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ASSOCIATION OF THE TRIGLYCERIDE-GLUCOSE–BODY MASS INDEX WITH ALBUMINURIA AND ESTIMATED GLOMERULAR FILTRATION RATE AMONG PATIENTS WITH TYPE 2 DIABETES MELLITUS

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ABSTRACT

Background: Diabetic kidney disease is a major microvascular complication of type 2 diabetes mellitus (T2DM), associated with increased morbidity and progressive renal dysfunction. The triglyceride-glucose–body mass index (TyG-BMI) is an emerging surrogate marker of insulin resistance that may help identify metabolic abnormalities associated with albuminuria and impaired renal function. The aim is to evaluate the association of TyG-BMI with albuminuria and estimated glomerular filtration rate (eGFR) among patients with type 2 diabetes mellitus.

Materials and Methods: The present hospital-based observational cross-sectional study was designed to include 95 patients with T2DM attending a tertiary care hospital. Demographic characteristics, anthropometric measurements, glycemic parameters, lipid profile, serum creatinine, urinary albumin-to-creatinine ratio (UACR), and eGFR were assessed. TyG-BMI was calculated using the triglyceride-glucose index and BMI. Statistical analysis was performed using SPSS version 28.0, with $p<0.05$ considered statistically significant.

Results: In the illustrative dataset, the mean age was 54.31 ± 10.71 years, and the mean TyG-BMI was 259.11 ± 34.89. Albuminuria was present in 62.11% of patients, while 23.16% had reduced eGFR. Albuminuria increased from 31.25% in the lowest TyG-BMI tertile to 81.25% in the highest tertile ($p<0.001$). TyG-BMI showed a positive correlation with UACR ($r=0.575$) and a negative correlation with eGFR ($r=-0.699$), both statistically significant ($p<0.001$). The areas under the ROC curve were 0.752 for albuminuria and 0.846 for reduced eGFR.

Conclusion: Higher TyG-BMI was associated with increased albuminuria and reduced renal function in the illustrative analysis. TyG-BMI may serve as an inexpensive supplementary marker for renal risk assessment in patients with T2DM, subject to validation using actual clinical data.

Keywords: Type 2 diabetes mellitus; Triglyceride-glucose–body mass index; Albuminuria; Estimated glomerular filtration rate; Diabetic kidney disease.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major global public health concern characterised by persistent hyperglycaemia resulting from insulin resistance, progressive pancreatic beta-cell dysfunction, and disturbances in carbohydrate and lipid metabolism. Its increasing prevalence has been attributed to rapid urbanisation, sedentary lifestyles, unhealthy dietary habits, obesity, and population ageing. Long-standing diabetes is associated with various microvascular and macrovascular complications, including diabetic retinopathy, neuropathy, nephropathy, cardiovascular disease, and peripheral arterial disease. Among these complications, diabetic kidney disease represents an important cause of

morbidity, premature mortality, and increased healthcare expenditure. The growing burden of diabetes highlights the importance of identifying metabolic indicators associated with the development of renal complications.[1]

Diabetic kidney disease is a progressive microvascular complication characterised by structural and functional abnormalities of the kidneys. Persistent hyperglycaemia, hypertension, oxidative stress, chronic inflammation, and activation of the renin–angiotensin–aldosterone system contribute to glomerular injury and deterioration of renal function. Prolonged exposure to metabolic disturbances may cause glomerular basement membrane thickening, mesangial expansion, podocyte injury, and tubulointerstitial fibrosis. These alterations may eventually lead to progressive loss of functioning nephrons and chronic kidney disease. Early identification of renal involvement is particularly important because timely glycaemic management, blood pressure control, and appropriate pharmacological interventions may delay disease progression and reduce associated cardiovascular complications.[2] Albuminuria and estimated glomerular filtration rate (eGFR) are established clinical indicators for assessing renal involvement in patients with diabetes mellitus. The urinary albumin-to-creatinine ratio (UACR) provides a convenient method for detecting increased urinary albumin excretion and identifying abnormalities in glomerular permeability. Albuminuria is classified into normal to mildly increased, moderately increased, and severely increased categories according to UACR values. The eGFR reflects the filtration capacity of the kidneys and is used to categorise the severity of renal dysfunction. However, albuminuria and reduced eGFR may develop independently, making their combined assessment essential for comprehensive renal evaluation.[3] Serum creatinine-based estimation of glomerular filtration rate is widely used because of its accessibility, affordability, and applicability in routine clinical practice. The Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equations provide standardised approaches for estimating kidney function using serum creatinine and selected demographic variables. Nevertheless, serum creatinine is influenced by muscle mass, age, nutritional status, and other non-renal factors. Moreover, early renal injury may occur before a measurable decline in eGFR becomes apparent. Therefore, additional metabolic indicators capable of identifying patients with increased susceptibility to albuminuria and renal impairment may complement conventional kidney function assessment and improve clinical risk stratification.[4] Insulin resistance plays a central role in the pathogenesis of type 2 diabetes mellitus and its associated metabolic complications. It is frequently accompanied by increased circulating triglycerides, impaired glucose utilisation, compensatory hyperinsulinaemia, obesity, and dyslipidaemia. Direct assessment of insulin resistance using the hyperinsulinaemic-euglycaemic clamp technique is technically demanding and unsuitable for routine clinical practice. Consequently, simpler surrogate markers derived from commonly available biochemical investigations have gained attention. The triglyceride-glucose (TyG) index, calculated using fasting plasma glucose and serum triglyceride concentrations, represents a practical indicator of metabolic dysfunction and insulin resistance. Its calculation does not require insulin estimation or specialised laboratory equipment.[5] The triglyceride-glucose–body mass index (TyG-BMI) is a composite metabolic index obtained by multiplying the TyG index by body mass index (BMI). This index incorporates disturbances in glucose metabolism, lipid metabolism, and overall adiposity into a single parameter. Because obesity contributes to insulin resistance, systemic inflammation, altered adipokine secretion, and metabolic dysfunction, combining BMI with the TyG index may provide additional information regarding cardiometabolic and renal risk. Increased TyG-BMI may reflect a metabolic environment associated with endothelial dysfunction, glomerular hypertension, oxidative injury, and progressive renal impairment. Consequently, the relationship between TyG-BMI and renal abnormalities has become an important area of clinical investigation.[6]

MATERIALS AND METHODS

The present study was designed as a hospital-based observational cross-sectional study conducted at a tertiary care hospital to evaluate the association of the triglyceride-glucose–body mass index (TyG-BMI) with albuminuria and estimated glomerular filtration rate (eGFR) among patients with type 2 diabetes mellitus (T2DM). A total of 95 patients with established T2DM were included in the study. Patients attending the Department of General Medicine and diabetic outpatient services were recruited through consecutive sampling according to predefined eligibility criteria. Demographic characteristics, clinical findings, biochemical parameters, and renal function indicators were systematically recorded using a structured study proforma.

Inclusion Criteria

Patients aged 18 years and above with a confirmed diagnosis of type 2 diabetes mellitus, irrespective of sex, were included in the study. Patients receiving oral antidiabetic medications, insulin therapy, or combination treatment were considered eligible. Participants who were clinically stable, willing to provide written informed consent, and able to undergo the required anthropometric, biochemical, and renal function investigations were included.

Exclusion Criteria

Patients with type 1 diabetes mellitus, gestational diabetes, acute kidney injury, known non-diabetic renal diseases, or those undergoing maintenance

dialysis were excluded. Patients with active urinary tract infections, acute febrile illnesses, severe hepatic dysfunction, malignancy, or other acute systemic conditions affecting glucose metabolism or renal function were excluded. Pregnant women and patients receiving medications known to substantially interfere with triglyceride measurements, such as systemic corticosteroids, were also excluded.

Demographic and Clinical Assessment: Detailed demographic and clinical information was obtained from all 95 participants, including age, sex, residential background, socioeconomic status, duration of diabetes, family history of diabetes, smoking status, alcohol consumption, and physical activity. Associated comorbidities, including hypertension, dyslipidaemia, cardiovascular disease, and previous diabetic complications, were documented. Treatment history included oral antidiabetic drugs, insulin, antihypertensive medications, lipid-lowering agents, and sodium-glucose cotransporter-2 inhibitors. Blood pressure was measured using a calibrated sphygmomanometer after adequate rest. Clinical examination included assessment of peripheral oedema and other manifestations suggestive of diabetic complications.

Anthropometric Measurements: Anthropometric assessment included body weight, height, body mass index (BMI), waist circumference, and waist-to-hip ratio. Body weight was measured using a calibrated digital weighing scale, while height was recorded using a stadiometer. BMI was calculated as weight in kilograms divided by the square of height in metres (kg/m^2). Waist circumference was measured midway between the lower costal margin and the iliac crest. These measurements were used to assess general and central obesity and their association with metabolic abnormalities and renal function.

Biochemical Investigations: Venous blood samples were collected following an overnight fast of 8–12 hours under standard aseptic precautions. Biochemical investigations included fasting plasma glucose, postprandial blood glucose, glycated haemoglobin (HbA1c), serum triglycerides, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, serum creatinine, blood urea, serum uric acid, and serum albumin. Fasting plasma glucose and lipid parameters were measured using standard enzymatic methods on an automated biochemical analyser. HbA1c was estimated using a standardised laboratory method. All investigations were performed according to established laboratory quality-control procedures.

Calculation of Triglyceride-Glucose–Body Mass Index

The triglyceride-glucose (TyG) index was calculated using the formula: TyG index = ln [fasting triglycerides (mg/dL) × fasting plasma glucose (mg/dL) / 2], where ln represented the natural logarithm. The TyG-BMI index was subsequently calculated by multiplying the TyG index by BMI (kg/m^2). Higher TyG-BMI values indicated a greater combined metabolic burden related to insulin resistance and adiposity. Participants were categorised into tertiles according to their calculated TyG-BMI values for comparative analysis.

Assessment of Albuminuria and Renal Function: Renal function was assessed using serum creatinine, eGFR, and urinary albumin-to-creatinine ratio (UACR). An early-morning spot urine sample was collected to determine urinary albumin and creatinine concentrations. Albuminuria was classified as normal to mildly increased (A1: UACR <30 mg/g), moderately increased (A2: 30–299 mg/g), and severely increased (A3: ≥300 mg/g). The eGFR was calculated using the 2021 CKD-EPI creatinine-based equation and expressed in mL/min/1.73 m^2. Renal function was categorised as G1 (≥90), G2 (60–89), G3a (45–59), G3b (30–44), G4 (15–29), and G5 (<15 mL/min/1.73 m^2). Reduced eGFR was defined as <60 mL/min/1.73 m^2. A single abnormal renal measurement was not considered sufficient to establish chronic kidney disease without evidence of persistence.

Statistical Analysis: Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS), version 28.0. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, whereas categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Student's t-test, one-way ANOVA, Mann–Whitney U test, and Kruskal–Wallis test were applied as appropriate. Categorical variables were compared using the Chi-square test or Fisher's exact test. Pearson's or Spearman's correlation coefficients were calculated to assess associations between TyG-BMI, UACR, and eGFR. Multivariable regression analysis was performed, where supported by the data, to adjust for relevant confounding variables, including age, sex, duration of diabetes, HbA1c, and hypertension. Receiver operating characteristic (ROC) curve analysis was used to assess the discriminatory ability of TyG-BMI for albuminuria and reduced eGFR. A p-value <0.05 was considered statistically significant.

RESULTS

[Table 1] Distribution of Patients According to Demographic, Anthropometric, and Clinical Characteristics (N=95)

[Table 1] presents the demographic and clinical characteristics of 95 patients with type 2 diabetes mellitus included in the study. The mean age of the participants was 54.31 ± 10.71 years. The largest proportion of patients belonged to the age group of ≥60 years (33.68%), followed by 50–59 years (32.63%), 40–49 years (25.26%), and <40 years (8.42%). Regarding sex distribution, 49 patients (51.58%) were males and 46 (48.42%) were females. Most participants belonged to rural areas (62.11%), whereas 37.89% were from urban areas. The mean

duration of diabetes was 8.15 ± 5.17 years. The maximum number of patients, 40 (42.11%), had diabetes for 5–10 years, followed by 28 patients (29.47%) with a duration of less than 5 years and 27 patients (28.42%) with diabetes for more than 10 years. The mean BMI was 27.47 ± 3.42 kg/m². Most patients, 53 (55.79%), had BMI values between 25 and <30 kg/m², while 21 patients (22.11%) each had BMI values below 25 kg/m² and ≥30 kg/m². Regarding associated clinical conditions, dyslipidaemia was observed in 56 patients (58.95%), hypertension in 49 patients (51.58%), and current smoking in 20 patients (21.05%). Assessment of antidiabetic treatment revealed that 57 patients (60.00%) were receiving oral antidiabetic medications alone, while 28 (29.47%) were receiving a combination of oral antidiabetic medications and insulin. Only 10 patients (10.53%) were receiving insulin therapy alone.

[Table 2] Distribution of Patients According to Biochemical Parameters, Albuminuria Categories, and Renal Function (N=95)

[Table 2] describes the biochemical, metabolic, and renal function parameters of the study participants. The mean fasting plasma glucose was 158.84 ± 33.95 mg/dL, while the mean postprandial glucose level was 246.40 ± 43.34 mg/dL. The mean HbA1c was 7.93 ± 0.97%. Regarding lipid profile, the mean serum triglyceride level was 169.64 ± 53.50 mg/dL, total cholesterol was 191.64 ± 30.15 mg/dL, HDL cholesterol was 42.30 ± 8.06 mg/dL, and LDL cholesterol was 115.63 ± 29.60 mg/dL. The mean serum creatinine level was 1.00 ± 0.39 mg/dL, whereas the mean estimated glomerular filtration rate was 82.89 ± 25.72 mL/min/1.73 m². The mean triglyceride-glucose index was 9.43 ± 0.39, while the mean TyG-BMI index was 259.11 ± 34.89. The median urinary albumin-to-creatinine ratio was 52.84 mg/g, with an interquartile range of 18.59–199.20 mg/g. These measurements represented the metabolic and renal function profiles evaluated among all 95 patients with type 2 diabetes mellitus. According to albuminuria classification, 36 patients (37.89%) belonged to category A1, 42 (44.21%) to category A2, and 17 (17.89%) to category A3. Overall, albuminuria was present in 59 patients (62.11%). Regarding eGFR categories, 39 patients (41.05%) were classified as G1, 34 (35.79%) as G2, 13 (13.68%) as G3a, 7 (7.37%) as G3b, and 2 (2.11%) as G4. No patient belonged to the G5 category. Reduced eGFR below 60 mL/min/1.73 m² was observed in 22 patients (23.16%).

[Table 3] Comparison of Clinical, Metabolic, and Renal Parameters According to Albuminuria Categories (N=95)

[Table 3] compares clinical, metabolic, and renal function parameters among patients classified into A1 (n=36), A2 (n=42), and A3 (n=17) albuminuria categories. The mean age was 53.42 ± 11.48 years in A1, 53.19 ± 10.23 years in A2, and 58.94 ± 9.50 years in A3, without a statistically significant difference (p=0.144). Median diabetes duration increased from 5.50 years in A1 to 8.00 years in A2 and 10.00 years in A3 (p=0.081). Mean BMI increased significantly across the groups, from 25.77 ± 3.34 to 27.74 ± 2.68 and 30.39 ± 3.21 kg/m², respectively (p<0.001). The median fasting plasma glucose levels were 159.85, 155.54, and 182.34 mg/dL in the A1, A2, and A3 groups, respectively, without a significant difference (p=0.383). Mean HbA1c increased from 7.79 ± 0.87% in A1 to 7.85 ± 1.04% in A2 and 8.42 ± 0.87% in A3 (p=0.069). Median serum triglycerides increased from 156.86 mg/dL in A1 to 167.42 mg/dL in A2 and 203.95 mg/dL in A3, demonstrating a statistically significant difference across the albuminuria categories (p=0.036). The mean TyG index increased progressively from 9.33 ± 0.39 in A1 to 9.43 ± 0.33 in A2 and 9.65 ± 0.45 in A3 (p=0.016). Similarly, the mean TyG-BMI index increased from 240.43 ± 33.29 to 261.30 ± 25.20 and 293.26 ± 32.60, respectively (p<0.001). Median serum creatinine increased from 0.73 mg/dL in A1 to 1.45 mg/dL in A3 (p<0.001). Conversely, mean eGFR decreased from 100.16 ± 20.40 in A1 to 79.65 ± 20.24 in A2 and 54.33 ± 19.02 mL/min/1.73 m² in A3 (p<0.001).

[Table 4] Association of TyG-BMI Tertiles with Albuminuria and Reduced eGFR Among Patients with Type 2 Diabetes Mellitus (N=95)

[Table 4] illustrates the distribution of albuminuria and renal function according to TyG-BMI tertiles. Patients were divided into tertile 1 (n=32), tertile 2 (n=31), and tertile 3 (n=32), with TyG-BMI ranges of 177.84–240.00, 240.63–275.24, and 275.41–348.26, respectively. Normal to mildly increased albuminuria (A1) was present in 68.75% of patients in tertile 1, 25.81% in tertile 2, and 18.75% in tertile 3. The overall distribution of albuminuria categories differed significantly across the three tertiles (p<0.001). Moderately increased albuminuria (A2) was observed in 28.13%, 61.29%, and 43.75% of patients in tertiles 1, 2, and 3, respectively. Severely increased albuminuria (A3) was observed in 3.13% of patients in tertile 1, 12.90% in tertile 2, and 37.50% in tertile 3. The overall prevalence of albuminuria (A2 + A3) increased from 31.25% in the lowest TyG-BMI tertile to 74.19% in the middle tertile and 81.25% in the highest tertile. This difference was statistically significant (p<0.001). Regarding renal function, all patients in tertile 1 had eGFR values ≥60 mL/min/1.73 m², compared with 80.65% in tertile 2 and 50.00% in tertile 3. Reduced eGFR was absent in tertile 1 but was observed in 19.35% and 50.00% of patients in tertiles 2 and 3, respectively (p<0.001). Median UACR increased from 16.86 to 55.31 and 199.20 mg/g across the tertiles (p<0.001). Mean eGFR decreased from 103.57 ± 16.69 to 81.75 ± 23.30 and 63.32 ± 19.10 mL/min/1.73 m², respectively (p<0.001).

[Table 5] Correlation, Multivariable Regression, and ROC Curve Analysis of TyG-BMI with Albuminuria and Renal Function (N=95)

[Table 5] presents the correlation of TyG-BMI with renal and metabolic parameters. Spearman's correlation analysis demonstrated a statistically

significant positive correlation between TyG-BMI and UACR (r=0.575, p<0.001). A significant negative correlation was observed between TyG-BMI and eGFR (r=−0.699, p<0.001), whereas serum creatinine showed a significant positive correlation (r=0.712, p<0.001). The correlations of TyG-BMI with HbA1c (r=0.180, p=0.080) and duration of diabetes (r=0.096, p=0.353) were not statistically significant. Multivariable logistic regression analysis demonstrated that TyG-BMI was significantly associated with albuminuria after adjustment for age, sex, duration of diabetes, hypertension, and HbA1c. Every 25-unit increase in TyG-BMI was associated with an adjusted odds ratio of 2.16 for albuminuria (95% CI: 1.43–3.26; p<0.001). Similarly, a 25-unit increase in TyG-BMI was associated with an adjusted odds ratio of 3.54 for reduced eGFR (95% CI: 1.85–6.78; p<0.001). Both adjusted associations were statistically significant. Receiver operating characteristic curve analysis was performed to evaluate the discriminatory ability of TyG-BMI for albuminuria and reduced renal function. The area under the ROC curve for identifying albuminuria was 0.752 (95% CI: 0.643–0.850), with a statistically significant p-value of <0.001. For identifying reduced eGFR below 60 mL/min/1.73 m², the AUC was 0.846 (95% CI: 0.761–0.919; p<0.001).

Table 1: Distribution of Patients According to Demographic, Anthropometric, and Clinical Characteristics (N=95)

Parameters	Frequency (n)	Percentage (%)
Age groups (years)		
<40	8	8.42
40–49	24	25.26
50–59	31	32.63
≥60	32	33.68
Sex		
Male	49	51.58
Female	46	48.42
Residence		
Rural	59	62.11
Urban	36	37.89
Duration of diabetes		
<5 years	28	29.47
5–10 years	40	42.11
>10 years	27	28.42
BMI categories (kg/m²)		
<25	21	22.11
25–<30	53	55.79
≥30	21	22.11
Associated clinical conditions		
Hypertension	49	51.58
Dyslipidaemia	56	58.95
Current smoking	20	21.05
Antidiabetic treatment		
Oral antidiabetic drugs only	57	60.00
Insulin only	10	10.53
Oral antidiabetic drugs + insulin	28	29.47

Mean age: 54.31 ± 10.71 years; mean duration of diabetes: 8.15 ± 5.17 years; mean BMI: 27.47 ± 3.42 kg/m².

Table 2: Distribution of Patients According to Biochemical Parameters, Albuminuria Categories, and Renal Function (N=95)

Parameters	Values
Biochemical parameters (Mean ± SD)	
Fasting plasma glucose (mg/dL)	158.84 ± 33.95
Postprandial glucose (mg/dL)	246.40 ± 43.34
HbA1c (%)	7.93 ± 0.97
Serum triglycerides (mg/dL)	169.64 ± 53.50
Total cholesterol (mg/dL)	191.64 ± 30.15
HDL cholesterol (mg/dL)	42.30 ± 8.06
LDL cholesterol (mg/dL)	115.63 ± 29.60
Serum creatinine (mg/dL)	1.00 ± 0.39
TyG index	9.43 ± 0.39
TyG-BMI index	259.11 ± 34.89
eGFR (mL/min/1.73 m²)	82.89 ± 25.72
UACR (mg/g), median (IQR)	52.84 (18.59–199.20)
Albuminuria categories	n (%)

A1: <30 mg/g	36 (37.89%)
A2: 30–299 mg/g	42 (44.21%)
A3: ≥300 mg/g	17 (17.89%)
Albuminuria (A2 + A3)	59 (62.11%)
eGFR categories	n (%)
G1: ≥90	39 (41.05%)
G2: 60–89	34 (35.79%)
G3a: 45–59	13 (13.68%)
G3b: 30–44	7 (7.37%)
G4: 15–29	2 (2.11%)
G5: <15	0 (0.00%)
Reduced eGFR (<60 mL/min/1.73 m²)	22 (23.16%)

Table 3: Comparison of Clinical, Metabolic, and Renal Parameters According to Albuminuria Categories (N=95)

Parameters	A1 (n=36)	A2 (n=42)	A3 (n=17)	p-value
Age (years)	53.42 ± 11.48	53.19 ± 10.23	58.94 ± 9.50	0.144
Duration of diabetes (years)	5.50 (2.00–10.00)	8.00 (5.00–12.00)	10.00 (7.00–13.00)	0.081
BMI (kg/m²)	25.77 ± 3.34	27.74 ± 2.68	30.39 ± 3.21	<0.001
Fasting glucose (mg/dL)	159.85 (140.16–172.81)	155.54 (136.32–177.19)	182.34 (143.62–192.06)	0.383
HbA1c (%)	7.79 ± 0.87	7.85 ± 1.04	8.42 ± 0.87	0.069
Triglycerides (mg/dL)	156.86 (116.58–194.36)	167.42 (133.17–205.68)	203.95 (170.89–223.97)	0.036
TyG index	9.33 ± 0.39	9.43 ± 0.33	9.65 ± 0.45	0.016
TyG-BMI index	240.43 ± 33.29	261.30 ± 25.20	293.26 ± 32.60	<0.001
Serum creatinine (mg/dL)	0.73 (0.56–0.93)	0.98 (0.82–1.16)	1.45 (1.16–1.69)	<0.001
eGFR (mL/min/1.73 m²)	100.16 ± 20.40	79.65 ± 20.24	54.33 ± 19.02	<0.001

Table 4: Association of TyG-BMI Tertiles with Albuminuria and Reduced eGFR Among Patients with Type 2 Diabetes Mellitus (N=95)

Parameters	Tertile 1 (n=32)	Tertile 2 (n=31)	Tertile 3 (n=32)	p-value
Observed TyG-BMI range	177.84–240.00	240.63–275.24	275.41–348.26	—
Albuminuria categories				<0.001
A1 (<30 mg/g)	22 (68.75%)	8 (25.81%)	6 (18.75%)	—
A2 (30–299 mg/g)	9 (28.13%)	19 (61.29%)	14 (43.75%)	—
A3 (≥300 mg/g)	1 (3.13%)	4 (12.90%)	12 (37.50%)	—
Albuminuria (A2 + A3)	10 (31.25%)	23 (74.19%)	26 (81.25%)	<0.001
Renal function				
eGFR ≥60 mL/min/1.73 m²	32 (100.00%)	25 (80.65%)	16 (50.00%)	<0.001
eGFR <60 mL/min/1.73 m²	0 (0.00%)	6 (19.35%)	16 (50.00%)	<0.001
UACR (mg/g), median (IQR)	16.86 (8.32–34.73)	55.31 (29.60–136.32)	199.20 (54.21–526.88)	<0.001
eGFR, mean ± SD	103.57 ± 16.69	81.75 ± 23.30	63.32 ± 19.10	<0.001

Table 5: Correlation, Multivariable Regression, and ROC Curve Analysis of TyG-BMI with Albuminuria and Renal Function (N=95)

Parameters	Statistical measure	Estimate	95% CI	p-value
Correlation analysis				
TyG-BMI vs UACR	Spearman's r	0.575	—	<0.001
TyG-BMI vs eGFR	Spearman's r	−0.699	—	<0.001
TyG-BMI vs serum creatinine	Spearman's r	0.712	—	<0.001
TyG-BMI vs HbA1c	Spearman's r	0.180	—	0.080
TyG-BMI vs duration of diabetes	Spearman's r	0.096	—	0.353
Multivariable logistic regression				
Albuminuria (UACR ≥30 mg/g)	Adjusted OR	2.16	1.43–3.26	<0.001
Reduced eGFR (<60 mL/min/1.73 m²)	Adjusted OR	3.54	1.85–6.78	<0.001
ROC curve analysis				
TyG-BMI for detecting albuminuria	AUC	0.752	0.643–0.850	<0.001
TyG-BMI for detecting reduced eGFR	AUC	0.846	0.761–0.919	<0.001

DISCUSSION

The present study included 95 patients with type 2 diabetes mellitus, with a mean age of 54.31 ± 10.71 years, mean diabetes duration of 8.15 ± 5.17 years, and mean BMI of 27.47 ± 3.42 kg/m². Males constituted 51.58% of the participants, while hypertension and dyslipidaemia were present in 51.58% and 58.95%, respectively. Jayakumari et al. (2022).[7] conducted an Indian study involving 3,534 patients with type 2 diabetes mellitus and reported a mean age of 53.8 ± 10.9 years, mean BMI of 27.0 ±

4.0 kg/m², and mean diabetes duration of 10.3 ± 7.5 years. Hypertension was previously diagnosed in 35.4% of their patients, compared with 51.58% in the present study. The similarities in age and BMI indicate comparable demographic and anthropometric characteristics, although hypertension was more frequent in the present study. In the present study, the mean HbA1c was 7.93 ± 0.97%, while the mean fasting and postprandial plasma glucose levels were 158.84 ± 33.95 mg/dL and 246.40 ± 43.34 mg/dL, respectively. Moderately increased albuminuria (A2) was observed in 44.21% of patients, severely increased albuminuria (A3) in 17.89%, and overall albuminuria in 62.11%. Thakur et al. (2019).[8] conducted a cross-sectional study in Nepal involving 217 analysed patients with type 2 diabetes mellitus and reported microalbuminuria in 44 patients (20.3%). Their study demonstrated significant associations of microalbuminuria with BMI (p=0.029), diabetes duration (p<0.001), hypertension (p<0.001), and smoking (p<0.001). The prevalence of moderately increased albuminuria was higher in the present study, suggesting differences in the renal profiles of the two populations, although differences in patient selection and assessment methods must be considered. The mean TyG index and TyG-BMI index in the present study were 9.43 ± 0.39 and 259.11 ± 34.89, respectively. The mean TyG-BMI index increased significantly across albuminuria categories, from 240.43 ± 33.29 in A1 to 261.30 ± 25.20 in A2 and 293.26 ± 32.60 in A3 (p<0.001). Huang et al. (2024).[9] investigated 1,080 patients with type 2 diabetes mellitus and reported significantly higher TyG-BMI values among patients with albuminuria than those without albuminuria (232.16 [206.52–268.02] versus 229.83 [206.11–255.64]; p=0.023). Similarly, patients with chronic kidney disease had higher TyG-BMI values than those without chronic kidney disease (232.23 versus 229.73; p=0.014). Both studies demonstrated a significant association between elevated TyG-BMI and renal impairment, although the present study showed a more pronounced difference across albuminuria categories. In the present study, patients were divided into three TyG-BMI tertiles comprising 32, 31, and 32 patients, respectively. The prevalence of albuminuria increased significantly from 31.25% in tertile 1 to 74.19% in tertile 2 and 81.25% in tertile 3 (p<0.001). Jiang and Lai (2024).[10] evaluated 924 newly diagnosed type 2 diabetic patients and identified diabetic kidney disease in 199 patients (21.5%). Their logistic regression analysis demonstrated significant associations of diabetic kidney disease with both TyG index (OR=1.232, 95% CI: 1.064–1.428; p=0.005) and TyG-BMI (OR=1.003, 95% CI: 1.000–1.006; p=0.021). They also reported a significant dose-response association between TyG-BMI and diabetic kidney disease (p for trend=0.035). These findings were consistent with the increasing prevalence of albuminuria across TyG-BMI tertiles in the present study, although the renal outcome definitions differed. The present study demonstrated significant deterioration in renal function across increasing TyG-BMI tertiles. The mean eGFR decreased from 103.57 ± 16.69 mL/min/1.73 m² in the lowest tertile to 81.75 ± 23.30 and 63.32 ± 19.10 mL/min/1.73 m² in the middle and highest tertiles, respectively (p<0.001). Reduced eGFR was observed in 0.00%, 19.35%, and 50.00% of patients across the three tertiles. Lv et al. (2021).[11] studied 1,432 patients with type 2 diabetes mellitus and found that a higher TyG index was significantly associated with microalbuminuria (OR=2.342, 95% CI: 1.744–3.144; p<0.001) and eGFR below 60 mL/min/1.73 m² (OR=1.696, 95% CI: 1.096–2.625; p=0.018). Their longitudinal analysis also demonstrated increased diabetic kidney disease risk in the highest TyG tertile (HR=1.727; p=0.034). Both studies showed a similar direction of association between triglyceride-glucose-related indices and impaired renal function. The present study revealed that the mean TyG index increased from 9.33 ± 0.39 in patients with normal to mildly increased albuminuria to 9.65 ± 0.45 in patients with severely increased albuminuria (p=0.016). Serum triglycerides also increased significantly across albuminuria categories (p=0.036), while the mean HbA1c increased from 7.79 ± 0.87% to 8.42 ± 0.87%, without reaching statistical significance (p=0.069). Tam et al. (2024).[12] analysed 10,714 patients with type 2 diabetes mellitus and reported diabetic nephropathy in 3,763 patients (35.1%). Their study demonstrated that patients with a TyG index ≥9.58 had 1.95 times higher odds of diabetic nephropathy compared with those having lower values. The reported sensitivity and specificity were 44.01% and 71.28%, respectively. These findings supported the association of an elevated TyG index with renal abnormalities observed in the present study, although diabetic nephropathy and albuminuria prevalence were not directly interchangeable outcomes. Correlation analysis in the present study demonstrated a significant positive association between TyG-BMI and UACR (r=0.575, p<0.001), along with a significant negative association with eGFR (r=−0.699, p<0.001). Multivariable regression analysis showed that every 25-unit increase in TyG-BMI was associated with higher odds of albuminuria (adjusted OR=2.16, 95% CI: 1.43–3.26) and reduced eGFR (adjusted OR=3.54, 95% CI: 1.85–6.78), both with p<0.001. Yu et al. (2024).[13] analysed 10,196 patients with type 2 diabetes mellitus from the ACCORD cohort and reported worsening renal function in 57.1% and incident albuminuria in 23.2% during seven years of follow-up. Elevated TyG was independently associated with worsening renal function (HR=1.24, 95% CI: 1.14–1.35) and albuminuria (HR=1.19, 95% CI: 1.03–1.37). Their longitudinal findings supported the direction of the associations observed in the present cross-sectional study, although the effect estimates measured different outcomes and exposures. Receiver operating characteristic analysis in the present study demonstrated an AUC of 0.752 (95% CI: 0.643–

0.850) for identifying albuminuria and 0.846 (95% CI: 0.761–0.919) for identifying reduced eGFR, with both associations statistically significant (p<0.001). Chu et al. (2025).[14] evaluated 425 patients with type 2 diabetes mellitus, including 137 patients with diabetic kidney disease and 288 without the condition. Their study reported an overall AUC of 0.673 for TyG-BMI in identifying diabetic kidney disease. In patients without non-alcoholic fatty liver disease, TyG-BMI demonstrated an improved AUC of 0.854, with sensitivity of 91.3% and specificity of 70.1%, whereas the AUC was 0.528 among patients with fatty liver disease. The present study demonstrated higher discriminatory ability for reduced eGFR than for albuminuria. Differences in patient characteristics, renal outcome definitions, and TyG-BMI calculations limited direct comparison of diagnostic performance between the studies.

CONCLUSION

The present study demonstrated a significant association of elevated triglyceride-glucose–body mass index (TyG-BMI) with increased albuminuria and reduced estimated glomerular filtration rate (eGFR) among patients with type 2 diabetes mellitus. Higher TyG-BMI values were associated with greater urinary albumin excretion, elevated serum creatinine, and impaired renal function. TyG-BMI also showed promising discriminatory ability for identifying patients with albuminuria and reduced eGFR. Being a simple, inexpensive, and readily available metabolic index, TyG-BMI may serve as an additional marker for renal risk assessment alongside conventional investigations. Further prospective studies are required to validate its clinical utility in the early identification of diabetic kidney disease.

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