relationship to metabolic markers, including the TyG index. Comparatively, Selvi et al. (15) studied a population of 140 subjects with a shorter duration of diabetes (less than 2.5 years). The demographic composition in Selvi et al.'s study was nearly balanced between males and females, with slight variations in the two groups, whereas our study focused on gender and age distributions in greater detail, providing insights into gender-specific trends in TyG index and lipid metabolism.

In contrary to our study, Gedikli et al.[16] included a significantly larger sample of 2,938 patients, with 41.3% males and 58.7% females, and a mean age of 57.42 years. However, the mean age our studies were similar.

The mean fasting blood sugar (FBS) level in this study was 137.10 mg/dL (SD = 49.47), accompanied by an average HbA1c of 8.62% (SD = 2.52). This highlights that a significant proportion of participants exhibited poor glycemic control, with 46% having HbA1c levels above 8%. This result is consistent with the findings of Selvi et al. [15], where the poor glycemic control group also exhibited markedly elevated HbA1c levels (10.7%). Both studies emphasize the prevalence of poorly controlled diabetes in their respective populations and underscore the importance of aggressive glycemic management strategies.

In the present study, Lipid profile analysis revealed a mean triglyceride level of 179.36 mg/dL (SD = 94.42) and a mean HDL level of 37.56 mg/dL (SD = 11.99). Triglyceride levels showed a statistically significant increase with worsening glycemic control, from a mean of 100.80 mg/dL in participants with HbA1c <6% to 291.25 mg/dL in those with HbA1c >10% ($p < 0.001$). This aligns with the study by Selvi et al. (15), which also observed significantly elevated triglyceride levels and a higher TG/HDL ratio in participants with poor glycemic control. However, while Selvi et al. [15] reported significantly lower HDL levels in their poor glycemic control group, our study found a slight, non-significant decline in HDL levels with increasing HbA1c ($p = 0.257$). This discrepancy could stem from differences in population characteristics or sample size. Also, Gedikli et al. [16] reported a mean triglyceride level of 1.99 mmol/L and mean HDL cholesterol of 1.13 mmol/L in their research.

When determining the extent of insulin resistance in T2DM, the TyG index is helpful [17]. According to Lee et al. [18], the TyG index may be utilized as a diagnostic criterion to identify people who are metabolically obese but of normal weight. Due to its impact on glucose metabolism, elevated triacylglycerol in diabetic patients results in poor glycemic control. Research has indicated that the TyG index was an excellent predictor of insulin resistance in addition to reflecting glycemic control [19].

In our study, the TyG index showed a marked increase with higher HbA1c levels, from a mean of 4.5980 (SD = 0.13) in participants with HbA1c <6% to 5.3908 (SD = 0.19) in those with HbA1c >10% ($p < 0.001$). Similar to our study, Selvi et al. [15] reported a positive correlation between the TyG index and HbA1c ($r=0.541$, $p < 0.001$), reinforcing the index's role as a reliable marker for insulin resistance and glycemic control. Moreover, the TyG index in Selvi et al.'s study demonstrated predictive utility with an area under the ROC curve (AUC) of 0.806, highlighting its diagnostic potential, which

complements our findings of its significant association with poor glycemic control. Like our study, Gedikli et al. [16] provided specific TyG index values across HbA1c categories: 4.07 for HbA1c <6%, 6.05 for HbA1c 6–8%, 8.84 for HbA1c 8–10%, and 12.03 for HbA1c >10%, depicting significant increases in the TyG index with higher HbA1c levels.

While studies revealed that poor glycemic control is strongly associated with hypertriglyceridemia and a higher TyG index, our findings suggest that other lipid parameters such as LDL and total cholesterol show minimal changes across HbA1c groups, consistent with their lesser involvement in short-term glycemic variability. On the other hand, Selvi et al.'s study reported a significant increase in the TG/HDL ratio, further supporting the interplay between dyslipidemia and poor glycemic control [15].

It was demonstrated in a study by da Silva et al. [22] that patients with a high TyG index had a greater prevalence of CAD. According to recent research, the TyG index is frequently employed as an indicator of insulin resistance. According to Luo et al.'s study [23], patients with ST-elevation myocardial infarction receiving percutaneous coronary intervention who have a high TyG index are at higher risk of experiencing cardiac and cerebrovascular complications. An increase in the TyG index was found to be correlated with an increased risk of ischemic stroke in a research by Shi et al. Zhao et al. [9] demonstrated that a high TyG index was substantially linked to an increased risk of arterial stiffness and microvascular injury.

Overall, our results reinforce the role of the TyG index as a robust surrogate marker for metabolic dysregulation in T2DM. They also highlight hypertriglyceridemia as a key contributor to metabolic and cardiovascular risk in poorly controlled diabetes. Future studies could explore the potential integration of TyG-derived indices, to provide a more comprehensive assessment of cardiometabolic risk factors in diverse populations.

Conclusion

Our study highlighted the significant association between the Triglyceride-Glucose (TyG) index and glycemic control, as measured by HbA1c levels, in patients with type 2 diabetes mellitus. This study finding demonstrate that the TyG index, an easily calculable marker of insulin resistance, increases significantly with worsening glycemic control. Patients with higher HbA1c levels not only exhibited elevated TyG indices but also had markedly higher triglyceride levels, indicating a strong link between poor glycemic management and metabolic dysregulation. These results suggest that the TyG index can serve as a valuable tool in assessing metabolic and cardiovascular risk in diabetic patients, particularly those with poorly controlled blood glucose levels.

Our study also revealed that hypertriglyceridemia is a key contributor to elevated TyG indices in poorly controlled diabetes, whereas changes in other lipid parameters such as HDL, LDL, and total cholesterol were less pronounced. This underscores the importance of targeted interventions to reduce triglyceride levels in addition to improving glycemic control. Given the growing prevalence of type 2 diabetes mellitus and its associated complications, the TyG index offers a simple and cost-effective measure that can assist clinicians in identifying high-risk patients who may benefit from more intensive management strategies.

Furthermore, our study reaffirms the critical need for effective glycemic management to mitigate not only microvascular but also macrovascular complications in

diabetes. Integrating routine TyG index calculation into clinical practice could enhance risk stratification and guide tailored treatment plans, thereby improving patient outcomes.

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Tables and Figures

Table 1: Age Distribution of Study Participants

Age	Frequency	Percent
40-50	18	36.0
51-60	21	42.0
61-70	10	20.0
71-80	1	2.0
MEAN±SD	54.26±7.824	

Figure 1: Age Distribution of Study Participants

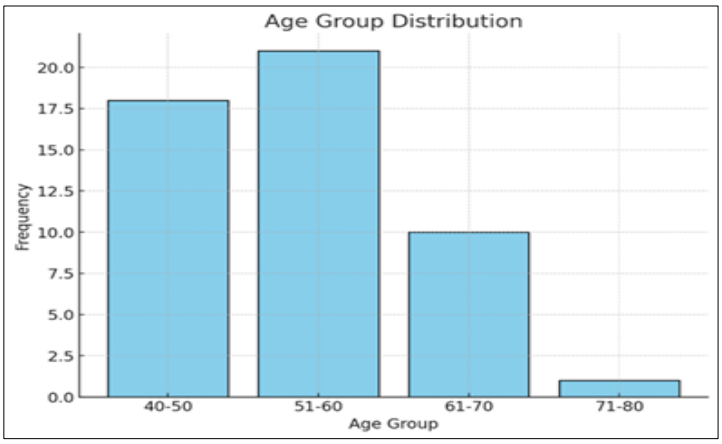


Table 2: Laboratory Parameters

Laboratory Parameters	Mean	Std. Deviation
FBS	137.10	49.470
Triglycerides	179.36	94.415
HDL	37.56	11.987
Total Cholesterol	167.58	49.214
LDL	104.28	42.041
VLDL	29.48	15.349
Hba1c	8.618	2.5231
TyG ratio	4.9680	.36258

Figure 2: Laboratory Parameters

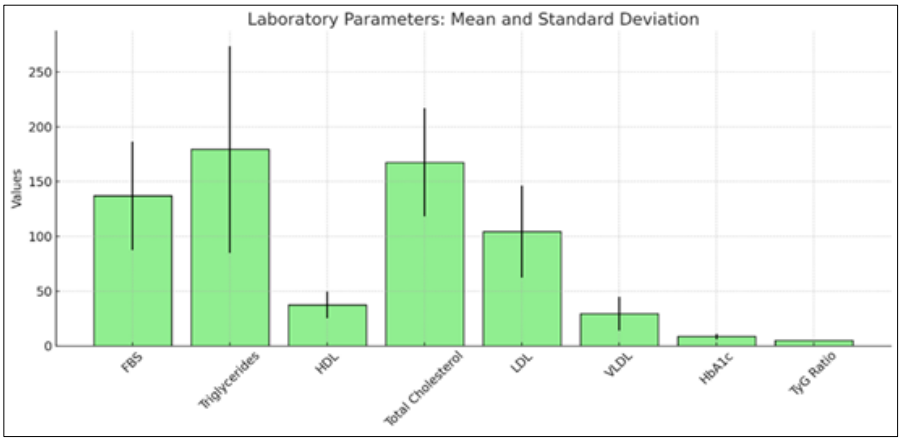


Table 3: Hba1c Level Categories

HbA1c levels	Frequency	Percent
<6	5	10.0
6-8	22	44.0

8-10	11	22.0
>10	12	24.0

Figure 3: Hba1c Level Categories

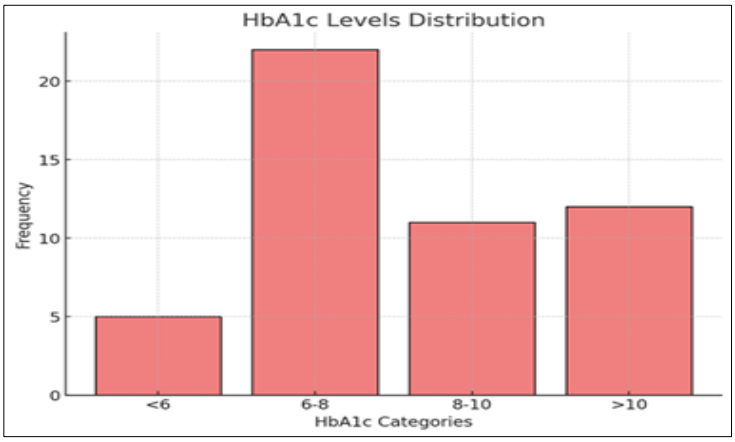
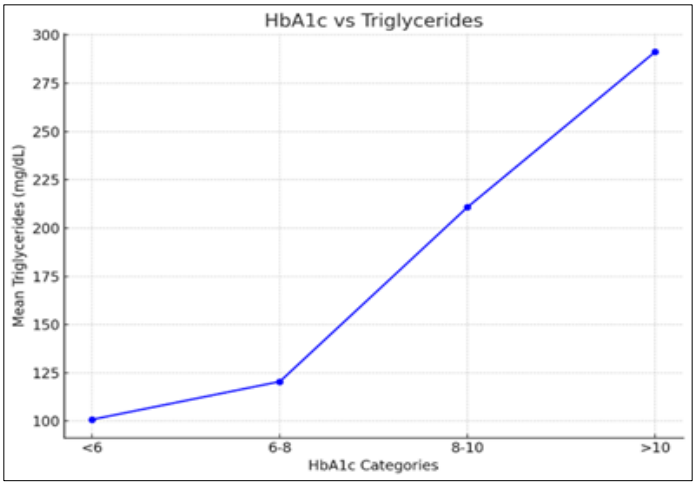
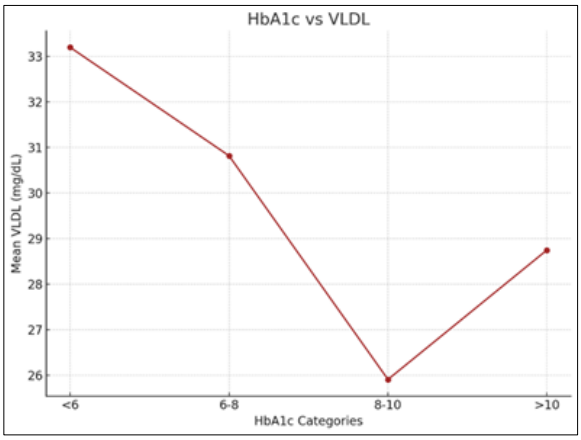


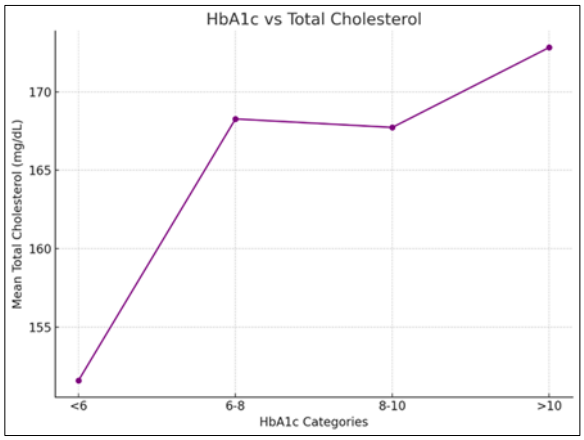
Table 4: Analysis of Lipid Profiles among Hba1c Categories

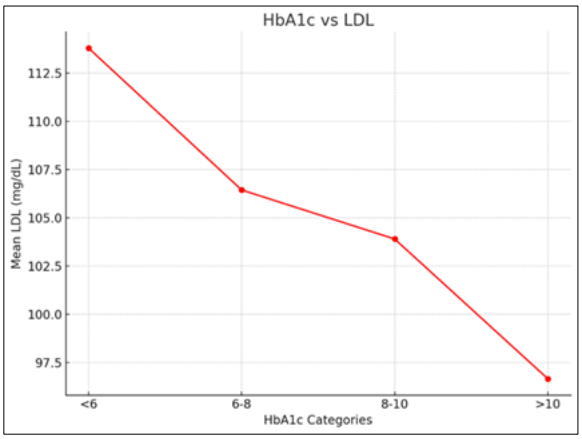
Hba1c		Triglycerides	HDL	Total Cholesterol	LDL	VLDL
<6	Mean	100.80	38.20	151.60	113.80	33.20
	SD	20.462	8.585	36.842	26.790	9.884
6-8	Mean	120.45	40.77	168.27	106.45	30.82
	SD	34.685	14.118	39.550	37.419	15.738
8-10	Mean	210.82	36.73	167.73	103.91	25.91
	SD	77.065	11.723	55.013	51.333	11.300
>10	Mean	291.25	32.17	172.83	96.67	28.75
	SD	86.421	7.383	66.414	49.290	20.046
P value		<0.001	0.257	0.888	0.878	0.654

Figure 4 (A TO E): Trends of Lipid Profile Among Hba1c Levels









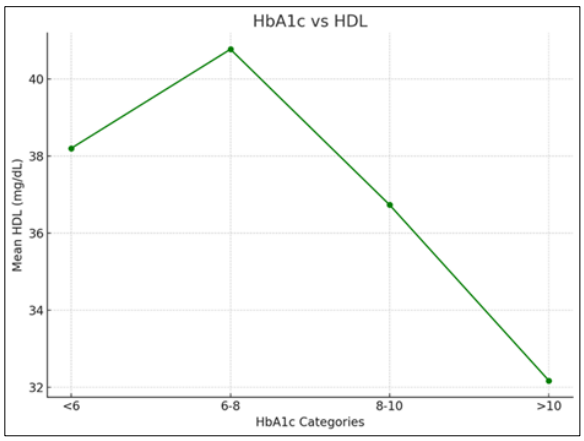


Table 5: Analysis of TYG Ratio among Hba1c Levels

HbA1c levels	TyG Ratio		P value
	Mean	SD	
<6	4.5980	.13461	<0.001
6-8	4.7209	.20679	
8-10	5.1691	.21672	
>10	5.3908	.18672	

Figure 5: Trends of TYG Ratio among Hba1c Levels