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Association Between Triglyceride-Glucose Index and HbA1c in Prediabetes: A Preliminary Evaluation of a Potential Biomarker

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Abstract

Background: Prediabetes is an intermediate metabolic state associated with a high risk of progression to type 2 diabetes mellitus. Identifying early markers of insulin resistance is essential to prevent disease progression. The Triglyceride Glucose (TyG) index has emerged as a simple and cost-effective surrogate marker of insulin resistance, but its utility in prediabetic individuals remains underexplored.

Aim: To evaluate the Triglyceride Glucose index and its association with HbA1c among prediabetic patients and assess its role as a potential early biomarker of insulin resistance.

Methodology: A preliminary cross-sectional study was conducted among prediabetic subjects and healthy controls. Fasting plasma glucose, triglycerides, and HbA1c levels were measured and the TyG index was calculated. Correlation analysis between HbA1c and TyG index was performed.

Results: Prediabetic individuals showed higher fasting glucose, triglycerides, HbA1c, and TyG index values compared to controls. A significant positive correlation was observed between TyG index and HbA1c among prediabetic participants ($r = 0.32$, $p = 0.022$), indicating that higher TyG values are associated with poorer glycemic control.

Conclusion: The TyG index demonstrated comparable utility to HbA1c in identifying prediabetes and offers a simple, accessible, and cost-effective marker for early detection of insulin resistance. Routine use of the TyG index may support early intervention strategies in high-risk individuals. Larger longitudinal studies are recommended to validate these findings and establish population-specific cutoff values.

Keywords: Prediabetes, Triglyceride Glucose Index, TyG Index, HbA1c, Insulin Resistance, Biomarker, Metabolic Risk, Early Detection, Type 2 Diabetes Prevention

Introduction

Diabetes mellitus (DM) is one of the most common endocrine disorders globally, and its prevalence continues to rise in both developed and developing countries. According to the International Diabetes Federation (IDF), approximately 537 million adults were living with diabetes in 2021, and this number is projected to increase to 783 million by 2045 if effective preventive strategies are not implemented [1]. India, often considered the diabetes capital of the world, currently has more than 77 million individuals diagnosed with diabetes and an estimated 25 million with prediabetes [2].

Prediabetes is defined by impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or glycated haemoglobin (HbA1c) levels ranging from 5.7 percent to 6.4 percent [3]. It represents an intermediate metabolic state between normal glucose regulation and type 2 diabetes mellitus (T2DM). Individuals with prediabetes are at a significantly higher risk of progressing to T2DM, and they also experience early

metabolic abnormalities, including cardiovascular disease, microvascular complications, and metabolic syndrome, even before diabetes develops [4][5].

Insulin resistance (IR) represents a central mechanism linking prediabetes to overt diabetes and associated complications. It impairs glucose uptake and utilization, leading to hyperglycaemia and compensatory hyperinsulinemia. Additionally, IR contributes to dyslipidaemia, systemic inflammation, oxidative stress, and endothelial dysfunction [6]. Therefore, early identification of IR in prediabetic individuals is essential for timely intervention and prevention of diabetes progression. The triglyceride-glucose (TyG) index, introduced by Simental-Mendía et al. in 2008, is a reliable surrogate marker of insulin resistance, calculated using fasting triglycerides (TG) and fasting plasma glucose (FPG) levels [7]. It is derived based on the established association between dyslipidaemia and insulin resistance. The TyG index is computed using the formula: TyG = ln (fasting triglycerides × fasting plasma glucose) / 2. The index offers advantages of simplicity, affordability, and accessibility, since it utilizes routine biochemical parameters. This makes it feasible for use in large-scale screening and primary healthcare settings, unlike the hyperinsulinemia-euglycemic clamp method or HOMA-IR, which require specialized testing and fasting insulin levels [8][9].

Numerous studies have demonstrated strong correlations between the TyG index and the hyperinsulinemia-euglycemic clamp test, as well as with HOMA-IR [8,9]. Furthermore, elevated TyG values have been linked to increased risk of T2DM, metabolic syndrome, non-alcoholic fatty liver disease, and cardiovascular diseases [10-15]. On the other hand, HbA1c is a well-established biomarker for long-term glycaemic control and is used widely for the diagnosis and monitoring of diabetes and prediabetes. Studying the association between TyG index and HbA1c in prediabetic individuals may therefore help determine whether TyG can serve as a dual indicator reflecting both lipid-related insulin resistance and long-term glycaemic burden. Although global evidence supports the utility of the TyG index as a marker of metabolic risk, limited data exist from India, particularly among prediabetic populations. There is a lack of studies from South India, especially in Karnataka, assessing the association between TyG index and HbA1c. Early identification of high-risk individuals using cost-effective surrogate markers such as TyG may support timely preventive strategies and reduce diabetes burden in the region [16-19]. The present study aims to assess TyG index levels and examine their association with HbA1c in prediabetic patients compared to healthy controls. The objectives are: (1) To estimate fasting plasma glucose, triglyceride, and HbA1c levels in prediabetic individuals and healthy controls. (2) To calculate the TyG index using the formula TyG = ln (fasting triglycerides × fasting plasma glucose) / 2. (3) To determine the correlation between TyG index and HbA1c levels in the study population.

Materials & Methods

Study Design

This hospital-based cross-sectional case–control study was conducted to evaluate the association between the Triglyceride–Glucose (TyG) index and glycated hemoglobin (HbA1c) among individuals with prediabetes.

Study Setting and Duration

The study was carried out in the Department of General Medicine, Raja Rajeswari Medical College and Hospital (RRMCH), Bengaluru, after obtaining approval from the Institutional Ethics Committee. Participants were recruited from the General Medicine Outpatient Department during the study period.

Study Population

The study population comprised adults aged 30 to 60 years, including patients diagnosed with prediabetes and apparently healthy age- and sex-matched controls. Prediabetic participants were identified according to the American Diabetes Association (ADA) diagnostic criteria, while healthy controls had no evidence of impaired glucose metabolism or diabetes.

Sample Size

A total of 100 participants were included in the study, consisting of 50 prediabetic patients and 50 age- and sex-matched healthy controls.

Inclusion Criteria

Adults aged 30 to 60 years diagnosed with prediabetes according to ADA criteria and willing to provide written informed consent were included in the case group. Apparently healthy age- and sex-matched individuals without diabetes served as the control group.

Exclusion Criteria

Individuals with known type 2 diabetes mellitus, chronic liver disease, chronic kidney disease, pancreatic disorders, HIV infection, pregnancy, lactation, or any chronic systemic illness were excluded. Participants receiving medications known to influence glucose or lipid metabolism, including corticosteroids, nicotinic acid, fibrates, statins, or other lipid-lowering agents, were also excluded from the study.

Data Collection Tool

After obtaining written informed consent, demographic and clinical information was recorded using a structured case record proforma. All participants underwent overnight fasting for 8–10 hours before venous blood sample collection under aseptic precautions. Fasting plasma glucose was measured using the glucose oxidase–peroxidase (GOD-POD) method, while serum triglyceride levels were estimated by the enzymatic colorimetric method. Glycated hemoglobin (HbA1c) was determined using high-performance liquid chromatography (HPLC). The Triglyceride–Glucose (TyG) index, a surrogate marker of insulin resistance, was calculated using the following formula:

TyG Index = ln [Fasting Triglycerides (mg/dL) × Fasting Plasma Glucose (mg/dL)] / 2

All biochemical investigations were performed in the central clinical biochemistry laboratory using standardized quality control procedures, and the obtained values were recorded systematically for subsequent statistical analysis.

Ethical Considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee of Raja Rajeswari Medical College and Hospital, Bengaluru, before commencement of the study. Written informed consent was obtained from all participants after explaining the objectives and procedures of the study. Confidentiality and anonymity were maintained throughout data collection, analysis, and reporting, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the Indian Council of Medical Research (ICMR) guidelines.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS software version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Comparisons between prediabetic participants and healthy controls were performed using the independent sample t-test. The relationship between the TyG index and HbA1c was evaluated using Pearson's correlation coefficient. A p-value less than 0.05 was considered statistically significant.

Results

Table 1: Baseline Characteristics of Study Participants

Variable	Cases (n = 50)	Controls (n = 50)	*p*-value
Age (years, Mean ± SD)	45.2 ± 6.5	44.8 ± 6.1	0.72
Sex (Male/Female)	28 / 22	27 / 23	0.84
BMI (kg/m², Mean ± SD)	26.5 ± 3.2	24.8 ± 2.9	0.041*

The baseline characteristics of the study participants are summarized in the table. The mean age of the cases (45.2 ± 6.5 years) was comparable to that of the controls (44.8 ± 6.1 years), with no significant difference ($p = 0.72$). The sex distribution was also similar between the two groups (28 males/22 females vs. 27 males/23 females, $p = 0.84$). However, the mean BMI was significantly higher among cases (26.5 ± 3.2 kg/m²) compared to controls (24.8 ± 2.9 kg/m²), indicating a statistically significant association with prediabetes ($p = 0.041$).

Table 2: Comparison of Glycemic Parameters

Parameter	Cases (n = 50)	Controls (n = 50)	*p*-value
Fasting Blood Glucose (mg/dl)	104 ± 8.6	89 ± 7.5	0.022*
HbA1c (%)	5.9 ± 0.3	5.2 ± 0.2	0.022*

The comparison of biochemical parameters between the two groups shows that prediabetic cases had significantly higher fasting blood glucose levels (104 ± 8.6 mg/dl) compared to controls (89 ± 7.5 mg/dl, $p = 0.022$). Similarly, HbA1c levels were elevated in cases (5.9 ± 0.3%) relative to controls (5.2 ± 0.2%, $p = 0.022$). These findings highlight a clear glycemic derangement among prediabetic individuals when compared with healthy controls.

Table 3: Comparison of Lipid Profile

Parameter	Cases (n = 50)	Controls (n = 50)	*p*-value
Triglycerides (mg/dl)	203 ± 22.4	114 ± 18.7	0.022*
Total Cholesterol (mg/dl)	184 ± 25	176 ± 21	0.11
HDL-C (mg/dl)	42 ± 5	46 ± 6	0.09

The lipid profile comparison between cases and controls indicates that prediabetic individuals had significantly higher triglyceride levels (203 ± 22.4 mg/dl) compared to controls (114 ± 18.7 mg/dl, $p = 0.022$), suggesting early dyslipidemic changes associated with prediabetes. Although total cholesterol and HDL-C levels were slightly different between groups (184 ± 25 mg/dl vs. 176 ± 21 mg/dl and 42 ± 5 mg/dl vs. 46 ± 6 mg/dl, respectively), these differences were not statistically significant ($p > 0.05$), indicating that triglycerides may be a more sensitive marker of metabolic disturbance in the prediabetic state.

Table 4: TyG Index between Groups

Group	Mean TyG Index ± SD	
Cases	4.96 ± 0.2	**0.349**
Controls	4.58 ± 0.15	

The mean TyG index was higher in prediabetic cases (4.96 ± 0.2) compared to controls (4.58 ± 0.15); however, this difference did not reach statistical significance ($p = 0.349$). This suggests a trend toward increased insulin resistance among prediabetic individuals, although larger studies may be needed to confirm the significance of this association.

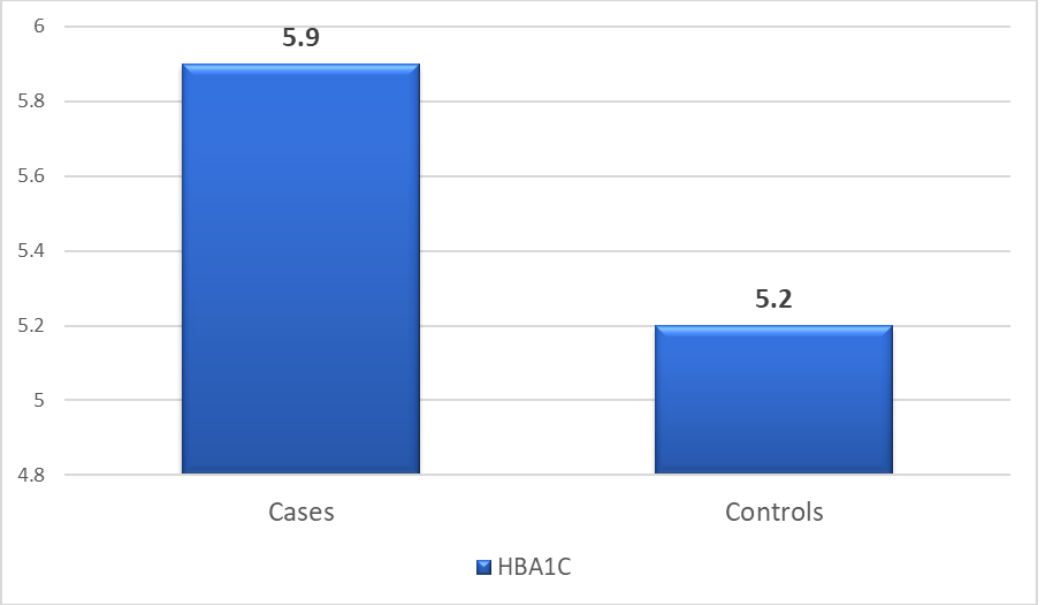
Table 5: Comparison of Biochemical Parameters between Cases and Controls

Group	HbA1c (%)	FBS (mg/dl)	TG (mg/dl)	TyG Index	*p*-value
Cases	5.9	104	203	4.96	0.022*
Controls	5.2	89	114	4.58	0.349

The comparison of key biochemical parameters between cases and controls shows that prediabetic individuals had significantly higher HbA1c (5.9% vs. 5.2%), fasting blood glucose (104 vs. 89 mg/dl), and triglyceride levels (203 vs. 114 mg/dl) compared to healthy controls, with statistical significance observed for HbA1c, FBS, and TG ($p = 0.022$). The TyG index was higher in cases (4.96) than in controls (4.58),

indicating a trend toward increased insulin resistance, though this difference was not statistically significant (p = 0.349). These findings collectively suggest early glycemic and lipid abnormalities in prediabetic subjects.

Figure 1: Comparison of HBA1C between Cases and Controls



Discussion

Prediabetes represents an intermediate state of hyperglycaemia in which plasma glucose levels are above normal but below the diagnostic threshold for diabetes. Individuals with prediabetes carry a substantially increased risk of developing type 2 diabetes mellitus (T2DM) and cardiovascular complications if early intervention is not initiated. Insulin resistance (IR) plays a central role in the transition from prediabetes to diabetes by impairing cellular glucose uptake, resulting in hyperglycaemia and compensatory hyperinsulinemia. Elevated triglyceride levels further exacerbate glycaemic dysregulation by interfering with insulin signalling pathways, reinforcing IR as a key modifiable contributor to diabetes progression, as described by Tabák et al. [1] and Huang et al. [2]. The Triglyceride-Glucose (TyG) index has gained recognition as a simple, cost-effective, and reliable surrogate marker of insulin resistance, as it incorporates fasting triglyceride and fasting glucose levels. This index reflects early metabolic abnormalities that may not be captured by fasting glucose or HbA1c alone. Simental-Mendía et al. [3] first proposed the TyG index as a surrogate marker of insulin resistance. In the present study, prediabetic subjects demonstrated significantly higher fasting glucose, HbA1c, and triglyceride levels compared to healthy controls, consistent with the coexistence of dysglycaemia and dyslipidaemia in the prediabetic stage. Similar metabolic alterations were reported by Vasques et al. [4], who observed higher TyG values among insulin-resistant individuals using hyperglycaemic clamp validation. A noteworthy finding of the present study was the positive correlation between TyG index and HbA1c among prediabetic participants, indicating that higher TyG values are associated with poorer glycaemic control. This observation aligns with findings by Venkateshan et al. [5], who demonstrated a significant correlation between TyG index and HbA1c in prediabetic individuals. Comparable associations were also reported by Lee et al. [6], who identified strong links between the TyG index, insulin resistance, and metabolic syndrome in a Korean population. Furthermore, Zhang et al. [7] reported that elevated TyG values predicted future development of T2DM and cardiovascular disease, reinforcing its utility as an early biomarker of metabolic risk. Although the mean TyG index was higher in prediabetic subjects than in healthy controls, the difference did not reach statistical significance. This lack of significance may be attributable to the relatively small sample size and cross-sectional study design, which may limit the detection of modest differences. Nevertheless, the observed upward trend is consistent with reports by Simental-Mendía et al. [3] and Vasques et al. [4], both of whom documented significantly higher TyG values in insulin-resistant and prediabetic populations.

From a clinical perspective, the TyG index offers several advantages, including low cost, ease of calculation, and reliance on routinely available laboratory parameters. The observed correlation between TyG index and HbA1c in the present study suggests that combined use of these markers may enhance early identification of individuals at high metabolic risk. Several recent studies have emphasized the expanding clinical relevance of the TyG index in predicting prediabetes, diabetes, and cardiovascular outcomes, as highlighted by Ye et al. [19], Liu et al. [20], Shi et al. [21], Park et al. [22], Wen et al. [23], and Liu et al. [24]. Early screening using the TyG index may therefore play a crucial role in delaying or preventing the progression from prediabetes to overt diabetes.

Conclusion

The present study demonstrates that the Triglyceride-Glucose (TyG) index shows significant potential as a reliable biomarker for identifying individuals with prediabetes and assessing insulin resistance, exhibiting utility comparable to HbA1c. Since the TyG index is derived from routine laboratory tests, including fasting plasma glucose and fasting triglycerides, it is simple, inexpensive, and easily accessible across healthcare settings. This makes it a particularly valuable tool in resource-constrained environments where advanced glycemic markers may not be routinely available. Based on our findings, the TyG index can serve as an effective adjunct, and in certain circumstances a viable alternative, to HbA1c for early detection and risk stratification in prediabetes and metabolic dysregulation. Therefore, integration of the TyG index into clinical evaluation protocols may support timely intervention and prevention of progression to type 2 diabetes.

Conflict of Interest: Nil

Reference

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