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Association of Triglyceride–Glucose Index with Heart Failure with Preserved Ejection Fraction and Diastolic Dysfunction in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study

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ABSTRACT

Background: Heart failure with preserved ejection fraction (HFpEF) is increasingly recognized as a major cardiovascular complication in patients with type 2 diabetes mellitus (T2DM). Insulin resistance plays a central role in the pathogenesis of HFpEF, and the triglyceride–glucose (TyG) index has emerged as a simple surrogate marker of insulin resistance. This study aimed to evaluate the association between the TyG index, HFpEF, and diastolic dysfunction among patients with T2DM.

Methods: This hospital-based cross-sectional study included 65 patients with T2DM aged between 18 and 70 years without known hypertension or overt cardiovascular disease. Clinical, anthropometric, biochemical, and echocardiographic parameters were assessed. The TyG index was calculated using fasting triglyceride and fasting blood glucose levels. HFpEF was evaluated using the HFA-PEFF scoring system and echocardiographic parameters of diastolic dysfunction. Statistical analysis was performed using SPSS version 26.

Results: The mean age of participants was 52.74 ± 8.69 years, and 18.5% had an HFA-PEFF score ≥5 suggestive of HFpEF. Patients with a higher TyG index demonstrated significantly greater waist circumference, fasting blood glucose, fasting triglyceride levels, and E/e′ ratio compared to those with a lower TyG index ($p < 0.05$). Participants with HFpEF had significantly higher TyG index values, fasting triglyceride levels, E/e′ ratio, and left atrial volume index. Binary logistic regression analysis demonstrated that an elevated TyG index was significantly associated with HFpEF (OR: 9.75; 95% CI: 1.98–47.94; $p < 0.001$).

Conclusion: An elevated TyG index was significantly associated with subclinical HFpEF and markers of diastolic dysfunction in patients with T2DM. The TyG index may serve as a simple, inexpensive, and clinically useful marker for early cardiovascular risk stratification in diabetic patients

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a rapidly growing global health problem and is associated with a substantial burden of cardiovascular morbidity and mortality.[1,2] Among the cardiovascular complications associated with T2DM, heart failure with preserved ejection fraction (HFpEF) has emerged as an increasingly recognized clinical entity. HFpEF accounts for nearly half of all heart failure cases[3] and is more commonly observed in patients with T2DM because of shared metabolic and inflammatory mechanisms, including insulin resistance, endothelial dysfunction, oxidative stress, chronic low-grade inflammation, and myocardial fibrosis.[4,5]

HFpEF is characterized by the presence of symptoms and signs of heart failure despite preserved left ventricular ejection fraction, along with evidence of impaired ventricular relaxation and diastolic dysfunction.[6] In patients with T2DM, persistent hyperglycemia and insulin resistance contribute to alterations in myocardial energy metabolism, microvascular dysfunction, accumulation of advanced glycation end products, and myocardial fibrosis.[7,8] These pathological mechanisms lead to increased myocardial stiffness and impaired ventricular compliance, ultimately resulting in diabetic cardiomyopathy and HFpEF.[7,8]

Diastolic dysfunction frequently develops during the early stages of diabetic cardiomyopathy before overt clinical manifestations of heart failure become apparent. Therefore, the identification of simple, reliable, and easily accessible markers for early cardiac dysfunction in diabetic patients is of considerable clinical importance. The triglyceride–glucose (TyG) index, derived from fasting triglyceride and fasting blood glucose levels, has recently emerged as a practical surrogate marker of insulin resistance.[9] Previous studies have demonstrated a strong correlation between the TyG index and insulin resistance measured using the hyperinsulinemic–euglycemic clamp technique.[9,10]

Recent evidence suggests that an elevated TyG index is associated with an increased risk of several cardiovascular disorders, including hypertension, coronary artery disease, metabolic syndrome, and heart failure.[11] Insulin resistance has also been implicated in the development of myocardial lipotoxicity, endothelial dysfunction, and systemic inflammation, all of which contribute to impaired diastolic function.[12] Furthermore, higher TyG index values have been shown to correlate with echocardiographic markers of diastolic dysfunction such as elevated E/e′ ratio and increased left atrial volume index (LAVI).[13]

Because the TyG index can be easily calculated using routine laboratory parameters, it may serve as a simple, inexpensive, and clinically useful marker for identifying diabetic patients at increased risk of subclinical HFpEF. However, limited data are available regarding the association between TyG index and subclinical HFpEF among asymptomatic patients with T2DM, particularly in the Indian population. Early identification of high-risk individuals may facilitate timely lifestyle interventions and cardiovascular risk reduction strategies. Therefore, the present study was undertaken to evaluate the association between the triglyceride–glucose index and subclinical HFpEF in patients with type 2 diabetes mellitus.

METHODOLOGY

This hospital-based cross-sectional analytical study was conducted in the Department of General Medicine at SRM Medical College Hospital and Research Centre over a period of 12 months after obtaining approval from the Institutional Ethics Committee. The study population comprised patients with type 2 diabetes mellitus (T2DM) attending the outpatient and inpatient departments of General Medicine. Patients aged between 18 and 70 years who fulfilled the World Health Organization (WHO) diagnostic criteria for T2DM and who did not have symptoms suggestive of cardiac disease were included in the study after obtaining written informed consent.

Patients with known coronary artery disease, atrial fibrillation, structural heart disease, hypertension (systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg), and diabetic microvascular complications such as retinopathy, nephropathy, or neuropathy were excluded from the study.

The sample size was calculated using the formula:

$$n = \frac{4pq}{L^2}$$

where p = 21% (prevalence from a previous study), q = 79, and L = 10% absolute precision. Based on this calculation, the final sample size was determined to be 65 participants.

Data were collected using a pretested semi-structured proforma that included socio-demographic details, duration of diabetes, treatment history, and clinical examination findings. Anthropometric measurements including body mass index (BMI) and waist circumference were recorded. Laboratory investigations included fasting blood glucose, postprandial blood glucose, HbA1c, fasting lipid profile, and NT-proBNP levels.

The triglyceride–glucose (TyG) index was calculated using the formula:

$$\text{TyG Index} = \ln\left(\frac{\text{Fasting Triglycerides (mg/dL)} \times \text{Fasting Blood Glucose (mg/dL)}}{2}\right)$$

All participants underwent electrocardiography (ECG) and two-dimensional echocardiography for assessment of cardiac function. Heart failure with preserved ejection fraction (HFpEF) was evaluated using the HFA-PEFF scoring system proposed by Pieske et al.[6] Echocardiographic parameters including E/e′ ratio and left atrial volume index (LAVI) were assessed to evaluate diastolic dysfunction.

Data entry was performed using Microsoft Excel, and statistical analysis was carried out using SPSS version 26. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequency and percentage. Independent sample t-test was used to compare continuous variables between groups, and Chi-square test was used for categorical variables. Binary logistic regression analysis was performed to determine the association between TyG index and HFpEF. Odds ratios (OR) with 95% confidence intervals (CI) were calculated, and a p-value <0.05 was considered statistically significant.

RESULT

A total of 65 patients with type 2 diabetes mellitus were included in the study. The mean age of the study population was 52.74 ± 8.69 years. Males constituted 52.3% of the participants, while females accounted for 47.7%. The baseline clinical, biochemical, and echocardiographic characteristics of the study population are shown in Table 1.

Table 1. Baseline Characteristics of the Study Population

Variable	Mean ± SD / n (%)
Male sex, n (%)	34 (52.3%)
Female sex, n (%)	31 (47.7%)
Age (years)	52.74 ± 8.69
Duration of diabetes (years)	5.15 ± 2.01
Body mass index (kg/m²)	24.73 ± 3.49
Waist circumference (cm)	88.58 ± 9.79
Fasting blood glucose (mg/dL)	159.83 ± 52.53
Postprandial blood glucose (mg/dL)	261.31 ± 82.40
HbA1c (%)	10.13 ± 2.28
Fasting triglycerides (mg/dL)	209.80 ± 96.83
Triglyceride–glucose index	9.51 ± 1.81
E/e′ ratio	12.89 ± 4.98
Left atrial volume index (mL/m²)	45.98 ± 10.64
NT proBNP (pg/mL)	111.86 ± 56.41
HFA-PEFF score ≥5, n (%)	12 (18.5%)
HFA-PEFF score <5, n (%)	53 (81.5%)

Participants were categorized into high TyG index (n = 33) and low TyG index (n = 32) groups based on literature-derived cut-off values. Patients with higher TyG index values demonstrated significantly greater waist circumference, fasting blood glucose levels, fasting triglyceride levels, E/e′ ratio, and NT-proBNP levels compared to those with lower TyG index values. However, no statistically significant differences were observed in age, duration of diabetes, body mass index, postprandial blood glucose, HbA1c, or left atrial volume index between the groups. The comparison of clinical and biochemical parameters between the two groups is shown in Table 2.

Table 2. Comparison of Clinical and Biochemical Parameters According to TyG Index Group

Parameter	High TyG Index (n= 33)	Low TyG Index (n = 32)	p-value
Male sex, n (%)	16 (48.5%)	18 (56.3%)	0.622
Female sex, n (%)	17 (51.5%)	14 (43.8%)	
Age (years)	53.12 ± 9.20	52.34 ± 8.25	0.721
Duration of diabetes (years)	4.94 ± 2.69	5.38 ± 2.19	0.478
Body mass index (kg/m²)	25.45 ± 3.57	23.97 ± 3.36	0.088
Waist circumference (cm)	91.72 ± 10.35	85.35 ± 8.12	0.006
Fasting blood glucose (mg/dL)	191.52 ± 48.23	127.16 ± 33.55	<0.001
Postprandial blood glucose (mg/dL)	260.94 ± 80.29	261.72 ± 85.81	0.970
HbA1c (%)	10.41 ± 2.23	9.85 ± 2.34	0.324
Fasting triglycerides (mg/dL)	287.70 ± 120.69	129.47 ± 63.31	<0.001
E/e′ ratio	15.27 ± 4.19	8.74 ± 2.59	<0.001
Left atrial volume index (mL/m²)	46.83 ± 11.96	44.91 ± 10.34	0.472
NT-proBNP (pg/mL)	132 ± 75.59	90.16 ± 69.63	0.001

Participants were further categorized based on HFA-PEFF score into HFpEF group (HFA-PEFF score ≥5; n = 12) and non-HFpEF group (HFA-PEFF score <5; n = 53). The HFpEF group showed female predominance and demonstrated significantly higher fasting blood glucose levels, fasting triglyceride levels, E/e′ ratio, and left atrial volume index compared to the non-HFpEF group. These findings are summarized in Table 3.

Table 3. Association of Clinical and Biochemical Parameters with HFA-PEFF Score

Parameter	HFA-PEFF Score ≥5 (n = 12)	HFA-PEFF Score <5 (n = 53)	p-value
Male sex, n (%)	3 (25.0%)	31 (58.5%)	0.036
Female sex, n (%)	9 (75.0%)	22 (41.5%)	
Age (years)	51.83 ± 6.96	52.94 ± 9.07	0.692
Duration of diabetes (years)	5.17 ± 2.79	5.15 ± 2.40	0.984
Body mass index (kg/m²)	25.28 ± 4.59	24.60 ± 3.31	0.543
Waist circumference (cm)	92.31 ± 11.32	87.74 ± 9.32	0.147
Fasting blood glucose (mg/dL)	193.92 ± 52.83	152.11 ± 49.77	0.012
Postprandial blood glucose (mg/dL)	273.50 ± 72.84	258.57 ± 84.80	0.575
HbA1c (%)	10.35 ± 2.24	10.08 ± 2.31	0.729
Fasting triglycerides (mg/dL)	280.08 ± 118.58	193.89 ± 131.69	0.041
E/e′ ratio	16.57 ± 5.71	11.04 ± 4.13	0.004
Left atrial volume index (mL/m²)	51.49 ± 12.22	44.62 ± 9.93	0.042
NT-proBNP (pg/mL)	138.66 ± 31.77	105.43 ± 69.60	0.410

Patients with HFpEF demonstrated significantly higher TyG index values compared to those without HFpEF (10.16 ± 1.76 vs 9.36 ± 1.45; p = 0.001), as shown in Table 4.

Table 4. Comparison of TyG Index According to HFA-PEFF Score

Parameter	HFA-PEFF Score ≥5	HFA-PEFF Score <5	p-value
Triglyceride–glucose index	10.16 ± 1.76	9.36 ± 1.45	0.001

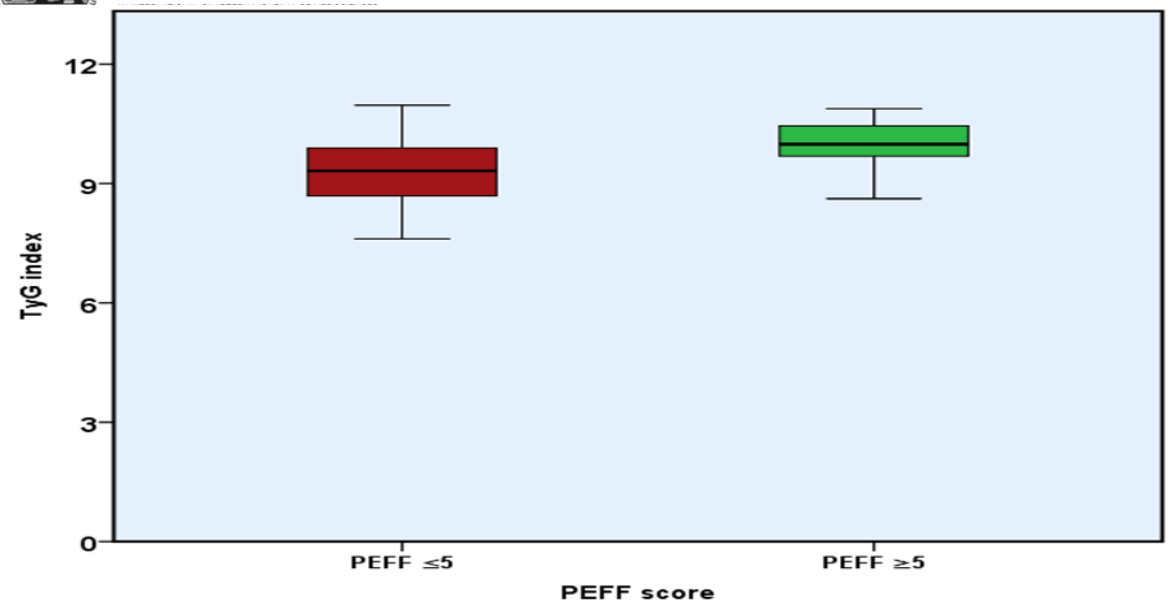


Figure 1: Comparison of Triglyceride–Glucose (TyG) Index Across HFA-PEFF Score Categories

Binary logistic regression analysis demonstrated that participants with elevated TyG index values had significantly higher odds of HFpEF compared to those with lower TyG index values (OR: 9.75; 95% CI: 1.98–47.94; p < 0.001).

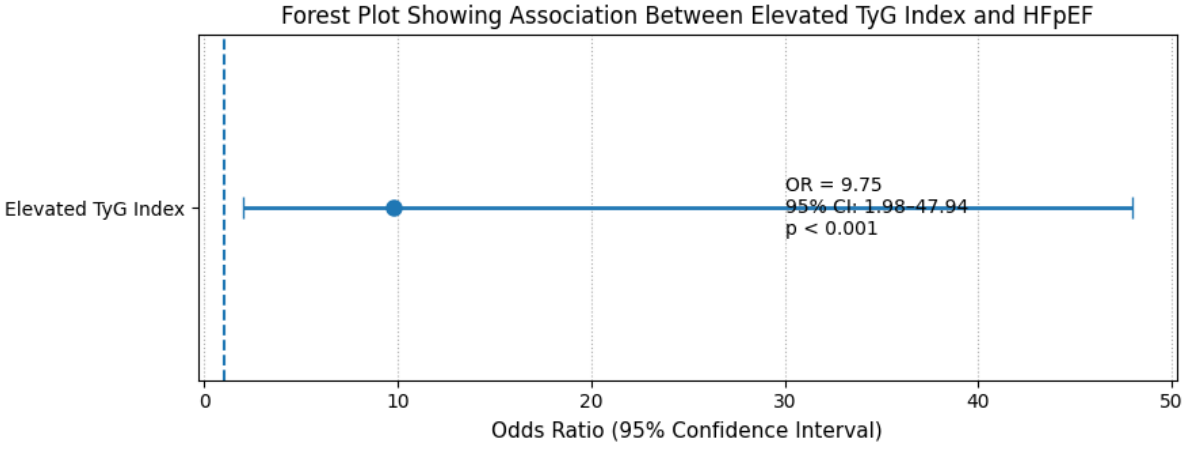


Figure 2: Forest Plot Showing Binary Logistic Regression Analysis for Association Between TyG Index and HFpEF

DISCUSSION

The present study evaluated the association between the triglyceride–glucose (TyG) index and subclinical heart failure with preserved ejection fraction (HFpEF) among patients with type 2 diabetes mellitus (T2DM). The findings demonstrated that patients with elevated TyG index values had significantly higher fasting blood glucose levels(191.52 ± 48.23 mg/dL vs 127.16 ± 33.55 mg/dL; p<0.001), fasting triglyceride levels(287.70 ± 120.69 mg/dL vs 129.47 ± 63.31 mg/dL; p<0.001), waist circumference(91.72 ± 10.35 cm vs 85.35 ± 8.12 cm; p=0.006), and echocardiographic markers of diastolic dysfunction, particularly the E/e′ ratio(15.27 ± 4.19 vs 8.74 ± 2.59; p<0.001). In addition, participants with HFpEF demonstrated significantly higher TyG index values(10.16 ± 1.76 vs 9.36 ± 1.45; p=0.001) compared to those without HFpEF, suggesting a significant association between insulin resistance and early cardiac dysfunction in patients with T2DM.

The mean age of the study population was 52.74 ± 8.69 years, with an almost equal distribution of male and female participants. These findings are comparable to previous epidemiological studies that reported a higher prevalence of T2DM among middle-aged individuals.[1,14] Although body mass index (BMI) did not differ significantly between the groups, waist circumference was significantly greater among participants with elevated TyG index values. This finding suggests that central obesity may be more closely associated with cardiometabolic risk and insulin resistance than BMI alone.[15]

In the present study, fasting blood glucose and triglyceride levels were significantly elevated in the high TyG group. Since the TyG index is derived from fasting glucose and triglyceride levels, this observation further supports the utility of the TyG index as a surrogate marker of insulin resistance. Previous studies have similarly demonstrated a strong association between the TyG index and insulin resistance in individuals with metabolic disorders.[9,10,11]

An important finding of the present study was the significant association between elevated TyG index and echocardiographic evidence of diastolic dysfunction. Participants with a higher TyG index demonstrated significantly increased E/e′ ratio values compared to those with lower TyG index values. Elevated E/e′ ratio reflects increased left ventricular filling pressure and impaired ventricular relaxation, which are characteristic features of early HFpEF.[6,16] Similar observations have been reported in earlier studies evaluating the relationship between metabolic dysfunction, insulin resistance, and HFpEF.[13,17]

The present study also demonstrated significantly higher left atrial volume index (LAVI) and E/e′ ratio values among participants with HFpEF. Left atrial enlargement is recognized as an important marker of chronic diastolic dysfunction and elevated left ventricular filling pressure.[18] These findings are consistent with the HFA-PEFF diagnostic criteria proposed for the evaluation of HFpEF[6] and support the role of echocardiographic parameters in the early identification of subclinical cardiac dysfunction.
A female predominance was observed among patients with HFpEF in the present study. Similar findings have been reported previously, suggesting that hormonal influences, endothelial dysfunction, and sex-related differences in myocardial remodeling may contribute to the increased susceptibility of women to HFpEF.[20,21]

Binary logistic regression analysis demonstrated that an elevated TyG index was significantly associated with HFpEF, with patients in the high TyG index group showing nearly tenfold higher odds of HFpEF compared to those with lower TyG index values. This finding suggests that insulin resistance may play an important role in the development of diastolic dysfunction and HFpEF among patients with T2DM. Previous studies have also reported that elevated TyG index is associated with metabolic abnormalities, cardiovascular dysfunction, and increased risk of heart failure.[11,13,17.]

The TyG index has several clinical advantages because it is inexpensive, simple to calculate, and based on routinely available laboratory parameters. Therefore, it may be useful as an early screening tool for identifying diabetic patients at increased risk of developing subclinical HFpEF, particularly in resource-limited settings where advanced diagnostic modalities may not be readily available. Early identification of high-risk individuals could facilitate timely lifestyle modification and cardiovascular risk reduction strategies.[9,13]

CONCLUSION

The present study demonstrated a significant association between elevated triglyceride–glucose (TyG) index and subclinical heart failure with preserved ejection fraction (HFpEF) in patients with type 2 diabetes mellitus. Patients with higher TyG index values showed significantly greater echocardiographic markers of diastolic dysfunction, particularly increased E/e′ ratio and left atrial volume index. These findings suggest that the TyG index, a simple and inexpensive surrogate marker of insulin resistance, may be useful for early identification and cardiovascular risk stratification of diabetic patients, especially in resource-limited settings. However, further large-scale prospective studies are needed to validate these findings and determine the prognostic role of the TyG index in HFpEF.

Strengths and limitations:
The strengths of the present study include the use of the triglyceride–glucose (TyG) index as a simple, inexpensive, and easily obtainable surrogate marker of insulin resistance in routine clinical practice. The study also included comprehensive assessment of heart failure with preserved ejection fraction (HFpEF) using echocardiographic parameters such as E/e′ ratio, left atrial volume index, and HFA-PEFF scoring system, which improved the evaluation of diastolic dysfunction in patients with type 2 diabetes mellitus.

However, the study had certain limitations. The relatively small sample size and single-center design may limit the generalizability of the findings. In addition, the cross-sectional nature of the study prevented establishment of a causal relationship between elevated TyG index and HFpEF. Further large-scale prospective studies are required to validate these findings.

DECLARATIONS
Ethics Approval: Approved by Institutional Ethics Committee of SRM Medical College Hospital and Research Centre.
Informed Consent: Written informed consent was obtained from all patients or their legally acceptable representatives.
Funding: None
Conflict of interest: The authors declare no conflict of interest

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