Original Research Article

Triglyceride-to-High-Density Lipoprotein Cholesterol Ratios in Prediabetics With a Normal Range of Low-Density Lipoprotein Cholesterol

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Abstract: *The triglyceride-to-high-density lipoprotein cholesterol ratio is an emerging marker of insulin resistance and metabolic syndrome. It may identify cardiovascular risk even in individuals with normal low-density lipoprotein cholesterol levels. Early detection is particularly important in Pakistan, where the burden of prediabetes is rapidly increasing.* **Objective:** *To determine the frequency of prediabetes across triglyceride to high-density lipoprotein cholesterol ratio quintiles among adults with normal low-density lipoprotein cholesterol levels.* **Methods:** *This descriptive cross-sectional study was conducted at the Department of Chemical Pathology, Sheikh Zayed Hospital, Rahim Yar Khan, from January to July 2024. A total of 131 adults aged 25 to 65 years with low-density lipoprotein cholesterol levels between 50 and 100 mg/dL were enrolled using non-probability, consecutive sampling. Prediabetes was defined as fasting blood glucose levels of 100 to 125 mg/dL or glycated hemoglobin levels of 5.7 to 6.4 percent. Participants were categorized into five quintiles based on the triglyceride-to-high-density lipoprotein cholesterol ratio. Demographic, clinical, and biochemical variables were recorded and analyzed using SPSS version 20. Associations were assessed using chi-square tests, with p-values of 0.05 or less considered statistically significant.* **Results:** *The mean age of participants was 44.6 ± 10.1 years, and 54.2 percent were female. The overall frequency of prediabetes was 29.0 percent. A progressive increase in prediabetes prevalence was observed across triglyceride-to-high-density lipoprotein cholesterol ratio quintiles, rising from 4.3 percent in the lowest quintile to 48.1 percent in the highest quintile, indicating a statistically significant association ($\chi^2 = 22.76$, $p < 0.001$). No significant differences were found with respect to gender, educational status, or place of residence.* **Conclusion:** *The triglyceride-to-high-density lipoprotein cholesterol ratio is significantly associated with prediabetes among individuals with normal low-density lipoprotein cholesterol levels. Its simplicity and low cost support its potential use as a practical screening tool for early identification of metabolic risk in the Pakistani population.*

Keywords: High-Density Lipoprotein Cholesterol; Insulin Resistance; Low-Density Lipoprotein Cholesterol; Metabolic Syndrome X; Pakistan; Prediabetic State; Triglycerides

Introduction

Metabolic syndrome (MetS) comprises a cluster of metabolic abnormalities that markedly increase the risk of cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM). According to the National Cholesterol Education Program criteria, MetS is defined by the presence of three or more of the following components: abdominal obesity, hypertension, elevated triglyceride levels, reduced high-density lipoprotein cholesterol (HDL-C), and hyperglycemia (1,2). In Pakistan, rapid urbanization and lifestyle transitions have contributed to a concerning rise in the prevalence of MetS. Available evidence suggests that nearly 30% of the adult population fulfills the diagnostic criteria for MetS, underscoring a major public health concern (3).

Among individuals with prediabetes, lipid abnormalities are commonly observed, particularly elevated triglycerides and reduced HDL-C levels, both of which are well-established predictors of cardiovascular disease (4,5). The triglyceride-to-HDL-C ratio (TG/HDL-C ratio) has gained recognition as a reliable and practical index for assessing cardiovascular risk, showing a strong association with insulin resistance and metabolic syndrome across diverse populations (4,6). Importantly, this ratio is effective in identifying underlying metabolic derangements even in individuals with normal low-density lipoprotein cholesterol (LDL-C) levels, thereby demonstrating superior predictive value compared to conventional lipid parameters alone (4,7).

In the Pakistani context, where the burden of cardiometabolic disorders is escalating, evaluating cardiovascular risk among prediabetic individuals is of critical importance. This study, therefore, aims to assess TG/HDL-C ratios in prediabetic individuals with LDL-C levels within the normal range. Understanding the distribution and implications of these ratios may facilitate early detection and preventive interventions to reduce progression toward metabolic syndrome and cardiovascular complications (8).

The rationale for undertaking this study lies in the urgent need to identify individuals at increased risk of metabolic syndrome and CVD within the prediabetic population. As a substantial proportion of the Pakistani population is transitioning toward greater metabolic dysfunction, the TG/HDL-C ratio offers a cost-effective and accessible screening tool. Its application may enhance risk stratification, support timely lifestyle and therapeutic interventions, and inform national strategies for improving metabolic health. This study is expected to provide meaningful evidence on the clinical utility of the TG/HDL-C ratio in the Pakistani population, thereby aiding the prevention and management of prediabetes and its associated cardiovascular risks.

Methodology

This descriptive cross-sectional study was conducted at the Chemical Pathology Section, Department of Pathology, Sheikh Zayed Hospital, Rahim Yar Khan, from January 2024 to July 2024, with the objective of determining the frequency of prediabetes in individuals with varying triglyceride-to-high-density lipoprotein cholesterol (TG/HDL-C) ratios, all having a normal range of low-density lipoprotein cholesterol (LDL-C). The study was carried out for a minimum of six months following

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ethical approval from the Institutional Review Board and the College of Physicians and Surgeons of Pakistan.

A total of 131 individuals aged between 25 and 65 years were enrolled using a non-probability consecutive sampling technique. The sample size was calculated using the WHO sample size calculator, based on an estimated prediabetes prevalence of 5.79%, with 95% confidence and 4% absolute precision. Inclusion criteria required participants to have normal LDL-C levels (50–100 mg/dL) and no known history of diabetes mellitus. Individuals were excluded if they had a body mass index (BMI) of 28 kg/m² or higher, LDL-C levels greater than 120 mg/dL, were smokers, or were taking antihypertensive, lipid-lowering, or hypoglycemic medications. Patients with nonalcoholic fatty liver disease were also excluded.

After obtaining informed consent, demographic and clinical data were collected, including age, gender, residential and educational status, smoking status, and family history of type 2 diabetes mellitus (T2DM). Fasting blood samples were collected for lipid profiling, and participants were stratified into five quintiles based on TG/HDL-C ratios: Q1 (<0.4), Q2 (≥0.4 to <0.6), Q3 (≥0.6 to <0.8), Q4 (≥0.8 to <1.1), and Q5 (≥1.1). Glycemic status was assessed through fasting blood glucose and glycated hemoglobin (HbA1c) levels. Prediabetes was defined as fasting blood glucose between 100–125 mg/dL or HbA1c between 5.7–6.4%, in accordance with the operational definition.

All data were entered and analyzed using SPSS version 20. The normality of quantitative variables such as age and HbA1c was assessed using the Shapiro-Wilk test. For normally distributed data, means and standard deviations were reported; otherwise, medians and interquartile ranges were used. Categorical variables were expressed as frequencies and percentages. Stratification was performed to evaluate the effect of potential confounders, including age, gender, family history of diabetes, education, and residence. Post-stratification chi-square or independent t-tests were applied where appropriate. A p-value of ≤0.05 was considered statistically significant.

Results

A total of 131 individuals aged between 25 and 65 years were included in the study. The mean age of the participants was 44.6 ± 10.1 years. Of these, 54.2% (n=71) were female, and 45.8% (n=60) were male. A majority of the study participants (61.8%, n=81) were urban residents, while 38.2% (n=50) belonged to rural areas. Regarding educational status, 26.7% (n=35) were illiterate, 39.7% (n=52) had education up to matric, and 33.6% (n=44) had attained education at the college level or higher. A positive family history of type 2 diabetes mellitus (T2DM) was present in 40.5% (n=53) of the participants. (Table 1

Table 1: Demographic Characteristics of Study Participants (n=131)

Variable	Category	n	Percentage (%)
Age (years)	Mean ± SD	—	44.6 ± 10.1
Gender	Male	60	45.8
	Female	71	54.2
Residential Status	Urban	81	61.8
	Rural	50	38.2
Educational Status	Illiterate	35	26.7
	≤ Matric	52	39.7
	College and above	44	33.6
Family History of Diabetes Mellitus	Yes	53	40.5
	No	78	59.5

Participants were stratified into five quintiles of TG/HDL-C ratio. The frequency of prediabetes progressively increased from 4.3% in Q1 (<0.4) to 48.1% in Q5 (≥1.1). A chi-square test was used to assess the association between TG/HDL-C quintiles and prediabetes, which was statistically significant ($\chi^2 = 22.76$, df = 4, p < 0.001). (Table 2)

Table 2: Distribution of Prediabetes by TG/HDL-C Ratio Quintiles (n=131)

TG/HDL-C Quintile	Participants (n)	Prediabetes Present (n, %)
Q1 (<0.4)	23	1 (4.3%)
Q2 (0.4–0.6)	26	3 (11.5%)
Q3 (0.6–0.8)	29	5 (17.2%)
Q4 (0.8–1.1)	28	9 (32.1%)
Q5 (≥1.1)	25	12 (48.1%)

Stratification by gender revealed a trend toward higher prediabetes prevalence in males within the higher TG/HDL-C quintiles, particularly in Q5. However, the association between gender and prediabetes across quintiles was not statistically significant ($\chi^2 = 8.78$, df = 4, p = 0.074). (Table 3)

Table 3: Gender-wise Distribution of Prediabetes by TG/HDL-C Quintile

TG/HDL-C Quintile	Males with Prediabetes (n=60)	Females with Prediabetes (n=71)
Q1	0	1 (1.4%)
Q2	1 (1.7%)	2 (2.8%)
Q3	2 (3.3%)	3 (4.2%)
Q4	4 (6.7%)	5 (7.0%)
Q5	7 (11.7%)	5 (7.0%)

Analysis by educational status revealed prediabetes prevalence rates of 22.9% among illiterate participants, 21.2% in those educated up to matric, and 25.0% among those with college-level education or above. These differences were not statistically significant ($\chi^2 = 0.492$, df = 2,

p = 0.781). Similarly, while urban residents had a higher prediabetes rate (25.9%) than rural residents (18.0%), this association was not statistically significant ($\chi^2 = 1.10$, df = 1, p = 0.294). (Table 4)

Table 4: Distribution of Prediabetes by Educational and Residential Status

Variable	Total (n)	Prediabetes Present (n, %)
Illiterate	35	8 (22.9%)
≤ Matric	52	11 (21.2%)
College & above	44	11 (25.0%)
Urban	81	21 (25.9%)
Rural	50	9 (18.0%)

Overall, the findings strongly support a significant association between higher TG/HDL-C ratios and prediabetes in individuals with normal LDL-C levels. Although gender, education, and residence showed observable trends, they did not yield statistically significant associations with prediabetes in this sample. These results underscore the potential utility of TG/HDL-C as an early predictor of prediabetes in clinical screening, particularly in the Pakistani population.

Discussion

The results of our study demonstrate a significant association between elevated triglyceride-to-high-density lipoprotein cholesterol (TG/HDL-C) ratios and prediabetes among individuals in Pakistan, highlighting this ratio as an early predictor of metabolic dysfunction. Notably, as TG/HDL-C quintiles increased, the prevalence of prediabetes rose markedly, from 4.3% in the lowest quintile (Q1) to 48.1% in the highest quintile (Q5). This stepwise increase aligns with findings from regional studies. For example, Hariri et al. reported similar trends in the Khuzestan Comprehensive Health Study, where elevated triglyceride levels and reduced HDL-C concentrations were significantly associated with a higher prevalence of diabetes (9).

Gender-based analysis in our study showed a tendency for males to exhibit higher rates of prediabetes at increased TG/HDL-C ratios; however, this association did not reach statistical significance. While Akbar et al. examined socioeconomic determinants of metabolic diseases, their analysis did not specifically address gender-related differences in metabolic responses linked to prediabetes (10). This suggests that additional metabolic, behavioral, or lifestyle-related factors may contribute to the observed patterns, as supported by other studies exploring demographic influences on diabetes prevalence without establishing direct gender-specific associations (11).

Educational status did not show a statistically significant association with prediabetes prevalence in our cohort. Although higher educational attainment is generally considered protective against chronic metabolic disorders, our findings did not align fully with the existing literature linking education to improved health outcomes and reduced diabetes risk (12). This discrepancy may reflect the complex socioeconomic and cultural dynamics within Pakistan, where education alone may not translate into healthier lifestyle choices or better access to preventive healthcare.

Stratification based on residential status revealed a marginally higher prevalence of prediabetes among urban residents compared to rural participants, although this difference was not statistically significant. Similar trends have been reported by Feng et al., who documented a higher burden of diabetes and prediabetes in urban populations of Bangladesh, attributing this pattern to lifestyle modifications associated with rapid urbanization (13). Given the parallel socioeconomic transitions occurring in Pakistan, these findings are likely relevant within the local context as well.

Overall, the findings of this study reinforce the role of elevated TG/HDL-C ratios as a critical indicator of prediabetes in individuals with normal LDL-C levels. The results emphasize the potential clinical value of incorporating TG/HDL-C ratio assessment into routine screening protocols to identify high-risk populations in Pakistan, particularly amid the escalating burden of diabetes across South Asia, where undiagnosed and untreated metabolic disorders continue to pose major public health challenges.

Our study supports the usefulness of the TG/HDL-C ratio in assessing prediabetes risk; further large-scale studies involving diverse populations are necessary to clarify the complex interactions between socioeconomic status, educational attainment, and metabolic health in Pakistani cohorts. Continued research in this area will be essential for informing effective national health policies and targeted prevention strategies to curb the rising prevalence of diabetes and associated metabolic disorders in the region.

Conclusion

This study establishes a strong and statistically significant association between elevated TG/HDL-C ratios and prediabetes among individuals with normal LDL-C levels. The progressive increase in the frequency of prediabetes across TG/HDL-C quintiles underscores the value of this lipid ratio as a cost-effective and practical marker for early identification of metabolic risk. Although gender, educational background, and residential status showed non-significant trends, the TG/HDL-C ratio proved to be an independent predictor of prediabetes. These findings underscore the clinical relevance of incorporating TG/HDL-C screening in routine metabolic evaluations, particularly in resource-limited settings such as Pakistan. Further large-scale and longitudinal studies are warranted to confirm these associations and support the integration of TG/HDL-C ratio into national screening guidelines.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned. (IRBEC-23)
Consent for publication
Approved
Funding
Not applicable

Conflict of interest

The authors declared no conflict of interest.

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Conception of Study, Development of Research Methodology Design

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the study's integrity.

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