# TRIGLYCERIDE–GLUCOSE INDEX: AN INDICATOR OF THE INTERRELATIONSHIP BETWEEN LIPIDS AND GLUCOSE IN DIABETIC PATIENTS

**Jonida ALITI[1], Luzana SHABANI[1], Mimoza BAFQARI-BAKIJI[2], Nexhbedin BEADINI[2], Mije REÇI[1]**

*Faculty of Mathematics and Natural Science, Department of Biology – Biochemistry, University of Tetova*
*[2] Faculty of Medical Sciences, University of Tetova*
*E-mail of corresponding author: j.aliti252121@unite.edu.mk*

**Abstract**

Diabetes mellitus represents one of the most prevalent chronic diseases worldwide and is associated with a considerable health and economic burden, primarily due to its metabolic and cardiovascular complications. Insulin resistance (IR) is a key mechanism in the pathogenesis of these disorders, while the triglyceride–glucose (TyG) index has been proposed as a simple, practical, and reliable indicator for its indirect assessment. The aim of this study was to evaluate the role and clinical validity of the TyG index in patients with diabetes in the Tetovo region, as well as to analyze its association with metabolic parameters. This study is a retrospective investigation and included a total of 251 participants, of whom 201 were patients with diabetes mellitus, and 50 were healthy individuals serving as the control group. Blood samples were collected in the fasting state and analyzed for glucose and triglycerides using standard laboratory methods. The TyG index was calculated according to the formula ln [TG (mg/dL) × FBG (mg/dL) / 2]. Statistical analysis was performed using IBM SPSS software, with the level of statistical significance set at $p < 0.05$. The results showed a statistically significant increase in the TyG index in the diabetic group compared to the control group (8.91 ± 0.62 vs. 8.64 ± 0.29; $p = 0.003$). Furthermore, a progressive increase in the TyG index was observed in relation to fasting glucose levels, particularly in patients with hyperglycemia ≥ 6.1 mmol/L. Correlation analysis revealed a positive and statistically significant association between glucose and triglycerides in diabetic patients ($r = 0.234$; $p = 0.001$). In conclusion, the TyG index represents a valuable, cost-effective, and easily applicable biomarker for the assessment of insulin resistance and metabolic disturbances, supporting its use in the early identification of high-risk individuals and in optimizing the clinical management of diabetes mellitus.

*Key words:* Triglyceride–glucose index (TyG), diabetes, glucose, triglycerides

## Introduction

Diabetes is one of the most widespread and serious chronic diseases worldwide. It represents a major cause of mortality and is increasingly considered a significant threat to global development. The chronic nature of diabetes and its associated complications make it a high-cost disease (Afroz et al., 2018). According to global estimates, approximately 415 million individuals worldwide are living with diabetes, while nearly 193 million others are believed to have the disease without being aware of it due to underdiagnosis. The most common form is type 2 diabetes, which accounts for more than 90% of all cases. This condition is associated with the development of microvascular and macrovascular complications, which significantly affect patients' quality of life, leading to both physical consequences and psychological burden for affected individuals and their families. Consequently, diabetes poses a considerable challenge to healthcare systems and substantially increases medical care costs (Chatterjee et al., 2017). In 2021, the global prevalence of diabetes among individuals aged 20–79 years was estimated at approximately 10.5%, corresponding to about 536.6 million affected individuals. Projections indicate that by 2045, this proportion may rise to 12.2%, encompassing around 783.2 million people. The distribution by sex appears to be nearly equal between males and females, while the highest incidence is observed in the 75–79 age group (Sun et al., 2022). Insulin resistance (IR) is considered an important metabolic factor that contributes to the development of primary hypertension through various pathogenic mechanisms. The identification of IR in patients with hypertension is of particular clinical importance, as it enables more accurate assessment and stratification of additional cardiovascular risk. Moreover, recognizing the presence of insulin resistance facilitates the selection of an appropriate therapeutic approach, optimizing both the management of IR and the overall treatment of hypertension (Minh et al., 2021). The predictive value of the triglyceride–glucose (TyG) index as a biomarker for detecting insulin resistance (IR) has been the subject of numerous studies across different populations. Current evidence suggests that the TyG index may serve as a practical and simple indicator for identifying individuals with IR, as well as for detecting groups at increased risk of developing diabetes in the future (VK et al., 2022). Findings from recent studies indicate that the triglyceride–glucose (TyG) index and the TG/HDL-C ratio represent important and independent indicators for predicting the progression from prediabetes to type 2 diabetes mellitus. These metabolic biomarkers reflect early disturbances in glucose and lipid metabolism, making them valuable tools for identifying individuals at increased risk. Consequently, early monitoring and management of the components that constitute these indices may play a key role in preventing or delaying the development of type 2 diabetes (Sharafi et al., 2023). Individuals with prediabetes often present with overweight and metabolic disturbances that require early lifestyle interventions. One of the indicators used for the early assessment of insulin resistance is the triglyceride–glucose (TyG) index. This index is considered a simple, practical, and valuable marker for identifying metabolic disturbances that precede the development of diabetes (Navas-Carretero et al., 2021; Wang et al., 2021; Srinivasan et al., 2021). Since insulin measurement is expensive and often unavailable in most laboratories, particularly in cities of developing countries, it is being investigated whether the fasting triglyceride–glucose (TyG) index can be used as an alternative indicator for the assessment of insulin resistance, compared with the HOMA-IR (Homeostasis Model Assessment of Insulin Resistance) index (Simental-Mendía et al., 2008). Therefore, the triglyceride–glucose (TyG) index has been suggested as a novel and reliable surrogate marker of insulin resistance (Gao et al., 2023). The aim of this study is to evaluate the role and validity of the triglyceride–glucose (TyG) index in patients with diabetes in the Tetovo region, by examining its association with metabolic disturbances. The study seeks to determine whether TyG can be used as a reliable and practical indicator for the early identification of individuals at high metabolic risk and to support clinical decision-making in the management of diabetes.

## Materials and Methods

This study was designed as a retrospective investigation and was conducted during the period May 2024 – January 2025 in the Diagnostic Laboratory of the Clinical Hospital of Tetovo. A total of 251 outpatient participants were included in the analysis, of whom 201 were diagnosed with diabetes mellitus (type 1 or type 2), while 50 healthy individuals without known metabolic disorders were selected as the control group, based on documented clinical and laboratory data. Venous blood samples were collected in the morning, in a fasting state, following at least 12 hours of fasting, in order to avoid the influence of food intake on biochemical parameters. Blood was collected into tubes for serum separation, and after centrifugation, the serum was used for laboratory analyses.

Blood glucose concentration was determined using the hexokinase method, while triglycerides were analyzed using an enzymatic spectrophotometric method, according to standard laboratory protocols. The analyses were performed using the Advia Centaur analyzer. Based on the obtained values, the triglyceride–glucose (TyG) index was calculated using the following formula:

$$\mathbf{TyG = ln\ [TG\ (mg/dL) \times FBG\ (mg/dL)\ /\ 2]}$$

The TyG index was used as an indirect marker of insulin resistance in diabetic patients. For the interpretation of results, the following cut-off values were used as reference: TyG < 8.73 for females and TyG < 8.82 for males (Shabani et al., 2025).
The collected data were processed using the statistical software IBM SPSS (version 20). Descriptive statistics were calculated, including minimum and maximum values, mean, and standard deviation. The level of statistical significance was set at $p < 0.05$.

## Results

The study included a total of 251 patients, of whom 156 (62.15%) were female, and 95 (37.85%) were male. The mean age of the participants was 55.67 ± 16.01 years, with a minimum/maximum age range of 13–85 years. The inclusion of participants was based on available data from the laboratory archive and corresponding medical records.

*Table 1. Descriptive statistics of glucose, triglycerides, and TyG index across control and study groups stratified by fasting glucose levels*

| | N | Min | Max | Mean | SD |
|---|---|---|---|---|---|
| **Glucose (I)* (mg/dl)** | 50 | 70.00 | 115.20 | 91.10 | 10.60 |
| **Triglycerides (I)* (mg/dl)** | 50 | 69.03 | 212.39 | 130.09 | 41.59 |
| **TyG index (I)*** | 50 | 8.10 | 9.31 | 8.64 | 0.29 |
| **Glucose (II)** (mg/dl)** | 117 | 59.40 | 109.80 | 94.20 | 10.21 |
| **Triglycerides (II)** (mg/dl)** | 117 | 30.7 0 | 380.90 | 131.84 | 62.62 |
| **TyG index (II)**** | 117 | 7.17 | 9.81 | 8.62 | 0.48 |
| **Glucose (III)*** (mg/dl)** | 84 | 111.6 | 363.60 | 156.36 | 59.12 |
| **Triglycerides (III)*** (mg/dl)** | 84 | 50.50 | 490.20 | 164.23 | 80.74 |
| **TyG index (III)***** | 84 | 8.03 | 10.98 | 9.30 | 0.58 |

***Control group I; **Study group II (Diabetic) – level of glucose <6.1 mmol/L, Study group III (Diabetic) - level of glucose >6.1 mmol/L**

Table 1 presents the descriptive statistics for glucose, triglycerides, and the TyG index across three study groups: the control group (I), the group with glucose < 6.1 mmol/L (II), and the group with glucose ≥ 6.1 mmol/L (III). The TyG index values are similar between group I and group II (8.64 ± 0.29 vs. 8.62 ± 0.48), whereas a clear increase is observed in group III (9.30 ± 0.58). Similarly, group III is characterized by significantly higher levels of both glucose and triglycerides compared to the other two groups. Overall, the data indicate a progressive increase in the TyG index in accordance with rising fasting glucose levels, suggesting a potential association between hyperglycemia and metabolic disturbances.

*Table 2. Comparison of glucose, triglycerides, and TyG index between control and study groups stratified by fasting glucose levels*

| Group | Mean±SD | p value |
|---|---|---|
| **Glucose (I) vs. Glucose (II)** | 91.10±10.06 vs. 94.2±10.21 | 0.07 |
| **Glucose (I) vs. Glucose (III)** | 91.10±10.06 vs. 156.36±59.12 | < 0.0001 |
| **Glucose (II) vs. Glucose (III)** | 94.2±10.21 vs. 156.36±59.12 | < 0.0001 |
| **Triglycerides (I) vs. Triglycerides (II)** | 130.09±41.59 vs. 131.84±62.62 | 0.85 |
| **Triglycerides (I) vs. Triglycerides (III)** | 130.09±41.59 vs. 164.23±80.74 | 0.006 |
| **Triglycerides (II) vs. Triglycerides (III)** | 131.84±62.62 vs. 164.23±80.74 | 0.0016 |
| **TyG index (I) vs. TyG index (II)** | 8.64±0.29 vs. 8.62±0.48 | 0.78 |
| **TyG index (I) vs. TyG index (III)** | 8.64±0.29 vs. 9.30±0.58 | < 0.0001 |
| **TyG index (II) vs. TyG index (III)** | 8.62±0.48 vs. 9.30±0.58 | < 0.0001 |

Table 2 presents the comparison of glucose, triglycerides, and the TyG index among the three groups: control (I), the group with glucose < 6.1 mmol/L (II), and the group with glucose ≥ 6.1 mmol/L (III). No statistically significant differences were observed between the control group and group II for glucose ($p = 0.07$), triglycerides ($p = 0.85$), and the TyG index ($p = 0.78$). In contrast, group III showed a marked and statistically significant increase in all parameters compared with the other two groups, including glucose ($p < 0.0001$), triglycerides ($p = 0.006$ and $p = 0.0016$), and TyG ($p < 0.0001$). Overall, the results indicate that hyperglycemia ≥ 6.1 mmol/L is associated with a significant deterioration in lipid profile and an increase in the TyG index.

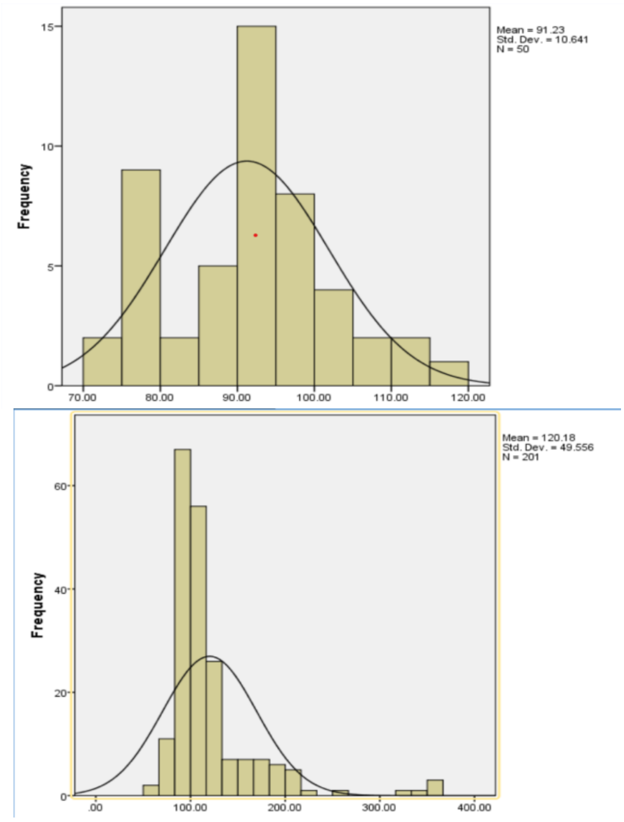


*Figure 1. Distribution of fasting glucose levels in the study population (A- Control group; B- Diabetic group)*

The figure presents the distribution of fasting glucose levels in two groups: the control group (A) and the diabetic group (B). In the control group, a more regular and approximately normal distribution is observed, with values concentrated around a mean of 91.23 mg/dL and a low standard deviation (±10.64), indicating low variability and stable glucose levels in this population. In contrast, the diabetic group shows a higher mean glucose level (120.18 mg/dL) and a considerably wider distribution (SD ±49.56), reflecting greater heterogeneity in the data and poor glycemic control. The histogram of group B is right-skewed, with the presence of extreme values reaching up to approximately 400 mg/dL, indicating cases of marked hyperglycemia in some patients. Overall, the comparison of the two groups clearly demonstrates higher glucose levels and greater variability in the diabetic group compared to the control group, supporting a clear clinical distinction between the populations.

*Table 3. Correlation between glucose and triglycerides in Diabetic patients*

| **Variables** | **Glucose (Diabetic)** | **Triglycerides (Diabetic)** |
|---|---|---|
| **Glucose (Diabetic)** | 1 | 0.234** |
| **Triglycerides (Diabetic)** | 0.234** | 1 |
| **Sig. (2-tailed)** | — | 0.001 |
| **N** | 201 | 201 |

****** The correlation is statistically significant at the 0.01 level (2-tailed).

Pearson correlation analysis showed a positive relationship between glucose and triglyceride levels in diabetic patients ($r = 0.234$; $p = 0.001$). This association is statistically significant at the 0.01 level ($p < 0.01$), suggesting that higher triglyceride levels are accompanied by higher glucose levels. The number of participants (N = 201) increases the reliability of this finding. Overall, these results indicate a statistically significant but weak association between the two metabolic parameters in the studied population.

*Table 4. Comparison of the TyG index between the control group and the diabetic group*

| | **Mean ±SD** | **P** |
|---|---|---|
| **TyG (Control) vs. TyG (Diabetic)** | 8.64±0.29 vs. 8.91±0.62 | 0.003 |

In this analysis, the TyG index was compared between the control group and the diabetic group. The results showed that the mean TyG value was lower in the control group (8.64 ± 0.29) compared to the diabetic group (8.91 ± 0.62). The difference between the two groups was statistically significant ($p = 0.003$), suggesting that patients with diabetes have higher TyG index levels. This supports the role of the TyG index as an important indicator of insulin resistance and metabolic disturbances in diabetic individuals.

## Discussion

The TyG index, calculated as the product of fasting triglyceride and glucose levels, represents an important indicator of disturbances in carbohydrate and lipid metabolism. Due to this pathophysiological basis, it is considered a reliable alternative biomarker for the assessment of insulin resistance and has been widely used in contemporary studies as a simple and practical tool for evaluating this metabolic phenomenon (Yao & Liu, 2025). In this context, the TyG index gains particular importance, as recent studies have shown that it has higher sensitivity and specificity in detecting disorders of glucose metabolism, including impaired fasting glucose, impaired glucose tolerance, and type 2 diabetes. This makes it a valuable tool not only for the evaluation of already diagnosed patients, but also for the early screening of metabolic disorders, as it can be applied even in apparently healthy individuals, including children and adolescents (Simental-Mendía et al., 2020).

Thus, the use of the TyG index strengthens the concept of an integrated approach to metabolic risk assessment, providing a simple yet highly informative indicator for the early identification and more effective management of disorders in glucose and lipid metabolism. In this context, comprehensive interventions aimed at controlling blood glucose levels, improving lipid profiles, and maintaining muscle mass and function are essential for the management of patients with diabetes. These measures not only contribute to the improvement of metabolic parameters but also have a direct impact on the long-term prognosis of patients by reducing the risk of further complications (Zhi-Wen & Zhong-Xin, 2025).

In the analysis of our data, it was observed that the comparison between the control group and diabetic patients with glucose levels < 6.1 mmol/L did not show a statistically significant difference in the TyG index ($p = 0.78$), suggesting that this single cut-off is not sufficient to clearly differentiate these two subgroups in this specific comparison. However, the results demonstrated a clear statistical significance when comparing the control group with patients with glucose levels > 6.1 mmol/L ($p < 0.0001$), reflecting a strong association between hyperglycemia and relevant metabolic alterations. Furthermore, a statistically significant difference ($p < 0.0001$) was also observed within the diabetic group, depending on glucose status (<6.1 mmol/L vs. >6.1 mmol/L), indicating considerable heterogeneity in glycemic control within this population.

Several studies have suggested that a higher baseline TyG index, as a marker for the assessment of insulin resistance severity, is consistently associated with the risk of developing type 2 diabetes mellitus (T2DM) in different ethnic populations, including Korea, Singapore, and Europe (Li et al., 2020). These findings are consistent with our study results, reinforcing the role of the TyG index as an early indicator of metabolic disturbances and diabetes risk.
Furthermore, similar evidence has been reported in a cohort study conducted in the Chinese population (Guerrero-Romero et al., 2016), which highlights that the TyG index may serve as an important predictor of type 2 diabetes mellitus (T2DM) even in individuals with a normal body mass index (BMI). This suggests that the prognostic value of TyG is not limited to obese individuals but also extends to those with normal body weight, making it a valuable indicator for identifying metabolic risk at an early stage. In a study conducted by Navarro-González et al., a progressive increase in the risk of developing diabetes was reported in individuals with TyG index values $\geq 8.31$. Furthermore, the authors emphasize that the TyG index may have a higher predictive ability compared to fasting plasma glucose (FPG) or triglycerides measured separately, particularly in normoglycemic individuals, making it a more sensitive indicator for early risk assessment of diabetes (Navarro-González et al., 2016).
In the Pearson correlation analysis, a positive association was found between glucose and triglyceride levels in diabetic patients ($r = 0.234$; $p = 0.001$). This relationship is statistically significant at the 0.01 level ($p < 0.01$), suggesting that increases in triglyceride levels are accompanied by increases in blood glucose levels. In line with these findings, another study involving a group of 142 patients reported a mean TyG index of $9.02 \pm 0.81$ (range 4.27–11.21), indicating considerable variability of this parameter in the studied population. Statistical analysis in that study demonstrated strong positive correlations between the TyG index and triglycerides ($r = 0.716$, $p < 0.001$), as well as between TyG and fasting blood glucose (FBS) ($r = 0.535$, $p < 0.001$), confirming the close association of this index with key components of lipid and glucose metabolism (Nehru et al., 2025).
The results of our study showed a positive correlation of the TyG index between diabetic and non-diabetic patients. This suggests that TyG index values tend to increase in parallel with the worsening of the metabolic profile, more clearly reflecting the interaction between glucose and lipid metabolism in both studied groups. These findings are in agreement with the conclusions of another study, which reported that the TyG index may serve as an indicator of increased cardiometabolic risk. In this context, patients with elevated values require closer monitoring and early preventive intervention (Yang & Wang, 2025). Furthermore, there is a need for the TyG index to be integrated into routine clinical assessment and interpreted alongside other cardiovascular disease (CVD) risk factors, in order to improve the accuracy of identifying high-risk patients and enhance preventive strategies. Other studies have also reported that patients with diabetic microvascular complications such as retinopathy, nephropathy, and peripheral neuropathy have significantly higher TyG index values. The index also shows a positive correlation with disease duration and the triglyceride/HDL ratio, suggesting its role in the progression of diabetes and metabolic disorders (Kassab et al., 2023).

## Conclusion

The results of this study indicate that the triglyceride–glucose (TyG) index is a valuable and reliable marker for the assessment of metabolic disturbances and insulin resistance in diabetic patients, as it was found to be higher in the diabetic group compared to the control group and to increase progressively according to fasting glucose levels, particularly in cases of hyperglycemia $\geq 6.1$ mmol/L. Additionally, a positive and statistically significant correlation between glucose and triglyceride levels was observed in the diabetic group, reflecting impaired metabolic interaction. These findings support the use of the TyG index as a practical, simple, and cost-effective tool for the early identification of individuals at increased risk and for improving the clinical management of diabetes.

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