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Assessing the Serum Triglyceride and Fasting Plasma Glucose Ratio as A Predictor of Left Ventricular Diastolic Dysfunction in Type 2 Diabetes Mellitus, A Cross-Sectional Study

Susmita Deb[1], Debashis Priyadarshan Sahoo[2]

[1]Consultant Physician, GNRC Hospital, Guwahati, Assam, India.
[2]Senior Resident, AIIMS, Guwahati, Assam, India.

ABSTRACT

Introduction: Cardiovascular complications, including left ventricular diastolic dysfunction (LVDD), are major concerns in Type 2 Diabetes Mellitus (T2DM) patients, often preceding heart failure and increasing mortality. Early detection of LVDD is essential to improving outcomes, yet current diagnostic methods are often costly and impractical for routine screening. This study aimed to evaluate the correlation between the serum triglyceride to fasting plasma glucose (TG/FPG) ratio and LVDD in T2DM patients, as a potential cost-effective biomarker for cardiovascular risk stratification.

Methodology: This observational analytical study was conducted over a period of one year at a tertiary care hospital in northeast India to assess the correlation of TG/FPG ratio with LVDD in patients with T2DM. A total of 100 participants, aged 18 years or above and diagnosed with T2DM, were included. Exclusion criteria comprised Type 1 Diabetes Mellitus, pregnancy, pre-existing hypertension, cardiovascular diseases, and patients denying consent. Participants were recruited using convenient sampling, with every alternate eligible patient enrolled until the target sample size was reached.

Data collection included measuring fasting plasma glucose (FPG) and postprandial blood glucose, HbA1c, fasting lipid profile, kidney function test, and urinalysis. The cardiovascular evaluation consisted of chest radiography, electrocardiogram, and echocardiography using standardized parameters to classify LVDD into grades I, II, and III, based on E/A and E/e' ratios. Statistical analysis was performed using SPSS version 15, with Chi-square test and student's t-tests applied for significance (p-value < 0.05), and regression analysis was used to identify associations. Ethical approval was obtained, and participant confidentiality was maintained throughout the study.

Result: A cross-sectional study was conducted over one years at a tertiary hospital in northeast India, enrolling 100 participants with T2DM, excluding those with comorbidities or cardiovascular symptoms. The mean age of participants was 45.52 years, with a male-to-female ratio of 1.21:1. Diastolic dysfunction was evaluated using echocardiography, and the TG/FPG ratio was calculated for each patient. LVDD was found in 58.7% of the participants, classified into grade I (40.4%), grade II (13.5%), and grade III (4.8%). Statistical analysis revealed a significant positive correlation between the TG/FPG ratio and LVDD (p-value= 0.0001). Higher TG/FPG ratios were associated with worse diastolic function, suggesting that this ratio reflects combined metabolic disturbances contributing to myocardial dysfunction. Patients with LVDD had significantly higher lipid profiles and poorer glycemic control compared to those with normal

LV function. The TG/FPG ratio, being easily obtainable from routine laboratory tests, offers a convenient tool for identifying individuals at higher risk for LVDD.
Conclusion: The TG/FPG ratio may serve as a simple, accessible, and cost-effective marker for early detection of LVDD in T2DM patients. Incorporating this ratio in clinical practice could improve cardiovascular risk stratification and facilitate timely interventions, ultimately reducing the burden of cardiovascular disease in diabetic populations.

KEY-WORDS: TG/FPG, Left Ventricular diastolic dysfunction, Type 2 Diabetes Mellitus

1. INTRODUCTION

Cardiovascular complications are among the most significant health concerns associated with Type 2 Diabetes Mellitus (T2DM), with left ventricular diastolic dysfunction (LVDD) being a common manifestation [1]. Early detection of LVDD in diabetic patients is crucial to mitigating adverse outcomes and reducing the overall burden of cardiovascular disease. Traditional diagnostic tools for LVDD often rely on advanced imaging techniques, which may not be readily available or practical for routine screening, particularly in resource-limited settings [2]. Thus, identifying simple, cost-effective biomarkers to predict LVDD risk in T2DM patients has become a priority in the realm of diabetic care and cardiovascular health.

In recent years, the serum triglyceride (TG) to fasting plasma glucose (FPG) ratio has emerged as a potential metabolic marker with implications for cardiovascular health [3]. Elevated serum triglyceride levels are known to reflect underlying insulin resistance and atherogenic dyslipidemia, while fasting plasma glucose serves as an indicator of glycemic control [4]. Both of these parameters are routinely measured in clinical practice, making the TG/FPG ratio a convenient candidate for risk assessment. Some studies have suggested that this ratio may correlate with markers of cardiac dysfunction, thus offering a new perspective in the early identification of patients at risk for LVDD [2,5].

The present study aimed to assess the relationship between the TG/FPG ratio and left ventricular dysfunction in individuals with T2DM. By employing a cross-sectional study design, we seek to explore whether this easily measurable metabolic marker could serve as a practical predictor for LVDD. If validated, the TG/FPG ratio could become an accessible tool to enhance cardiovascular risk stratification and guide timely intervention in diabetic patients.

2. AIM AND OBJECTIVES

2.1 Aim

To find out the correlation of Left ventricular diastolic dysfunction with serum triglyceride and fasting plasma glucose ratio.

2.2 Study objectives:

1. Assess serum triglyceride and fasting plasma glucose level in patients with T2DM, without any other comorbidity.
2. Assess LV dysfunction in patients with T2DM without any other comorbidity
3. To find the correlation of Left ventricular diastolic dysfunction with Serum Triglyceride and Fasting Plasma Glucose Ratio.

1. METHODOLOGY

3.1. Study population and sampling strategy

This cross-sectional study was conducted over a period of one years, from August 2021 to July 2022, at a tertiary care hospital in northeast India. The aim of the study was to find out any correlation of TG/FPG ratio with LVDD in patients with T2DM. LVDD is a condition characterised by the impaired filling of LV, a common, yet underdiagnosed cardiac complication in patients with T2DM. A total of 100 individuals aged 18 years and above with Diabetes Mellitus were included in the study. Exclusion criteria encompassed type 1 diabetes mellitus, pregnancy, history of hypertension (BP ≥140/90 mmHg), pre-existing cardiovascular diseases, and unwillingness to provide consent. Participants were selected through convenience sampling, wherein every alternate patient fitting the inclusion criteria was recruited until the desired sample size of 100 was achieved. The method was chosen due to practical constraints of the study setting and to ensure a steady stream of participants who presented to hospital diabetic clinic.

3.2. Data Collection and Screening

Upon enrollment, participants underwent a systematic and detailed data collection process, which began with the recording of demographic and clinical data, including age, gender, duration of diabetes, and relevant lifestyle factors such as smoking and alcohol use. A thorough clinical history was obtained, emphasizing symptoms related to cardiac health, previous hospitalizations, and family history of cardiovascular disease. Physical examinations were performed meticulously, focusing on anthropometric measurements like height, weight, and waist-hip ratio, as well as vital signs including pulse, blood pressure, and respiratory rate. This provided a comprehensive baseline profile for each participant.

Biochemical evaluations were performed to assess the participants' metabolic status and identify potential risk factors for cardiovascular complications. Fasting plasma glucose and postprandial blood glucose levels were measured to determine the participants' immediate glycemic control, while HbA1c testing was conducted to evaluate their long-term glycemic status over the past three months, as per ADA 2018 guidelines [6]. In addition to glucose measurements, a complete lipid profile was obtained, including total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglyceride levels, as dyslipidemia is a common and significant risk factor for cardiac disease in diabetic patients. Kidney function tests, including serum creatinine and blood urea nitrogen (BUN), were performed to assess renal health, considering that diabetic nephropathy is frequently associated with cardiovascular complications. Urinalysis was conducted to screen for microalbuminuria or proteinuria, which can be early indicators of diabetic kidney disease and cardiovascular risk.

The cardiovascular evaluation was a crucial component of the study methodology and involved a series of non-invasive imaging and diagnostic tests. Each participant underwent a chest radiography in the posteroanterior view to evaluate the size and silhouette of the heart and to detect any pulmonary changes suggestive of heart failure or fluid overload. This was followed by a detailed electrocardiography (ECG) to identify any electrical abnormalities, arrhythmias, or ischemic changes, which are often seen in diabetic patients with silent cardiac disease. The cornerstone of the cardiovascular assessment was the echocardiographic evaluation performed using the Philips X7-2 machine by a single experienced operator, ensuring consistency and minimizing inter-operator variability. Echocardiography is the gold standard for assessing diastolic function, and in this study, it was used to measure key parameters indicative of diastolic dysfunction. These parameters included the early-to-late diastolic trans mitral flow velocity (E/A) ratio and the early diastolic mitral annular tissue velocity (E/e') ratio. Based on these measurements, diastolic dysfunction was classified into three grades: Grade I (Impaired Relaxation), indicating a delay in left

ventricular relaxation; Grade II (Pseudo-Normal Filling), characterized by a deceptively normal E/A ratio due to elevated filling pressures; and Grade III (Restrictive Pattern), marked by severely impaired relaxation and increased left ventricular filling pressures [7].

3.3. Statistical analysis

Following data collection, the statistical analysis was performed using SPSS version 15 and Microsoft Excel 2010 to ensure robust data handling and interpretation. Categorical variables were analysed using chi-square tests, while continuous variables were compared using Student's t-tests. A p-value of < 0.05 was considered statistically significant. Furthermore, regression analysis was done to find out the probable association between the parameters.

3.4. Ethical consideration

The study was conducted following a strict ethical framework, as mandated by the Ethics Committee of the hospital. Ethical approval was obtained before the commencement of the research, and all participants were thoroughly informed about the study's objectives, methodology, potential risks, and benefits. Written informed consent was obtained from each participant, ensuring voluntary participation and compliance with ethical standards. The confidentiality and anonymity of the participants were maintained throughout the study, with all personal data being securely stored and used exclusively for research purposes. The study adhered to the principles of the Declaration of Helsinki, ensuring respect, dignity, and protection of the participants' rights throughout the research process.

2. RESULTS

4.1. Demography

The present study included 100 participants, all diagnosed with T2DM without any comorbidities. The mean age of the participants was 45.52 ± 10.85 years, with a male-to-female ratio of 1.12:1. The majority of participants (46.2%) were in the 41-50 years age group, followed by 29.8% who were over 50 years, 13.5% in the 31-40 years age group, and 10.6% in the 20-30 years age group. The mean duration of diabetes among participants was 8.22±4.86 years. The study population had a BMI of 24.65 ± 2.38 kg/m^2.

4.2. Assessment of serum TG and FPG in patients with T2DM

The mean fasting blood glucose level of 173.12 ± 34.25 mg/dL and a mean postprandial blood glucose level of 251 ± 57.73 mg/dL. The mean HbA1c value was 7.84 ± 0.96, indicating moderate glycemic control among the participants. In terms of lipid profile, the mean total cholesterol level was 205.95 ± 44.939 mg/dL, the mean triglycerides level was 216.27 ± 61.31mg/dL, the mean LDL was 127.33 ± 28.093 mg/dL, and the mean HDL was 41.5 ± 8.6 mg/dL. Cardiovascular assessments showed a mean systolic blood pressure of 118 ± 9.23 mmHg and a mean diastolic blood pressure of 71.2 ± 7.48 mmHg.

4.3. Assessment of LVDD in patients with T2DM without any other comorbidity

Echocardiographic parameters revealed a mean E/A ratio of 1.020 ± 0.348 and a mean E/e' ratio of 7.7824 ± 1.911. The prevalence of LVDD among T2DM patients without any comorbidities was 58.0%. Among the 100 participants, 42 individuals (41.3%) had no LVDD, while 41 patients (40.4%) were classified as having grade I LVDD. Additionally, 13 patients (13.5%) exhibited grade II LVDD, and 4 patients (4.8%) had grade III LVDD. Demographic parameters are compared with LVDD and interpreted in Table 1.

Table 1: Demographic parameters of the study population with LVDD

	Left ventricular diastolic dysfunction (LVDD) Number of individuals [n (%)]		
Age (years)	**Present**	**Absent**	**p- value**
18-30	2 (18.2%)	8 (81.8%)	0.006
31-40	9 (64.3%)	5 (35.7%)	
41-50	26 (54.2%)	21 (45.8%)	
>51	23 (77.4%)	6 (22.6%)	
Gender			
Female	26 (58.7%)	18 (41.3%)	0.994
Male	33 (58.6%)	23 (41.4%)	
Duration of T2DM			
< 5	14 (57.7%)	8 (30.8%)	0.016
5 to 10	22 (44.2%)	22 (44.2%)	
>10	5(19.2%)	10(42.3%)	

*LVDD: Left Ventricular Diastolic Dysfunction; T2DM: Type 2 Diabetes Mellitus; FPG: Fasting Plasma Glucose; PPPG: Post Prandial Blood Glucose

There was a significant difference between patients with LVDD and those with normal left ventricular (LV) function. The median E/A ratio was significantly lower in patients with LVDD (0.800±1.60) compared to those with normal LV function (1.20±0.500), with a p-value of 0.001, indicating impaired diastolic filling in LVDD. Additionally, the mean E/e' ratio was significantly higher in patients with LVDD (8.48 ± 2.20) compared to those with normal LV function (6.79 ± 0.55), also with a p-value of 0.001, reflecting elevated LV filling pressures in LVDD. Statistical tests for normality (Shapiro-Wilk) and equal variances (Levene's test) were performed, and the Mann-Whitney test was used where appropriate. These findings highlight the distinct echocardiographic patterns associated with LVDD, with lower E/A ratios and higher E/e' ratios being key indicators.

This study demonstrates that participants with LVDD have significantly higher lipid levels compared to those with normal LV function. Specifically, participants with LVDD have a higher median total cholesterol (TC) level of 210±20.21 mg/dL compared to 190±11.22 mg/dL in the normal LV group, with a statistically significant p-value of 0.006. Similarly, the mean TG levels are elevated in the LVDD group (244±68.6 mg/dL) compared to the normal LV group (199 ± 35.1 mg/dL), with a p-value of 0.001, indicating a significant difference. Furthermore, the median LDL levels are also higher in the LVDD group (123±22.43 mg/dL) compared to those with normal LV function (107±14.98 mg/dL), with a significant p-value of 0.005. Interestingly, although HDL levels are typically protective, participants with LVDD have lower median HDL levels (36±8.90 mg/dL) compared to those with normal LV function (46±7.89 mg/dL), and this difference is also statistically significant (p-value = 0.001). These findings suggest that abnormal lipid profiles are associated with LV diastolic dysfunction, further contributing to cardiovascular risk in these patients.

4.4. The correlation of TG/FPG ratio with LVDD

Serum TG/FPG ratio was calculated in each patient with a mean of 1.37±1.20 and was compared with grade of LVDD using chi-square test which revealed a significant relation between the both (p value= 0.0001). The regression analysis is as follows (Figure 1) with a positive correlation (r value= 0.38).

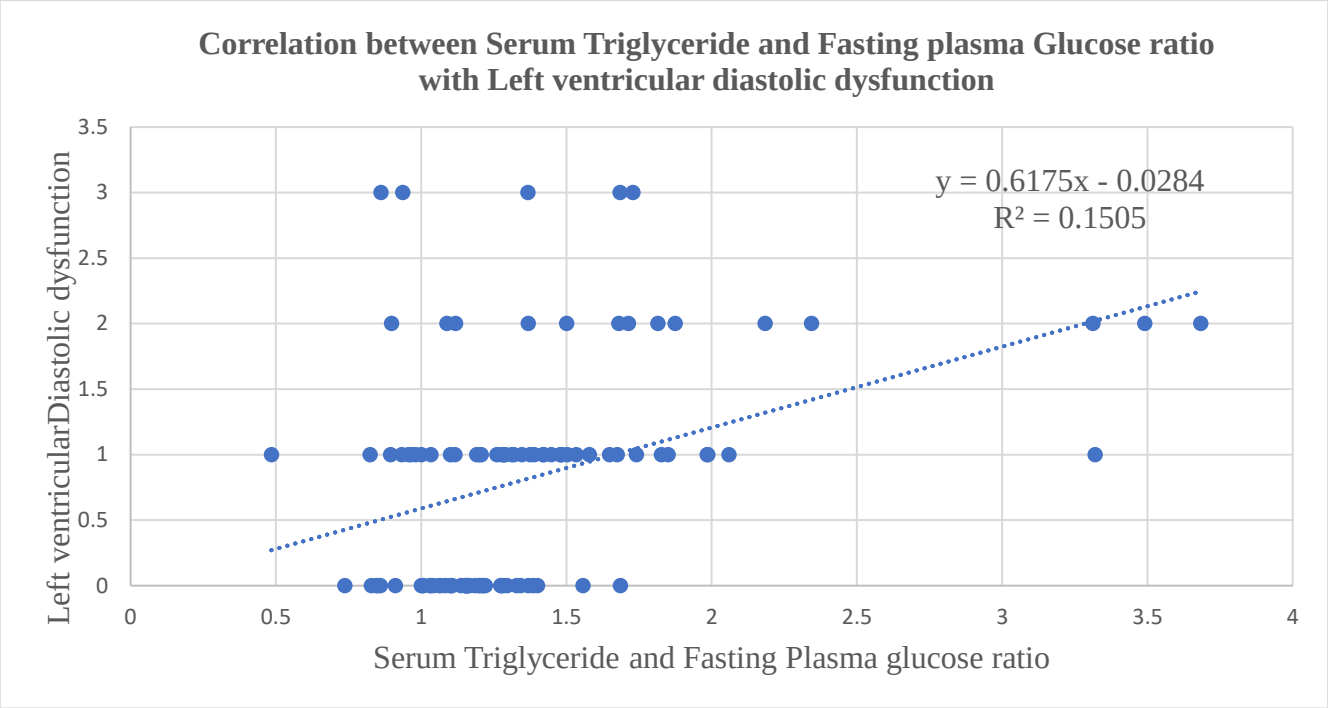

Figure 1: Showing positive correlation between Serum Triglyceride and Fasting plasma Glucose ratio with Left ventricular diastolic dysfunction

3. DISCUSSION

The positive correlation between the TG/FPG ratio and LVDD has important implications for understanding the metabolic contributors to heart disease [8]. This ratio reflects a combined assessment of dyslipidemia and impaired glucose metabolism, both of which play significant roles in the pathogenesis of LVDD [9]. LVDD is characterized by impaired relaxation and increased stiffness of the left ventricle, which often precedes heart failure with preserved ejection fraction (HFpEF) [10]. The TG/FPG ratio provides a useful indicator of metabolic health, and its association with LVDD underscores the close relationship between metabolic dysfunction and cardiac diastolic impairment.

5.1. Triglyceride/Glucose Ratio as a Marker of Metabolic Dysfunction

The TG/FPG ratio has been recognized as a marker of insulin resistance and an indicator of cardiometabolic risk [11]. Elevated serum triglycerides and fasting plasma glucose are often seen in individuals with metabolic syndrome, obesity, and T2DM. Both high TG levels and elevated FPG are independently associated with cardiovascular disease, but their combined effect, as reflected in the TG/FPG ratio, provides a more comprehensive indicator of metabolic stress on the cardiovascular system [12].

1. TG: Elevated triglycerides contribute to lipid accumulation in the myocardium (lipotoxicity), which can lead to cellular dysfunction, inflammation, and myocardial fibrosis—key factors in LV diastolic dysfunction [13].
2. FPG: Hyperglycemia is a well-established risk factor for diastolic dysfunction due to the formation of advanced glycation end-products (AGEs), which stiffen the myocardium, and increased oxidative stress, which damages the endothelial lining and promotes fibrosis [14].

5.2. Mechanistic Link Between TG/FPG Ratio and LV Diastolic Dysfunction

A positive correlation between the TG/FPG ratio and LVDD suggests that the combined burden of hypertr-

iglyceridemia and hyperglycemia exacerbates left ventricular diastolic impairment. The mechanisms underlying this relationship include:

1. **Insulin Resistance**: The TG/FPG ratio is a surrogate marker for insulin resistance, a condition where tissues become less responsive to insulin, leading to elevated blood glucose and triglyceride levels. Insulin resistance is known to impair cardiac energy metabolism, reduce myocardial efficiency, and promote myocardial stiffness, all of which contribute to diastolic dysfunction [15].
2. **Lipotoxicity and Glucotoxicity:** High triglyceride levels can lead to lipotoxicity, where excess fat is deposited in the heart, causing cellular damage and promoting fibrosis. Similarly, chronic hyperglycemia leads to glucotoxicity, which accelerates the formation of AGEs and increases oxidative stress. These processes collectively stiffen the myocardium and impair the relaxation phase of the cardiac cycle [16].
3. **Endothelial Dysfunction and Inflammation:** Elevated TG and FPG levels both contribute to endothelial dysfunction, a precursor to atherosclerosis and impaired microvascular function. The reduced availability of nitric oxide (NO), due to endothelial dysfunction, hampers myocardial relaxation and further impairs diastolic function. Additionally, both elevated triglycerides and glucose trigger systemic inflammation, which promotes cardiac fibrosis and worsening diastolic performance [17,18].
4. **Myocardial Remodelling**: Chronic exposure to high TG and glucose levels lead to structural changes in the heart, including increased left ventricular wall thickness and myocardial stiffness. This remodelling reduces the left ventricle's ability to fill during diastole, increasing filling pressures and contributing to the progression of LVDD [19,20].

There are some similar studies on the above findings. Jin JL, et al, in 2018 examined the prognostic value of the triglyceride-glucose (TyG) index in 3,745 patients with stable coronary artery disease (CAD). Over 11,235 person-years of follow-up, cardiovascular events (CVEs), including death, non-fatal MI, stroke, and revascularization, were recorded. A total of 290 patients with CVEs were compared to 1,450 matched controls. The TyG index was positively associated with increased CVE risk (HR: 1.364, p value = 0.005), and patients in the highest TyG quartile had the lowest event-free survival (p value = 0.029). These findings suggest that the TyG index may be a useful predictor of cardiovascular events in stable CAD patients [21].
Another study by Araújo SP, et al, in 2022 evaluated the predictive ability of the TyG for cardiovascular risk and establish its cutoff value in a cardiometabolic risk population. Conducted on 264 individuals (54.9% women, average age 43.1 years), it used demographic, clinical, and lifestyle data, alongside the Framingham risk score (FRS) for cardiovascular risk assessment. The TyG index was calculated using the formula Ln [fasting triglycerides × fasting plasma glucose/2]. ROC analysis identified a TyG cutoff of 9.04 (sensitivity = 62.5%, specificity = 66.7%), strongly associated with cardiometabolic risk factors and an increased prevalence of intermediate/high FRS risk (RP = 1.69). Thus, the TyG index demonstrates a robust predictive capacity for long-term cardiovascular risk [22].
Another study by Na L, et al, in 2023 explored the relationship between the TyG index and left ventricular global longitudinal strain (GLS) in patients with coronary heart disease (CHD), focusing on the role of GLS in detecting early cardiac dysfunction. In a cross-sectional study of 178 symptomatic CHD patients (excluding those with myocardial infarction or left ventricular dysfunction) in Jilin Province, China, clinical, biochemical, and echocardiographic data were collected. Myocardial strain parameters were compared between groups with higher and lower TyG indices. The study found that patients with a higher TyG index had lower GLS values, indicating worse subclinical cardiac function. This association remained

significant after adjusting for confounding factors. These findings suggest that a higher TyG index may be independently linked to early left ventricular dysfunction in CHD patients [23].

Another study by Zhang S, et al, in 2024 highlighted that the left ventricular GLS was more diagnostically and prognostically significant than the left ventricular ejection fraction (LVEF) in heart failure (HF) patients. The TyG index, a reliable indicator of insulin resistance (IR), was linked to adverse cardiovascular outcomes. However, the relationship between the TyG index and GLS in CHF patients is less understood. Analysing data from 427 CHF patients, the study found that those with a higher TyG index exhibited lower GLS values (p value = 0.01), indicating worsening cardiac function. This association persisted after adjusting for various factors, suggesting that an elevated TyG index may independently predict more severe left ventricular dysfunction in CHF patients [24].

Another study by Pan Y, et al, in 2024, interpreted that TyG index can be used in assessing severity of Diabetic complications like nephropathy, retinopathy, Peripheral vascular disease, neuropathy along with Cardiovascular complications [25].

These studies along with some other studies conducted by Chamroonkiadtikun P, et al (2019), Lopez-Jaramillo, et al (2023) and Yang Q, et al (2023) supported the fact that high TG/FPG ratio predicts the severity of LVDD and increasing cardiovascular morbidity and mortality [26,27,28]. And there are limited studies defying this result.

5.3. Clinical Implications of the TG/FPG Ratio in LVDD

The TG/FPG ratio offers a simple and valuable tool for identifying individuals at higher risk of LV diastolic dysfunction. Since LVDD is often asymptomatic in its early stages, using the TG/FPG ratio could help in early detection of at-risk individuals, especially those with metabolic syndrome or prediabetes. Managing the TG/FPG ratio through lifestyle changes or pharmacologic interventions aimed at lowering triglycerides and improving glucose control may help prevent or mitigate the progression of diastolic dysfunction.

5.4.Therapeutic Considerations

1. To reduce the TG/FPG ratio and its associated risk for LVDD, strategies targeting both lipid and glucose metabolism are crucial. Interventions that focus on [29,30]:
2. Improving insulin sensitivity through diet, exercise, or medications (e.g., metformin, GLP-1 receptor agonists) could simultaneously lower fasting plasma glucose and serum triglycerides.
3. Managing dyslipidemia through lifestyle interventions or lipid-lowering medications (e.g., statins, fibrates) could help reduce serum triglycerides, thereby lowering the TG/FPG ratio.

These strategies not only improve metabolic health but also have the potential to prevent the onset or progression of LVDD.

5.5. Limitations

The study has several limitations that need to be addressed. First, the cross-sectional design precludes establishing a causal relationship between the TG/FPG ratio and LVDD in T2DM patients. Second, the study sample size was relatively small and recruited from a single center, which may limit the generalizability of the findings. Additionally, potential confounding factors such as medication use, duration of diabetes, and lifestyle factors were not fully accounted for. Future research should focus on conducting large-scale, multi-center, longitudinal studies to confirm the prognostic value of the TG/FPG ratio for predicting diastolic dysfunction and to explore the underlying mechanisms in more detail. Moreover, investigating whether interventions aimed at modifying the TG/FPG ratio can directly improve diastolic function and reduce cardiovascular events in T2DM patients would provide valuable insights for clinical practice.

4. CONCLUSION

The positive correlation between the TG/FPG ratio and LVDD reflects the significant impact of combined metabolic disturbances on cardiac function. The TG/FPG ratio serves as a valuable marker of cardiometabolic risk and highlights the interplay between lipid and glucose metabolism in the development of diastolic dysfunction. By addressing the metabolic factors driving this relationship, clinicians may be able to reduce the burden of LVDD and its progression to heart failure in at-risk populations.

5. REFERRENCES

1. Dal Canto E, Ceriello A, Rydén L, et al. Diabetes as a cardiovascular risk factor: An overview of global trends of macro and micro vascular complications. Eur J Prev Cardiol. 2019 ;26 (2_suppl): 25–32.
2. Thomas L, Marwick TH, Popescu BA, et al. Left Atrial Structure and Function, and Left Ventricular Diastolic Dysfunction. J Am Coll Cardiol [Internet]. 2019: 23; 73 (15): 1961–1977. Available from: https://www.jacc.org/doi/10.1016/j.jacc.2019.01.059.
3. Liu C, Liang D. The association between the triglyceride–glucose index and the risk of cardiovascular disease in US population aged ≤ 65 years with prediabetes or diabetes: a population-based study. Cardiovasc Diabetol. 2024; 23 (1): 168. Available from: https://doi.org/10.1186/s12933-024-02261-8.
4. G. Parhofer K, Laufs U. The Diagnosis and Treatment of Hypertriglyceridemia. Dtsch Ärztebl Int. 2019 ;116 (49): 825–832. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6962767.
5. Upadhyay RK. Emerging Risk Biomarkers in Cardiovascular Diseases and Disorders. J Lipids. 2015: 971453. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4407625.
6. Standards of Medical Care in Diabetes—2018 Abridged for Primary Care Providers. Clinical Diabetes American Diabetes Association. Available from: https://diabetesjournals.org/clinical/article/36/1/14/31812/Standards-of-Medical-Care-in-Diabetes-2018.
7. Lee AR. Diastolic Dysfunction: Causes, Symptoms and Treatment. Medical News Today. 2023 (updated April 23). Available from: https://my.clevelandclinic.org/health/diseases/23434-diastolic-dysfunction.
8. Zhang S, Liu Y, Liu F, et al. Correlation between the triglyceride-glucose index and left ventricular global longitudinal strain in patients with chronic heart failure: a cross-sectional study. Cardiovasc Diabetol. 2024;23 (1): 182. Available from: https://doi.org/10.1186/s12933-024-02259-2.
9. Jialal I, Singh G. Management of diabetic dyslipidemia: An update. World J Diabetes [Internet]. 2019; 10 (5): 280–290. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6522756.
10. Shillcutt SK, Chacon MM, Brakke TR, et al. Heart Failure with Preserved Ejection Fraction: A Perioperative Review. J Cardiothorac Vasc Anesth. 2017; 31 (5): 1820–1830. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6071869.
11. Zhuang Y, Qiu L, Han D, et al. The association between triglyceride-glucose index and related parameters and risk of cardiovascular disease in American adults under different glucose metabolic states. Diabetol Metab Syndr. 2024; 16 (1): 102. Available from: https://doi.org/10.1186/s13098-024-01340-w.
12. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and Management of the Metabolic Syndrome. Circulation. 2005: 12 (17): 2735–2752. Available from: https://www.ahajournals.org/doi/10.1161/circulationaha.105.169404.

13. Ruberg FL. Myocardial Lipid Accumulation in the Diabetic Heart. Circulation [Internet]. 2007; 116 (10): 1110–1112. Available from: https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.107.721860.
14. González P, Lozano P, Ros G, Solano F. Hyperglycemia and Oxidative Stress: An Integral, Updated and Critical Overview of Their Metabolic Interconnections. Int J Mol Sci. 2023; 24 (11): 9352. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10253853.
15. Er LK, Wu S, Chou HH, et al. Triglyceride Glucose-Body Mass Index Is a Simple and Clinically Useful Surrogate Marker for Insulin Resistance in Nondiabetic Individuals. PLOS ONE [Internet]. 2016; 11 (3): e0149731. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0149731.
16. Glucolipotoxicity, β-Cells, and Diabetes: The Emperor Has No Clothes | Diabetes | American Diabetes Association [Internet]. [cited 2024 Sep 30]. Available from: https://diabetesjournals.org/diabetes/article/69/3/273/39762/Glucolipotoxicity-Cells-and-Diabetes-The-Emperor.
17. Theofilis P, Sagris M, Oikonomou E, et al. Inflammatory Mechanisms Contributing to Endothelial Dysfunction. Biomedicines [Internet]. 2021; 9 (7): 1-4. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8301477.
18. Medina-Leyte DJ, Zepeda-García O, Domínguez-Pérez M, et al. Endothelial Dysfunction, Inflammation and Coronary Artery Disease: Potential Biomarkers and Promising Therapeutical Approaches. Int J Mol Sci [Internet]. 2021; 22 (8): 3850. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8068178.
19. Heusch G, Libby P, Gersh B, et al. Cardiovascular remodelling in coronary artery disease and heart failure. The Lancet [Internet]. 2014; 383 (9932):1933–1943. Available from: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)60107-0/abstract.
20. Azevedo PS, Polegato BF, Minicucci MF, et al. Cardiac Remodeling: Concepts, Clinical Impact, Pathophysiological Mechanisms and Pharmacologic Treatment. Arq Bras Cardiol [Internet]. 2016; 106 (1): 62. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4728597.
21. Jin JL, Cao YX, Wu LG, You XD, Guo YL, Wu NQ, et al. Triglyceride glucose index for predicting cardiovascular outcomes in patients with coronary artery disease. J Thorac Dis. 2018; 10 (11): 6137–6146.
22. Araújo SP, Juvanhol LL, Bressan J, et al. Triglyceride glucose index: A new biomarker in predicting cardiovascular risk. Prev Med Rep. 2022; 29: 101941. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9502283.
23. Na L, Cui W, Li X, et al. Association between the triglyceride–glucose index and left ventricular global longitudinal strain in patients with coronary heart disease in Jilin Province, China: a cross-sectional study. Cardiovasc Diabetol. 2023; 22 (1): 321. Available from: https://doi.org/10.1186/s12933-023-02050-9.
24. Zhang Q, Xiao S, Jiao X, et al. The triglyceride-glucose index is a predictor for cardiovascular and all-cause mortality in CVD patients with diabetes or pre-diabetes: evidence from NHANES 2001–2018. Cardiovasc Diabetol. 2023; 22 (1): 279. Available from: https://doi.org/10.1186/s12933-023-02030-z.
25. Pan Y, Zhao M, Song T, et al. Role of Triglyceride-Glucose Index in Type 2 Diabetes Mellitus and Its Complications. Diabetes Metab Syndr Obes. 2024; 17: 3325–3333. Available from: https://www.tandfonline.com/doi/abs/10.2147/DMSO.S478287.

26. Chamroonkiadtikun P, Ananchaisarp T, Wanichanon W. The triglyceride-glucose index, a predictor of type 2 diabetes development: A retrospective cohort study. Prim Care Diabetes. 2020; 14 (2): 161–167.
27. Lopez-Jaramillo P, Gomez-Arbelaez D, Martinez-Bello D, et al. Association of the triglyceride glucose index as a measure of insulin resistance with mortality and cardiovascular disease in populations from five continents (PURE study): a prospective cohort study. Lancet Healthy Longev. 2023; 4 (1): e23–33. Available from: https://www.thelancet.com/journals/lanhl/article/PIIS2666-7568(22)00247-1/fulltext.
28. Yang Q, Xu H, Zhang H, et al. Serum triglyceride glucose index is a valuable predictor for visceral obesity in patients with type 2 diabetes: a cross-sectional study. Cardiovasc Diabetol. 2023: 29; 22 (1): 98.
29. Miao H, Zhou Z, Yang S, et al. The association of triglyceride-glucose index and related parameters with hypertension and cardiovascular risk: a cross-sectional study. Hypertens Res. 2024; 47 (4): 877–886. Available from: https://www.nature.com/articles/s41440-023-01502-9.
30. Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association | Diabetes Care | American Diabetes Association. [cited 2024 Sep 30]. Available from: https://diabetesjournals.org/care/article/39/11/2065/37249/Physical-Activity-Exercise-and-Diabetes-A-Position.