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Diagnostic Performance of Triglyceride Glucose (TyG) Index for Type 2 Diabetes in Bangladeshi Adults

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Abstract

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder in which the body cannot properly use insulin, leading to high levels of glucose in the blood. The rising prevalence of T2DM in Bangladesh necessitates accessible and cost-effective tools for early detection and metabolic risk assessment. The triglyceride–glucose (TyG) index has emerged as a reliable surrogate marker of insulin resistance, a central mechanism in T2DM pathogenesis. This analytical cross-sectional study evaluated the association between the TyG index and T2DM and assessed its diagnostic performance in Bangladeshi adults. A total of 91 participants were recruited from Gopalganj Diabetic Hospital and Gopalganj Medical College, including 61 T2DM patients (newly diagnosed, treated uncontrolled, and treated controlled) and 30 non-diabetic controls. Fasting triglycerides and fasting glucose were measured, and the TyG index was calculated as Ln [triglycerides (mg/dL) × fasting glucose (mg/dL) / 2]. The mean TyG index was significantly higher in T2DM patients than in controls (7.20 ± 0.092 vs. 6.01 ± 0.092, $p<0.0001$). Receiver operating characteristic analysis demonstrated excellent discriminatory ability with an area under the curve of 0.892 (95% CI: 0.821–0.963). At an optimal cutoff of 6.617, the sensitivity was 78.7%, specificity 93.3%, and positive predictive value 96.0%. These findings indicate a strong association between elevated TyG index values and T2DM. The TyG index represents a simple, affordable, and non-invasive marker with high diagnostic accuracy, making it a valuable tool for metabolic screening and risk stratification in resource-limited settings.

Keywords: TyG index; insulin resistance; diabetes mellitus; diagnostic marker

1. Introduction

Type 2 Diabetes Mellitus (T2DM) represents a significant and growing global public health challenge, characterized primarily by hyperglycemia due to defects in the production, secretion, or action of insulin (American Diabetes Association, 2024). Insulin resistance (IR), a condition where cells fail to respond effectively to insulin, often precedes the onset of overt T2DM by several years and is a core pathological mechanism underlying cardiometabolic diseases (DeFronzo et al., 2015). The incidence of diabetes continues to rise, affecting approximately 589 million individuals globally as of 2024, representing 11.1% of the global adult population. According to the International Diabetes Federation (IDF), 13.9 million adults in Bangladesh are currently living with diabetes, a figure projected to reach 23.1 million by 2050. Most cases are classified as T2DM, accounting for roughly 90% of cases worldwide, with over 81% of these individuals living in low- and middle-income countries (https://diabetesatlas.org/, accessed on January 23, 2025). Early and cost-effective identification of IR is therefore crucial for risk stratification and timely intervention (Levy et al., 1998).

Current diagnostic methods, including fasting plasma glucose (FPG), oral glucose tolerance tests (OGTT), and Hemoglobin A1c (HbA1c), have notable limitations. HbA1c can be unreliable in patients with erythrocyte disorders and is often costly for primary healthcare settings (Gallagher et al., 2009). Furthermore, the "gold standard" for measuring IR the hyperinsulinemic-euglycemic clamp is too invasive and expensive for large-scale clinical use (DeFronzo et al., 2015).

Surrogate markers like the Homeostatic Model Assessment for IR (HOMA-IR) require fasting insulin measurements, which lack global standardization (Wallace et al., 2004). Consequently, the Triglyceride-Glucose (TyG) index has emerged as a promising alternative. As a non-insulin-based marker, it integrates

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hypertriglyceridemia and hyperglycemia two pillars of IR pathophysiology (Simental-Mendía et al. 2008). Studies have validated its strong correlation with the euglycemic clamp and its predictive superiority over HOMA-IR in various populations (Guerrero-Romero et al., 2010; Du et al., 2014).

Given the rising prevalence of T2DM in Bangladesh, establishing context-specific markers is essential. This study aimed to investigate the association of the TyG index with IR in Bangladeshi T2DM patients. Preliminary findings show a significant difference between healthy participants (Mean TyG: 6.09) and T2DM patients (Mean TyG: 7.20). Receiver Operating Characteristic (ROC) analysis yielded an Area Under the Curve (AUC) of 0.892, demonstrating strong discriminatory power.

2. Materials and Methods

2.1. Study Design and Population

This analytical cross-sectional study was conducted to investigate the association between the Triglyceride-Glucose (TyG) Index and insulin resistance in Bangladeshi adults with type 2 diabetes mellitus (T2DM). This study was approved by the Department of BMB, Goplaganj Science and Technology University, Gopalganj (gstu/bmb/KKD). Data were collected from T2DM patients attending Gopalganj Diabetic Hospital between December 2023 and March 2024. A total of 91 participants were enrolled, comprising 61 diagnosed diabetes mellitus patients (26 male and 35 female patients) and 30 non-diabetic individuals (15 male and 15 female) serving as a control group. Participants in the control group had fasting glycemia below 5.9 mmol/L, were not on glucose-lowering medication, and had no history of diabetes or metabolic disorders.

2.2. Collection of Participant Data

Sociodemographic and clinical data were collected using a standardized questionnaire administered by trained medical personnel. The collected information included age, gender, body mass index (BMI), history of hypertension, cardiovascular disease or stroke, family history of diabetes, work stress, physical activity, smoking status, alcohol consumption, history of major health issues, and pregnancy frequency. BMI was calculated as weight (kg) divided by height squared (m2). Blood pressure (BP) was measured using automated sphygmomanometers on the right upper arm after 10 minutes of rest in a seated position. The average of two readings was recorded, and BP classification followed the American College of Cardiology (ACC)/American Heart Association (AHA) guidelines.

2.3. Blood Sample Collection and Processing

Approximately 2 ml of venous blood was collected from each participant under fasting conditions and two hours after ingesting 75 grams of glucose dissolved in 250 ml of water. Blood samples were drawn using vacuum blood collection EDTA (anticoagulant) tubes and immediately placed in a cooler box for transportation. The fasting and postprandial blood glucose levels were measured using an automatic blood glucose analyzer (GA series, Yokohama, Kanagawa, Japan) at the Biochemistry Lab of Gopalganj Diabetic Hospital. Upon arrival at the Department of Biochemistry and Molecular Biology, Gopalganj Science and Technology University, Bangladesh, blood samples were transferred to 2 ml round-bottom closed microcentrifuge tubes. Plasma was separated via centrifugation at 3000 rpm for 10 minutes using a TC-SPINPLUS-8 centrifuge (Topscien Instrument Company Limited, Italy). Separated plasma and cellular components were stored at −86 °C in a FROILABO 340L Vertical Deep Freezer (Collégien, France) for future biochemical analysis.

2.4. Lipid Profile Analysis

Lipid profile assessments were conducted at the Biochemistry Lab of Gopalganj Medical College Hospital, Gopalganj, using the Dimension® Xpand® Plus Integrated Chemistry System (Siemens Healthineers, Erlangen, Germany). The lipid parameters measured included total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c), and triglycerides (TG). Plasma samples (approximately 300μL) were analyzed, and dyslipidemia was defined in accordance with the American Diabetes Association guidelines, characterized by elevated triglycerides exceeding 150 mg/dL, total cholesterol greater than 200 mg/dL, and low-density lipoprotein cholesterol above 100 mg/dL, along with reduced high-density lipoprotein cholesterol levels below 40 mg/dL in men and below 50 mg/dL in women.

2.5. Calculation of Triglyceride-Glucose Index (TyG Index)

The TyG index was calculated using the formula:

$$\ln = \frac{Fasting\ triglycerides\ (mg/dL) \times Fasting\ glucose\ (mg/dL)}{2}$$

This index is a widely used surrogate marker for insulin resistance.

2.6. Statistical Analysis

Data were compiled, verified, and analyzed using Microsoft Excel 2016 and SPSS version 25.0 (IBM Corporation). Continuous variables are presented as mean ± standard deviation (SD), and categorical variables as percentages. The Chi-square test was used for categorical data, and analysis of variance (ANOVA) was employed to compare mean values across multiple groups. Linear regression was used to examine relationships between the TyG index and laboratory parameters. Statistical significance was defined as $p<0.05$.

2.7. Receiver Operating Characteristic (ROC) Analysis

The diagnostic performance of the Triglyceride–Glucose (TyG) index was assessed using receiver operating characteristic (ROC) curve analysis, a non-parametric method that evaluates the trade-off between sensitivity and specificity across a range of threshold values. The ROC curve was constructed by plotting sensitivity (true positive rate) against 1−specificity (false positive rate). Overall discriminatory accuracy was quantified by calculating the area under the ROC curve (AUC) using the trapezoidal rule, which reflects the probability that a randomly selected individual with type 2 diabetes mellitus (T2DM) would have a higher TyG index value than a randomly selected healthy control. An AUC value of 0.5 indicates no discriminative ability, whereas a value of 1.0 represents perfect diagnostic accuracy. The optimal cut-off value for distinguishing between T2DM patients and healthy individuals was determined using Youden's index, defined as sensitivity plus specificity minus one, with the maximum value indicating the best balance between true positive and true negative classification. At this optimal threshold, diagnostic performance measures including sensitivity, specificity, and positive predictive value (PPV) were calculated, with PPV defined as the proportion of individuals with a positive test result who were confirmed to have T2DM within the study population.

2.8. Ethical Considerations

This study was conducted in accordance with ethical principles outlined in the Declaration of Helsinki. All participants provided informed consent before data collection. Confidentiality of participant data was maintained throughout the study, and no personally identifiable information was disclosed in the final analysis and reporting.

3. Results

In the present study, 91 study participants (41 male and 50 female) were enrolled. Among them, 26 males and 35 females had type 2 diabetes, as determined by the biochemical parameters, based on the criteria of the American Heart Association/ National Heart, Lung, and Blood Institute Scientific Statement. Then study subjects were further evaluated by Triglycerides and Glucose Index (TyG Index) tool.

3.1. Association of TyG Index with T2DM

The mean TyG index was calculated and compared between the healthy control group and the overall T2DM patient group. As shown in **Fig. 1,** the TyG index was significantly higher in patients diagnosed with Type 2 Diabetes Mellitus (mean=7.20) compared to the healthy control group (mean=6.09) ($p<0.0001$). This substantial difference strongly suggests that the TyG index is significantly associated with the presence of T2DM in this Bangladeshi adult population.

3.2. TyG index according to age subgroups

The TyG index of each age group was also determined (**Fig. 2**). The highest computed index of 7.20 ± 0.12 belonged to patients aged 45 to 64, while the lowest index of 6.75 ± 0.29 belonged to elderly patients aged 65 and above. All the age groups of patients showed significant difference in the TyG indices when compared with healthy individuals. Regarding sex, a higher mean index (7.29 ± 0.11) was obtained from females, but this did not significantly differ from the mean index of male patients (7.07 ± 0.16) (**Fig. 1**). The mean TyG index between healthy male (6.14 ± 0.10) and female (6.05 ± 0.15) showed no significant difference (**Fig. 1**).

3.4. Discriminatory Power of the TyG Index

To assess the utility of the TyG index as a diagnostic marker, Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate its ability to discriminate between T2DM patients and healthy controls. The TyG index demonstrated excellent discriminatory power, yielding an Area Under the Curve (AUC) of 0.892 (95% CI: 0.821–0.963), as illustrated in **Fig. 3**. This AUC value is substantially greater than the 0.500 AUC for a random guess, confirming the high diagnostic accuracy of the TyG index in this cohort. At the cutoff point 6.617 (maximizing Youden's index), the sensitivity was 78.7%, the specificity was 93.3% and the positive predictive value (ppv) was 96.0%. This result suggests a highly reliable association between elevated TyG index values and T2DM status in this cohort.

Sensitivity, specificity, positive predictive value (PPV) of TyG Index in prediction of type 2 diabetes in male study subjects were 61.54%, 100.00% and 100.00% respectively (**Fig. 4**). However, in female study subjects, sensitivity, specificity and positive predictive value (PPV) were 91.43%, 86.67% and 94.12% respectively (**Fig. 5**). Receiver Operating Characteristic (ROC) curve analysis showed that the optimal cutoff value of TyG index in male study subjects was 6.755, and area under the curve (AUC) was 0.795; those indicated that TyG index is a good predictorof type 2 diabetes in adult males. (**Fig. 4**). Similarly, in female study subjects, the optimal cutoff value was 6.617, and area under the curve (AUC) value was 0.9448; those also indicated that TyG index is a good tool for prediction of type 2 diabetes in adult females (**Fig. 5**).

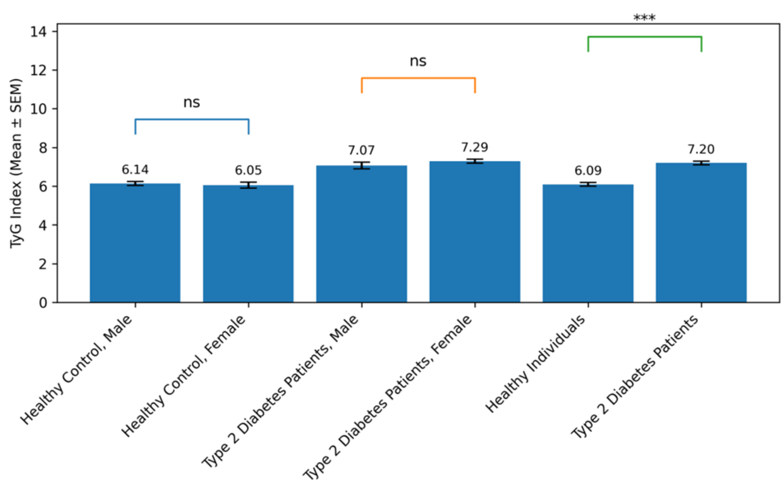

Fig. 1. Comparative analysis of mean triglyceride–glucose (TyG) index values between healthy individuals and patients with type 2 diabetes.

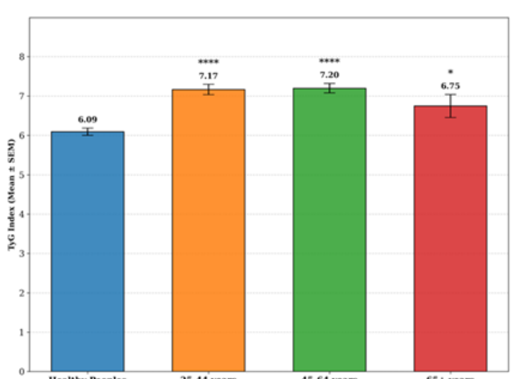

Fig. 2. Comparison of TyG index among type 2 diabetes patients of different age groups and healthy individuals

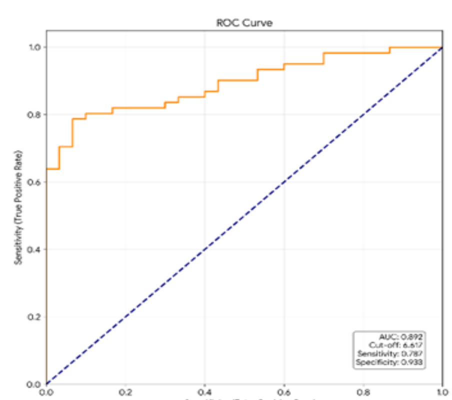

Fig. 3. Receiver operating characteristics (ROC) curve for TyG index for the prediction of type 2 diabetes.

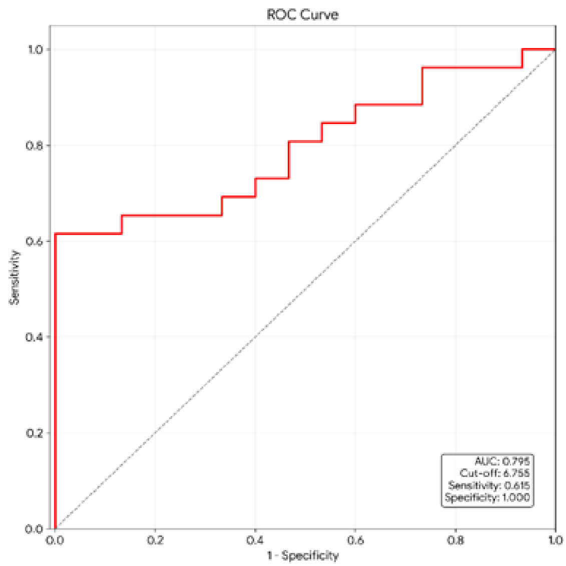

Fig. 4. Receiver operating characteristics (ROC) curve for TyG index for male study subjects

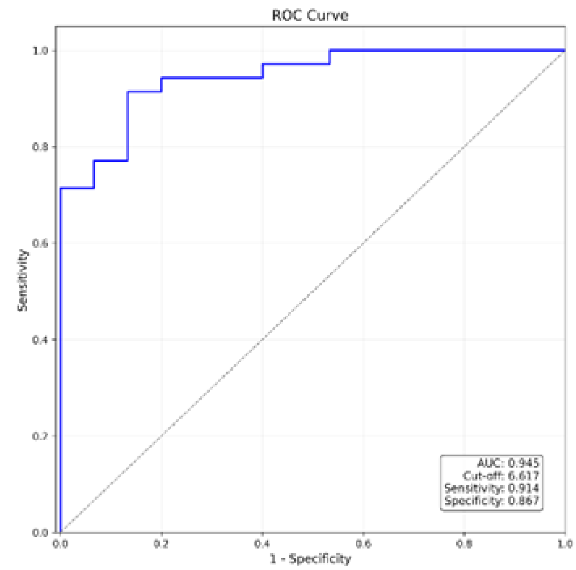

Fig. 5. Receiver operating characteristics (ROC) curve for TyG index for female study subjects

4. Discussion

The present study investigated the association between the triglyceride–glucose (TyG) index and type 2 diabetes mellitus (T2DM) in Bangladeshi adults, and evaluated its diagnostic utility as a surrogate marker of insulin resistance. Conventional diagnostic methods such as fasting plasma glucose (FPG), oral glucose tolerance test (OGTT), and hemoglobin A1c (HbA1c) have notable limitations. HbA1c is relatively costly for primary healthcare settings and may be unreliable in individuals with erythrocyte disorders (Gallagher et al., 2009). The hyperinsulinemic–euglycemic clamp, although the gold standard, is invasive and impractical for routine clinical use (DeFronzo et al., 2015). Similarly, surrogate indices like HOMA-IR require fasting insulin measurements, which lack standardization (Wallace et al., 2004).

In contrast, the TyG index has emerged as a simple and reliable alternative. As a non-insulin-based marker, it reflects both hypertriglyceridemia and hyperglycemia key components of insulin resistance (Simental-Mendía et al., 2008). Previous studies have demonstrated its strong correlation with the euglycemic clamp and, in some populations, superior predictive performance compared to HOMA-IR (Guerrero-Romero et al., 2010; Du et al., 2014). In line with these findings, our results show significantly higher TyG index values in individuals with T2DM compared to healthy controls, supporting its strong association with diabetic status in this population.

A marked difference in mean TyG index values was observed between T2DM patients and healthy individuals, with diabetic participants showing substantially higher values. In this study, the T2DM group comprised heterogeneous subcategories, including newly diagnosed, treated but uncontrolled, and treated controlled patients. These subgroups were combined into a single T2DM category to evaluate the overall diagnostic performance of the TyG index in distinguishing diabetic from non-diabetic individuals. Although treatment status may influence metabolic parameters, the consistently elevated TyG index observed across the diabetic group suggests that it reflects underlying metabolic dysfunction irrespective of disease stage or treatment status. Nevertheless, future studies with larger sample sizes should explore subgroup-specific differences in greater detail.

Age-stratified analysis revealed that elevated TyG index values were present across all diabetic age groups when compared with healthy controls, indicating that the association between TyG index and T2DM is not restricted to a specific age category. The highest TyG index values were observed in middle-aged adults, reflecting a period where metabolic dysregulation appears most pronounced. Although slightly lower values were seen in older individuals, the TyG index remained significantly elevated compared with healthy participants, highlighting its applicability across the adult lifespan.

Sex-based analysis showed that the TyG index was higher in female patients than in male patients, although the difference was not statistically significant. Importantly, diagnostic performance differed by sex. In female participants, the TyG index demonstrated very high sensitivity and strong overall discriminatory power, while in males it showed perfect specificity with comparatively lower sensitivity. These findings indicate that while the TyG index performs well in both sexes, its screening characteristics may vary, suggesting potential biological or metabolic differences in glucose–lipid interactions between men and women.

Receiver operating characteristic (ROC) curve analysis confirmed the strong diagnostic utility of the TyG index. The area under the curve indicated excellent discriminatory ability to differentiate individuals with T2DM from healthy controls. The identified optimal cutoff value provided a favorable balance between sensitivity and specificity, with particularly high specificity and positive predictive value. This implies that individuals with TyG index values above the cutoff are highly likely to have T2DM, minimizing the risk of false-positive classification.

The high positive predictive value observed in this study is especially relevant for clinical and public health use, as it suggests that the TyG index can reliably identify individuals with diabetes using only routinely available laboratory measurements. The strong performance of the index across age and sex subgroups further supports its robustness as a diagnostic and screening tool in diverse adult populations.

Overall, the findings of this study indicate that the TyG index is strongly associated with T2DM and demonstrates excellent diagnostic accuracy in Bangladeshi adults. Its simplicity, reliance on fasting glucose and triglyceride measurements, and strong discriminatory performance make it a practical and effective marker for identifying individuals with T2DM in routine clinical settings. The results support the potential use of the TyG index as a cost-effective tool for metabolic risk assessment and diabetes screening, particularly in resource-limited healthcare environments.

This study has several limitations. First, the sample size was relatively small, which may limit the generalizability of the findings despite the statistically robust associations observed. Second, potential confounding factors such as age, body mass index (BMI), physical activity, dietary habits, and the use of lipid-lowering or antidiabetic medications were not comprehensively analyzed in relation to the TyG index. Third, the cross-sectional design precludes any inference of causality or predictive value over time. Therefore, large-scale, longitudinal studies are required to validate these findings and to further assess the prognostic utility of the TyG index in the Bangladeshi population.

5. Conclusion

This study demonstrates a strong and significant association between the triglyceride–glucose (TyG) index and type 2 diabetes mellitus (T2DM) in Bangladeshi adults, confirming its value as a reliable surrogate marker of insulin resistance. The TyG index was markedly higher in T2DM patients than in healthy controls and showed excellent discriminatory ability, with a high area under the ROC curve and favorable sensitivity, specificity, and positive predictive value. These findings highlight the robustness of the TyG index in identifying individuals with T2DM across different age groups and in both sexes, with particularly strong performance observed among female participants. Given its simplicity, low cost, and reliance on routinely available laboratory parameters, the TyG index represents a practical and scalable tool for early detection of insulin resistance and metabolic risk in resource-limited settings such as Bangladesh. Incorporating the TyG index into routine clinical practice and community-based screening programs may facilitate timely intervention, improve risk stratification, and contribute to better prevention and management of T2DM and its associated complications. Future large-scale, longitudinal studies are warranted to validate these findings and to explore the predictive value of the TyG index for incident diabetes and cardiovascular outcomes in the Bangladeshi population.

Conflict of Interest

The authors declare no conflict of interest.

Declaration by authors

The project received significant contributions from all co-authors, including project design, facilities, data analysis, and guidance. The authors used ChatGPT (OpenAI, San Francisco, CA, USA) solely to improve grammar, language clarity, and formatting of the manuscript. All study design, data collection, analysis, interpretation, and intellectual content were conducted by the authors.

Ethical Approval

This study was approved by the Department of BMB, Goplaganj Science and Technology University, Gopalganj (gstu/bmb/KKD).

Approval of the research protocol

Not applicable

Informed consent

All participants provided informed consent.

Acknowledgement

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