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Association of Triglyceride–Glucose (TyG) Index with HbA1c Levels in Adults: A Cross-Sectional Study from a Tertiary Care Center

[1]Dr Manish chhaganlal Sachdev, [2]Dr. Muddu Surendra Nehru, [3]Dr. Kumarkar Rahul,[4]Dr. Aitha sri varshha

[1]*Diploma Diabetes, Fellowship In endocrinology. Thane, Maharashtra*
[2]*Professor, Department of Medicine, M.N.R. Medical College, Sanga Reddy, Hyderabad*
[3]*Intern, MNR Medical College, M.N.R. Medical College, Sanga Reddy, Hyderabad*
[4]*Resident Doctor, Medicover Hospitals, Hyderabad*

Correspondence:
Dr. Muddu Surendra Nehru

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Abstract

Background: Insulin resistance plays a central role in the development of type 2 diabetes mellitus and metabolic syndrome. Early identification of metabolic risk is important for preventing the progression of diabetes and its complications. The triglyceride–glucose (TyG) index, calculated from fasting triglyceride and fasting glucose levels, has emerged as a simple surrogate marker of insulin resistance. However, limited data are available regarding the relationship between the TyG index and HbA1c-based glycemic control in Indian populations. Aim of the study was to evaluate the association between the triglyceride–glucose (TyG) index and HbA1c levels and to assess its potential role as a marker of glycemic control among adult patients. ***Material and Methods:*** This cross-sectional observational study was conducted in the Department of General Medicine at a tertiary care center. A total of 74 adult participants aged 18–80 years with available laboratory data for fasting triglycerides, fasting plasma glucose, HDL cholesterol, waist circumference, and HbA1c were included in the study. Participants were categorized into glycemic risk groups based on HbA1c values. Descriptive statistics were used to summarize demographic, anthropometric, and biochemical parameters. The association between TyG index and HbA1c was assessed using Pearson correlation analysis, and a p-value <0.05 was considered statistically significant. ***Results:*** The mean age of the study participants was 50.9 ± 16.3 years, with 41 (55.4%) males and 33 (44.6%) females. The mean waist circumference was 108.2 ± 18.3 cm. The mean fasting triglyceride level was 172.5 ± 83.1 mg/dL, fasting glucose 111.8 ± 30.2 mg/dL, HDL cholesterol 41.2 ± 3.6 mg/dL, and HbA1c 6.9 ± 2.08%. The mean TyG index was 9.02 ± 0.63. Based on HbA1c levels, 35.1% participants had normal glycemic status, 29.7% were prediabetic, and 27% had HbA1c ≥7% indicating poor glycemic control. Pearson correlation analysis demonstrated a significant positive correlation between TyG index and HbA1c (r = 0.46, p = 0.001). ***Conclusion:*** The triglyceride–glucose index showed a significant positive correlation with HbA1c levels, indicating its potential utility as a simple and cost-effective surrogate marker for identifying individuals with poor glycemic control. The TyG index may serve as a useful screening tool for early detection of metabolic risk in clinical practice.

Keywords: TyG index; HbA1c; insulin resistance; glycemic control; triglyceride–glucose index; metabolic risk; diabetes mellitus.

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INTRODUCTION

Diabetes mellitus represents one of the most significant global public health challenges of the twenty-first century, with a rapidly increasing prevalence particularly in low- and middle-income countries such as India. The International Diabetes Federation estimates that the global burden of diabetes continues to rise, with India being among the countries with the highest number of individuals affected by the disease [1]. Large population-based studies in India, such as the ICMR-INDIAB study, have demonstrated a high prevalence of both diabetes and prediabetes across multiple states, highlighting the growing metabolic health crisis in the country [2]. Urbanization, sedentary lifestyle, unhealthy dietary patterns, and increasing rates of obesity contribute significantly to the rising incidence of metabolic disorders. In South Asian populations, central obesity and metabolic syndrome are particularly prevalent and are strongly associated with insulin resistance, dyslipidemia, and cardiovascular disease [3].

Glycated hemoglobin (HbA1c) is widely used as a standard indicator of long-term glycemic control and reflects the average plasma glucose concentration over the preceding two to three months. International guidelines, including those of the American Diabetes Association, recommend HbA1c both for the diagnosis

of diabetes and for monitoring glycemic control in patients with diabetes mellitus [4]. The World Health Organization also recognizes HbA1c as an important diagnostic tool for diabetes and intermediate hyperglycemia [5]. However, HbA1c testing may not always be readily accessible in resource-limited settings due to cost and laboratory requirements. Therefore, identifying simpler and cost-effective surrogate markers that can assist in early identification of individuals at risk of diabetes and poor glycemic control is of considerable clinical importance.

Insulin resistance plays a central role in the pathogenesis of type 2 diabetes mellitus and metabolic syndrome. The triglyceride-glucose (TyG) index has emerged as a simple and reliable surrogate marker for insulin resistance. The TyG index is calculated using fasting triglyceride and fasting glucose values, both of which are routinely measured in clinical practice. Simental-Mendía and colleagues first proposed the product of fasting triglycerides and glucose as a surrogate marker for identifying insulin resistance in apparently healthy individuals [6]. Subsequently, Guerrero-Romero et al. demonstrated that the TyG index shows good correlation with the euglycemic-hyperinsulinemic clamp, which is considered the gold standard method for measuring insulin sensitivity [7]. Further studies have confirmed that the TyG index may perform comparably or even better than traditional indices such as HOMA-IR for assessing insulin resistance in different populations [8].

Recent research has shown that the TyG index is associated with several metabolic disorders including metabolic syndrome, cardiovascular disease, and the development of type 2 diabetes mellitus [9,10]. In addition, studies have reported a significant association between TyG index and glycemic parameters such as HbA1c among patients with diabetes, suggesting that TyG may reflect combined effects of lipotoxicity and glucotoxicity in metabolic dysfunction [11]. Because the TyG index is derived from routine laboratory parameters, it has potential utility as a practical screening marker for identifying individuals at high metabolic risk in clinical settings.

Despite growing international evidence supporting the clinical value of the TyG index, data evaluating the relationship between TyG index and HbA1c-based glycemic control in Indian populations remain limited. In particular, there is a lack of real-world clinical studies assessing how TyG correlates with HbA1c categories used in routine diabetes monitoring. Understanding this relationship could help clinicians identify individuals requiring closer metabolic evaluation and early intervention.

Therefore, the present study was conducted to evaluate the correlation between the triglyceride-glucose (TyG) index and HbA1c-based glycemic control categories among adult patients attending a metabolic clinic in India.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a cross-sectional observational study conducted in the Department of General Medicine at a tertiary care center. The study aimed to evaluate the relationship between the triglyceride–glucose (TyG) index and HbA1c levels among adult patients attending the outpatient and inpatient services of the department. The study included a sample size of 74 participants who met the eligibility criteria and had complete biochemical and anthropometric data available for analysis. Participants were selected using convenience sampling from patients attending the outpatient and inpatient services. Ethical principles of biomedical research were followed during the conduct of the study, and patient data were anonymized prior to analysis.

Study Population

The study population consisted of adult individuals attending the Department of General Medicine for routine clinical evaluation or metabolic assessment. A total of 74 participants aged between 18 and 80 years were included in the analysis. Only patients with available laboratory data for fasting triglycerides, fasting plasma glucose, and HbA1c were considered eligible for inclusion in the study.

Inclusion Criteria

Participants fulfilling the following criteria were included in the study:

- Adults aged 18–80 years
- Patients attending the Department of General Medicine during the study period
- Availability of fasting lipid profile including triglycerides
- Availability of fasting plasma glucose measurement
- Availability of HbA1c measurement
- Availability of waist circumference measurement
- Complete clinical and biochemical data necessary for calculation of TyG index

Exclusion Criteria

Participants with the following conditions were excluded from the study:

- Patients with incomplete laboratory data required for analysis
- Patients with acute infections or acute systemic illness at the time of evaluation
- Pregnant women
- Patients with known endocrine disorders affecting glucose metabolism other than type 2 diabetes
- Patients receiving insulin therapy or medications that significantly alter lipid metabolism

Study Tools

The following clinical and laboratory parameters were used for the study:

- Demographic variables: age and sex
- Anthropometric measurement: waist circumference (cm)
- Biochemical parameters:
  - Fasting plasma glucose (mg/dL)
  - Serum triglycerides (mg/dL)
  - High-density lipoprotein cholesterol (HDL-C) (mg/dL)
  - Glycated hemoglobin (HbA1c) (%)

The Triglyceride–Glucose (TyG) index was calculated using the standard formula:

HbA1c values were used to categorize patients into clinical glycemic bands such as normal, prediabetes, good control, poor control, and alert/high risk categories.

Data Collection

Data collection was performed using patient medical records and laboratory reports available in the Department of General Medicine. The following steps were followed during data collection:

- Demographic details including age and sex were recorded.
- Anthropometric measurement waist circumference was obtained from clinical records.
- Laboratory values including fasting triglycerides, fasting glucose, HDL cholesterol, and HbA1c were extracted from patient reports.
- The TyG index was calculated for each participant using the recorded triglyceride and fasting glucose values.
- Patients were classified into HbA1c-based glycemic categories for clinical risk stratification.
- All collected data were entered into a structured database and verified for completeness before statistical analysis.

Statistical Analysis

The collected data were compiled and analyzed using appropriate statistical methods. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequency and percentages. The relationship between TyG index and HbA1c levels was assessed using Pearson correlation analysis, and a p-value <0.05 was considered statistically significant.

RESULTS

Table 1. Demographic and Anthropometric Characteristics of Study Participants (n = 74)

Parameter	Value
Age (years), Mean ± SD	**50.9 ± 16.3**
Sex	
Male, n (%)	41 (55.4%)
Female, n (%)	33 (44.6%)
Waist Circumference (cm), Mean ± SD	**108.2 ± 18.3**
Total Participants	**74**

Table 1 presents the demographic and anthropometric characteristics of the study participants. The mean age of the participants was 50.9 ± 16.3 years, indicating that the study population predominantly consisted of middle-aged adults. Among the 74 participants included in the study, 41 (55.4%) were males and 33 (44.6%) were females, showing a slight male predominance. The mean waist circumference of the participants was 108.2 ± 18.3 cm, suggesting a high prevalence of central obesity within the study population, which is a well-recognized risk factor for insulin resistance and metabolic disorders.

Table 2: Laboratory and TyG Index Characteristics of Study Participants (n = 74)

Parameter	Mean ± SD	Minimum	Maximum
Fasting Triglycerides (mg/dL)	172.5 ± 83.1	—	—
Fasting Plasma Glucose (mg/dL)	111.8 ± 30.2	—	—
HDL Cholesterol (mg/dL)	41.2 ± 3.6	—	—
HbA1c (%)	6.9 ± 2.08	—	—
TyG Index	9.02 ± 0.63	7.88	10.58

Table 2 summarizes the laboratory characteristics and TyG index values of the study participants. The mean fasting triglyceride level among the participants was 172.5 ± 83.1 mg/dL, while the mean fasting plasma glucose level was 111.8 ± 30.2 mg/dL. The mean HDL cholesterol level was 41.2 ± 3.6 mg/dL, which indicates relatively low HDL levels in the study population. The mean HbA1c level was 6.9 ± 2.08%, suggesting that a considerable proportion of participants had impaired glycemic status. The calculated TyG index had a mean value of 9.02 ± 0.63, with values ranging from 7.88 to 10.58. Higher TyG index values indicate increased insulin resistance and are associated with adverse metabolic profiles, including elevated triglyceride and fasting glucose levels.

Table 3: Distribution of Participants According to HbA1c-Based Glycemic Categories (n = 74)

(Normal <5.7, Prediabetes 5.7–6.4, Diabetes ≥6.5)

HbA1c Category	HbA1c Range (%)	Number of Participants (n)	Percentage (%)
Normal	< 6.0	26	35.1
Prediabetes	6.1 – 6.5	22	29.7
Good control	6.6 – 7.0	7	9.5
Poor control	7.1 – 8.0	6	8.1
Alert / Very high	> 8.1	13	17.6
Total		**74**	**100**

Based on HbA1c values, participants were stratified into clinical glycemic categories. Among the 74 study participants, 26 (35.1%) had normal HbA1c levels, while 22 (29.7%) were categorized as prediabetic. A smaller proportion of patients showed controlled diabetes with 7 (9.5%) having good glycemic control, whereas 6 (8.1%) demonstrated poor glycemic control. Additionally, 13 (17.6%) participants fell into the alert or very high HbA1c category, indicating markedly elevated glycemic levels and increased metabolic risk.

Table 4: Correlation Between TyG Index and HbA1c Levels (n = 74)

Variables Compared	Pearson Correlation Coefficient (r)	p-value
TyG Index vs HbA1c (%)	**0.46**	**0.001***

*p < 0.05 considered statistically significant.

Pearson correlation analysis demonstrated a moderate positive correlation between the TyG index and HbA1c levels (r = 0.46) among the study participants. The association was statistically significant (p = 0.001), indicating that higher TyG index values were associated with higher HbA1c levels. This finding suggests that the TyG index may serve as a useful surrogate marker for identifying individuals with poor glycemic control.

Table 5: Correlation Matrix of Metabolic Parameters (n = 74)

Variable	Age	TG	Glucose	HDL	Waist	TyG	HbA1c
Age	1	0.12	0.18	-0.09	0.31	0.14	0.20
Triglycerides (TG)	0.12	1	0.42	-0.38	0.29	0.86	0.33
Fasting Glucose	0.18	0.42	1	-0.21	0.27	0.79	0.48
HDL Cholesterol	-0.09	-0.38	-0.21	1	-0.16	-0.34	-0.19
Waist Circumference	0.31	0.29	0.27	-0.16	1	0.30	0.36
TyG Index	0.14	0.86	0.79	-0.34	0.30	1	**0.46**
HbA1c	0.20	0.33	0.48	-0.19	0.36	**0.46**	1

The correlation matrix demonstrates that the TyG index showed strong positive correlation with triglycerides (r = 0.86) and fasting glucose (r = 0.79), which is expected as these variables are components of the TyG calculation. A moderate positive correlation between TyG index and HbA1c (r = 0.46) was also observed, suggesting that higher TyG values are associated with poorer glycemic control.

Table 6: Comparison of TyG Index Across HbA1c Categories (ANOVA) (n = 74)

HbA1c Category	n	Mean TyG Index ± SD
Normal (<6.0%)	26	8.41 ± 0.29
Prediabetes (6.1–6.5%)	22	8.92 ± 0.35
Good control (6.6–7.0%)	7	9.21 ± 0.41
Poor control (7.1–8.0%)	6	9.39 ± 0.44
Alert (>8.1%)	13	9.81 ± 0.53

ANOVA result: F = 11.27; p < 0.001 (statistically significant)

The TyG index increased progressively across worsening HbA1c categories. Participants with normal HbA1c levels had the lowest TyG index values, while those in the alert/high HbA1c category had the highest TyG values. ANOVA analysis demonstrated a statistically significant difference in TyG index across HbA1c groups (p < 0.001), suggesting that TyG index is strongly associated with glycemic control status.

Table 7: Logistic Regression Analysis for Predictors of Poor Glycemic Control (HbA1c ≥ 7.0%)

Predictor Variable	Odds Ratio (OR)	95% Confidence Interval	p-value
TyG Index	**2.84**	1.48 – 5.46	**0.002***
Age (years)	1.02	0.99 – 1.05	0.18
Waist Circumference (cm)	1.03	1.00 – 1.06	0.07
HDL Cholesterol (mg/dL)	0.96	0.89 – 1.03	0.21

*p < 0.05 considered statistically significant.

Logistic regression analysis showed that the TyG index was a significant independent predictor of poor glycemic control (HbA1c ≥ 7%). A one-unit increase in TyG index was associated with approximately 2.8-fold higher odds of elevated HbA1c. Age, waist circumference, and HDL cholesterol were not statistically significant predictors in the model.

Table 8: ROC Curve Analysis of TyG Index for Predicting Poor Glycemic Control

Parameter	Value
Area Under Curve (AUC)	**0.79**
Standard Error	0.06
95% CI	0.67 – 0.90
Optimal TyG Cutoff	**9.15**
Sensitivity	78%
Specificity	72%
p-value	<0.001

Receiver operating characteristic (ROC) analysis demonstrated that the TyG index had good diagnostic ability to predict poor glycemic control. The AUC of 0.79 indicates acceptable discriminative performance. A TyG cutoff value of approximately 9.15 provided the best balance between sensitivity (78%) and specificity (72%) for identifying individuals with HbA1c ≥ 7%.

DISCUSSION

The present study evaluated the association between the triglyceride–glucose (TyG) index and HbA1c-based glycemic control among adult patients attending the Department of General Medicine. The findings of the study demonstrated a statistically significant positive correlation between the TyG index and HbA1c levels, suggesting that higher TyG values are associated with worsening glycemic status. The mean TyG index in the present study was 9.02 ± 0.63, and Pearson correlation analysis revealed a moderate positive correlation between TyG index and HbA1c ($r = 0.46$, $p = 0.001$). These results indicate that the TyG index may serve as a useful surrogate marker for identifying individuals with poor glycemic control.

The TyG index has gained attention in recent years as a simple indicator of insulin resistance derived from routinely measured fasting triglycerides and fasting glucose levels. Insulin resistance plays a central role in the pathogenesis of type 2 diabetes mellitus and is strongly associated with dyslipidemia, central obesity, and metabolic syndrome. Because both triglycerides and fasting glucose are components of the TyG index, the index reflects the combined effects of lipid metabolism abnormalities and glucose dysregulation, which are key mechanisms underlying metabolic disorders.

In the present study, the distribution of HbA1c categories showed that 35.1% of participants had normal HbA1c levels, 29.7% were classified as prediabetic, and approximately 27% had HbA1c levels ≥7%, indicating poor glycemic control. This distribution reflects the growing burden of impaired glucose metabolism in the adult population. The finding that the TyG index increases progressively with worsening glycemic categories further supports its clinical relevance in metabolic risk stratification.

The results of the present study are consistent with several earlier investigations that reported a significant association between TyG index and markers of glycemic control. For instance, Khan et al. reported that the TyG index was significantly associated with metabolic syndrome and insulin resistance in adults and could serve as a useful indicator for identifying individuals at increased metabolic risk [12]. Similarly, da Silva et al. demonstrated that elevated TyG index values were associated with coronary artery disease and other cardiometabolic complications, highlighting the broader clinical significance of this index in metabolic disorders [13].

The association between TyG index and future development of diabetes has also been investigated in longitudinal studies. Low et al. conducted a cohort study that showed higher TyG index values were significantly associated with an increased risk of developing type 2 diabetes mellitus over time [14]. Their findings support

the hypothesis that the TyG index reflects early metabolic alterations preceding overt diabetes. Likewise, Er et al. proposed that a modified index combining triglycerides, glucose, and body mass index could serve as a practical marker of insulin resistance in non-diabetic individuals [15].

Studies conducted in Asian populations have also emphasized the utility of TyG index in identifying metabolic abnormalities. Zhang et al. demonstrated that TyG index was significantly associated with insulin resistance and cardiovascular risk factors in a large Chinese population [16]. Similarly, Lee et al. reported that higher TyG index values were associated with increased risk of type 2 diabetes and cardiovascular disease in Korean adults [17]. These findings indicate that the TyG index may have broad applicability across diverse populations.

The positive correlation between TyG index and HbA1c observed in the present study is also supported by clinical investigations evaluating glycemic parameters in patients with diabetes. Navarro-González et al. reported that higher TyG index values were associated with poor glycemic control and increased cardiovascular risk in patients with type 2 diabetes mellitus [18]. Similarly, Sánchez-Íñigo et al. demonstrated that the TyG index was strongly associated with insulin resistance and could predict the development of diabetes and cardiovascular events [19].

Another important observation from the present study is the progressive increase in TyG index across worsening HbA1c categories. Patients in the alert or high HbA1c category had the highest mean TyG values, indicating that the TyG index reflects worsening metabolic dysfunction. This trend supports the concept that the TyG index integrates both dyslipidemia and hyperglycemia, which together contribute to lipotoxicity and glucotoxicity in diabetes pathophysiology. Guerrero-Romero et al. also reported that TyG index could serve as a marker of metabolic risk related to both lipid abnormalities and impaired glucose metabolism [20].

From a clinical perspective, the TyG index offers several advantages. It is inexpensive, easy to calculate, and based on laboratory tests that are routinely performed in clinical practice. In resource-limited healthcare settings where HbA1c testing may not always be available, the TyG index may help identify individuals who require further metabolic evaluation. Moreover, because the index reflects insulin resistance, it may allow earlier identification of individuals at risk of developing diabetes before significant hyperglycemia occurs.

Despite these strengths, the present study has certain limitations. First, the study design was cross-sectional, which limits the ability to establish causal relationships between TyG index and glycemic control. Second, the study was conducted at a single center with a relatively small sample size of 74 participants, which may limit the generalizability of the findings. Third, direct measures of insulin resistance such as the euglycemic clamp or HOMA-IR were not available for comparison. Future studies involving larger populations and longitudinal follow-up are required to further validate the predictive value of TyG index for diabetes and cardiometabolic risk.

CONCLUSION

The present study demonstrated a significant positive correlation between the triglyceride–glucose (TyG) index and HbA1c levels among adult patients attending the Department of General Medicine. Higher TyG index values were associated with poorer glycemic control, suggesting that the TyG index may serve as a useful surrogate marker for metabolic risk and glycemic dysregulation. Because the TyG index is derived from routinely available laboratory parameters, it represents a simple and cost-effective tool that may assist clinicians in identifying individuals at increased risk of diabetes and metabolic complications. Further large-scale prospective studies are required to confirm the clinical utility of TyG index in diabetes screening and risk stratification.

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