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Original Research Article

ASSOCIATION BETWEEN TRIGLYCERIDE-TO-HDL CHOLESTEROL (TG/HDL-C) RATIO AND HYPERTENSION IN OVERWEIGHT AND OBESE KASHMIRI CHILDREN AGED 5 - 18 YEARS

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ABSTRACT

Background: Childhood obesity is an escalating global health concern and is closely linked to early cardiometabolic abnormalities. The triglyceride-to-high-density lipoprotein cholesterol (TG/HDL-C) ratio has emerged as a simple marker of metabolic risk, but its role in predicting hypertension among Kashmiri children remains unexplored. The objective is to evaluate the association between TG/HDL-C ratio and hypertension in overweight and obese Kashmiri children aged 5–18years.

Materials and Methods: This cross-sectional study was conducted over two years (July 2022–June 2024) at Sher I Kashmir Institute of Medical Sciences , J&K. A total of 112 children aged 5–18 years with BMI ≥85th percentile were included. Anthropometric measurements, blood pressure, and fasting lipid profiles were recorded. The TG/HDL-C ratio was calculated, and a cutoff >3.0 was considered high risk. Statistical analysis was performed using SPSS version 23, with $p<0.05$ considered significant.

Results: The mean age was 10.29 ± 2.71 years, with 71.4% obese. Hypertension was present in 32.1%, and 83.9% had a high-risk TG/HDL-C ratio. Triglycerides increased and HDL-C decreased significantly across TG/HDL-C categories ($p<0.05$), independent of BMI. Diastolic blood pressure was significantly higher in hypertensive children, while systolic differences were not significant. No significant differences were observed between overweight and obese groups, indicating similar cardiometabolic risk.

Conclusion: The TG/HDL-C ratio is a practical and sensitive marker for identifying cardiometabolic risk in overweight and obese Kashmiri children. Its integration into routine pediatric screening may facilitate early detection of high-risk individuals and guide targeted preventive strategies to reduce long-term cardiovascular morbidity.

Keywords: TG/HDL-C ratio, childhood obesity, hypertension, dyslipidemia, Kashmiri children.

INTRODUCTION

Childhood obesity has become a significant global public health concern, with its prevalence rising rapidly, particularly in low- and middle-income countries over the last two decades.[1,2] Increased adiposity during childhood is associated with a spectrum of metabolic disturbances, including dyslipidemia, insulin resistance, impaired glucose metabolism, and elevated blood pressure.[3] These abnormalities often persist into adulthood, predisposing individuals to early development of atherosclerotic cardiovascular disease.[4] In India, and notably in the Kashmir Valley, lifestyle transitions such as dietary changes, reduced physical activity, and urbanization have contributed to an increasing burden of pediatric obesity.[5] However, there is limited comprehensive data describing

cardiometabolic risk patterns among children in this region. The identification of simple and reliable biomarkers for early detection of hypertension risk in overweight and obese children could facilitate timely and targeted preventive interventions.

Dyslipidemia associated with pediatric obesity is typically characterized by an atherogenic lipid profile, including elevated triglyceride levels and reduced high-density lipoprotein cholesterol (HDLc).[6] The triglyceride-to-HDL cholesterol (TG/HDL-C) ratio integrates these two parameters into a single index and has been widely used for cardiometabolic risk assessment in adults. An increased TG/HDL-C ratio reflects higher levels of triglyceride-rich lipoproteins and reduced HDL particles, which are linked to endothelial dysfunction, arterial stiffness, and a pro-inflammatory state.[7] In pediatric populations, growing evidence suggests that elevated TG/HDL-C ratios are associated with insulin resistance, non-alcoholic fatty liver disease, and other components of metabolic syndrome.[8,9] Given that lipid profiles are routinely measured in clinical practice, the TG/HDL-C ratio represents a cost-effective and easily obtainable marker that may enhance risk stratification when used alongside anthropometric indicators.

Even mild elevations in blood pressure during childhood are clinically important, as they are predictive of future hypertension and early target organ damage in adulthood.[10,11] The relationship between dyslipidemia and hypertension is complex and multifactorial. Abnormal lipid metabolism contributes to vascular changes, including endothelial dysfunction and decreased nitric oxide availability, resulting in increased vascular resistance.[12] Additionally, insulin resistance commonly associated with adverse lipid profiles can stimulate the sympathetic nervous system and activate the renin–angiotensin–aldosterone system, thereby contributing to elevated blood pressure.[13] Several epidemiological studies in pediatric populations have demonstrated associations between elevated triglycerides, low HDLc levels, and increased blood pressure values.[14] However, the consistency and strength of the association between the TG/HDL-C ratio and insulin resistance and metabolic syndrome vary across studies due to differences in population characteristics, sample sizes, and adjustment for confounding variables such as body mass index (BMI), central obesity, and pubertal status.[13]

Population-specific research is crucial, as genetic predisposition, dietary practices, environmental influences, and socioeconomic conditions can significantly affect lipid metabolism and blood pressure regulation. In Kashmiri children changing dietary habits with more intake of fast foods often rich in refined carbohydrates and saturated fats along with environmental and lifestyle factors, may influence metabolic health and lead to overweight and obesity.[5] Despite these characteristics, there is a lack of sufficient data examining the TG/HDL-C ratio and its relationship with hypertension among Kashmiri children, particularly among those who are overweight or obese and thus at higher risk for cardiometabolic complications.

A cross-sectional study design focusing on overweight and obese children aged 5–18 years provides an opportunity to evaluate this association across both prepubertal and pubertal stages. Such an approach allows assessment of the relationship between TG/HDL-C ratio and hypertension prevalence, as well as its correlation with continuous blood pressure parameters, including systolic and diastolic values. Therefore, the present study aims to investigate the association between the TG/HDL-C ratio and hypertension prevalence among overweight and obese Kashmiri children aged 5–18 years. Additionally, it seeks to determine whether the TG/HDL-C ratio improves the identification of elevated blood pressure beyond traditional anthropometric and metabolic indicators. The findings may contribute to the development of effective screening strategies and early intervention measures tailored to this population, ultimately helping to reduce long-term cardiovascular risk.

MATERIALS AND METHODS

A detailed cross-sectional study was conducted over a period of two years, from July 2022 to June 2024, in the Department of Paediatrics and Neonatology at Sher I Kashmir Institute of Medical Sciences, J&K. Ethical approval for the study was obtained from the Institutional Ethics Committee. Written informed consent was secured from the parents or legal guardians prior to inclusion of participants.

Children and adolescents between 5 and 18 years of age attending the pediatric outpatient department, emergency services, or admitted to the wards, and fulfilling the eligibility criteria, were recruited for the study.

Inclusion Criteria:

Participants aged 5–18 years with a body mass index (BMI) between ≥85th and <95th percentile (classified as overweight) or ≥95th percentile (classified as obese) for age and sex were included.

Exclusion Criteria:

Children with chronic systemic illnesses, syndromic or endocrine causes of obesity, inborn errors of metabolism, or pre-existing hepatic, renal, or cardiovascular diseases were excluded from the study.

Data Collection and Investigations: Relevant demographic details, including age, sex, height, and weight, were recorded for all participants. A comprehensive family history focusing on obesity, diabetes mellitus, hypertension, and dyslipidemia among first-degree relatives was obtained. Each subject underwent a thorough clinical evaluation, including measurement of blood pressure and assessment of anthropometric parameters.

Fasting blood samples were collected and analyzed for biochemical parameters, including lipid profile components—serum triglyceride levels(TG),high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and total cholesterol—as well as liver function markers, namely aspartate aminotransferase (AST) and alanine aminotransferase (ALT). All laboratory values were interpreted based on standard reference ranges followed by the institutional laboratory.

The primary outcome measure of the study was the triglyceride-to-HDL cholesterol (TG/HDL-C) ratio. The risk stratification was done based on TG-HDLc ratio as : <2- low risk,>2 to ≤3 as moderate risk and >3 as high risk.

For children aged 1–12 years, blood pressure (BP) was defined based on age, sex, and height percentiles:

- Normal BP: Systolic BP (SBP) and Diastolic BP (DBP) < 90th percentile
- Elevated BP: SBP and/or DBP ≥ 90th percentile to < 95th percentile or 120/80 mmHg to < 95th percentile (whichever is lower)
- Stage 1 Hypertension: SBP and/or DBP ≥ 95th percentile to < 95th percentile + 12 mmHg or 130/80 to 139/89 mmHg (whichever is lower)
- Stage 2 Hypertension: SBP and/or DBP ≥ 95th percentile + 12 mmHg or ≥ 140/90 mmHg (whichever is lower) For adolescents aged ≥ 13 years, absolute BP was defined as:
- Normal BP: < 120/80 mmHg
- Elevated BP: 120/<80 to 129/<80 mmHg
- Stage 1 Hypertension: 130/80 to 139/89 mmHg
- Stage 2 Hypertension: ≥ 140/90 mmHg

Statistical Analysis: Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 23. Continuous variables were presented as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 112 children were included in the study, of whom 57.1% were male, with a mean age of 10.29 ± 2.71 years. Based on WHO BMI-for-age percentiles, 32 participants (28.6%) were categorized as overweight, while the majority, 80 children (71.4%), were classified as obese. A considerable proportion of the study population exhibited elevated blood pressure, with 32.1% (n=36) meeting the diagnostic criteria for Stage 1 or Stage 2 hypertension. Importantly, abnormalities in metabolic parameters were also observed in a substantial number of children who had blood pressure values within the normal range.

Table 1: Clinical and biochemical characteristics of the study population (n=112).

Variable	Mean ± SD	Median (IQR)	Range
Age (Years)	10.29 ± 2.71	10.0 (8.0–12.0)	5.0–15.0
BMI (kg/m²)	29.21 ± 3.64	28.6 (26.6–31.2)	21.5–42.1
Systolic BP (mmHg)	110.16 ± 8.62	110.0 (104.0–116.0)	90.0–135.0
Diastolic BP (mmHg)	69.46 ± 6.17	69.0 (65.0–74.0)	55.0–85.0
Triglycerides (mg/dL)	164.39 ± 62.66	153.0 (130.0–185.0)	50.0–381.0
HDL-C (mg/dL)	39.46 ± 7.94	39.0 (34.0–44.0)	24.0–60.0
TG/HDL-C Ratio	4.39 ± 1.95	3.8 (3.0–5.2)	1.0–11.9

Participants were categorized into three groups according to their TG/HDL-C ratio to assess the gradient of metabolic risk. The majority of subjects (83.9%) fell into the “high-risk” category (TG/HDL-C >3.0). As shown in [Table 2], the mean BMI did not differ significantly among the different ratio groups (p = 0.499). However, a strong and highly significant increasing trend was observed in lipid parameters across these categories (p < 0.001). This indicates that the TG/HDL-C ratio is able to detect underlying metabolic disturbances that are not reflected by BMI percentiles alone, irrespective of whether a child is classified as overweight or obese.

Table 2: Comparison of metabolic risk factors across TG/HDL-C ratio categories

Parameter	Low (<2.0)	Moderate (2.0–3.0)	High (>3.0)	p-value
Number (n)	7	11	94	—
BMI (kg/m²)	28.25 ± 3.86	30.25 ± 3.54	29.16 ± 3.65	0.499
Systolic BP (mmHg)	108.29 ± 10.23	111.82 ± 9.61	110.11 ± 8.45	0.694
Triglycerides (mg/dL)	68.00 ± 11.92	122.64 ± 17.91	176.46 ± 59.91	<0.001
HDL-C (mg/dL)	49.43 ± 5.83	45.27 ± 5.14	38.04 ± 7.53	<0.001

The association between lipid parameters and blood pressure status was evaluated to determine whether the TG/HDL-C ratio could distinguish between normotensive and hypertensive children. As presented in [Table 3], a substantial proportion of participants exhibited hypertension across all ratio categories, with nearly 30% of children in the high-risk group (TG/HDL-C >3.0) meeting criteria for clinical hypertension. On further analysis, when comparing blood pressure values between the “low” and “high” ratio groups using a cut-off of 3, children with elevated TG/HDL-C ratios demonstrated higher mean systolic and diastolic blood pressure levels with observed trend pointing towards a potential

physiological association between adverse lipid profiles and early increases in vascular pressure. Moreover, the consistently elevated TG/HDL-C ratio across the cohort including among normotensive individuals suggests that metabolic derangements may precede the overt clinical manifestation of hypertension in this population.

Table 3: Performance of the TG/HDL-C Ratio in Identifying Hypertension Risk

Parameter	Normotensive (n = 76)	Hypertensive (n = 36)	p-value
Systolic BP (mmHg)	109.13 ± 8.21	112.33 ± 9.14	0.066
Diastolic BP (mmHg)	68.62 ± 6.13	71.25 ± 5.95	0.035
TG/HDL-C Ratio	4.14 ± 1.90	4.51 ± 1.97	0.348
Ratio >3.0 Prevalence	70.2 %	29.8 %	—

An important aim of this study was to assess whether the TG/HDL-C ratio serves as a reliable indicator of risk across varying degrees of adiposity. As illustrated in Table 4, children in the obese category had a higher mean TG/HDL-C ratio (4.55 ± 2.07) compared to those who were overweight (4.00 ± 1.57), although both groups demonstrated values well above the normal threshold of 2.0. Importantly, no statistically significant differences were observed between the two groups in triglyceride levels (p = 0.525), HDL-C levels (p = 0.430), or systolic blood pressure (p = 0.182). These findings indicate that overweight children in this cohort exhibit a degree of metabolic impairment comparable to obese children. Consequently, the TG/HDL-C ratio appears to function as a consistent and sensitive marker of cardiometabolic risk, independent of conventional BMI-based classifications.

Table 4: Comparison of metabolic and hemodynamic risk between Overweight and Obese subjects

Variable	Overweight (n = 32)	Obese (n = 80)	p-value
BMI (kg/m²)	24.78 ± 1.45	30.98 ± 2.68	<0.001
TG/HDL-C Ratio	4.00 ± 1.57	4.55 ± 2.07	0.177
Triglycerides (mg/dL)	158.41 ± 70.39	166.79 ± 59.60	0.525
HDL-C (mg/dL)	40.41 ± 8.02	39.09 ± 7.93	0.430
Systolic BP (mmHg)	108.44 ± 10.12	110.85 ± 7.91	0.182
Diastolic BP (mmHg)	67.88 ± 6.25	70.10 ± 6.05	0.084

DISCUSSION

The principal strength of the present study lies in its ability to demonstrate the variability in metabolic status within a population that is conventionally categorized solely on the basis of body weight. Although BMI continues to serve as a widely accepted screening parameter,[15] its shortcomings are clearly evident in our findings. Children categorized under the "High-Risk" TG/HDL-C group (>3.0) and those in the "Low-Risk" group (<2.0) exhibited almost similar mean BMI values. This disparity underscores that excess body weight, as measured by anthropometry, does not necessarily correspond to metabolic risk or dysfunction.[16]

In South Asian populations, this phenomenon is often attributed to the "thin-fat" phenotype, wherein individuals may have a relatively normal or lower BMI but possess increased visceral adipose tissue (VAT).[17,18] Visceral fat is metabolically active and releases free fatty acids directly into the portal circulation, thereby promoting hepatic triglyceride synthesis. Our observations indicate that in our study population of Kashmiri children, the TG/HDL-C ratio may serve as a more sensitive marker of such concealed or "invisible" adiposity compared to conventional weight-based indices.

The clinical relevance of the elevated mean TG/HDL-C ratio (4.39) extends beyond isolated lipid abnormalities. The coexistence of high triglycerides and low HDL-C levels favors the formation of small dense low-density lipoprotein (sdLDL) particles.[19] These sdLDL particles, in contrast to larger LDL particles, exhibit greater atherogenic potential due to their enhanced ability to penetrate the arterial wall and undergo oxidative modification. Oxidized LDL initiates endothelial inflammation, resulting in multiple vascular alterations, including reduced nitric oxide (NO) availability, increased oxidative stress, and early arterial stiffening mechanisms that likely contribute to the development of hypertension, as observed in 32.1% of our study population.

The finding that 83.9% of participants fell within the high-risk TG/HDL-C category suggests that a large proportion of these children may already be in a metabolically adverse, "pro-hypertensive" state, even in the absence of clinically overt hypertension.

The regional context of our findings is particularly noteworthy. The traditional Kashmiri diet and increased intake of fast foods by children and adolescents appears to exert a dual adverse impact on cardiometabolic health.[5] Firstly, the high intake of refined carbohydrates, such as polished rice and traditional breads, contributes to postprandial hyperglycemia and hyperinsulinemia. This, in turn, promotes de novo lipogenesis and inhibits lipolysis, leading to elevated triglyceride levels and an increased TG/HDL-C ratio. Secondly, the widespread consumption of "Noon Chai" (salted tea) results in a substantial daily sodium intake,[20] which may predispose to salt-sensitive hypertension, particularly in the presence of underlying metabolic disturbances.

This combination of dietary factors likely explains the markedly elevated mean TG/HDL-C ratio (4.39) observed in our cohort, which is considerably higher than values typically reported in Western pediatric populations (1.5–2.5). In this setting, the TG/HDL-C ratio not only reflects lipid abnormalities but also serves as an indicator of lifestyle-related cardiovascular risk specific to the region.

From a clinical perspective, the TG/HDL-C ratio offers significant practical advantages due to its simplicity and cost-effectiveness. In settings with limited resources, where advanced metabolic testing or imaging modalities may not be readily accessible, this ratio can be easily derived from a routine lipid profile.

Our findings further suggest that an overweight child with an elevated TG/HDL-C ratio may carry a greater cardiovascular risk than an obese child with a normal ratio. Therefore, reliance on BMI alone may be insufficient for risk stratification. We recommend that clinicians, particularly in similar regional settings, incorporate the TG/HDL-C ratio into routine evaluation to identify children at higher cardiometabolic risk and to initiate early lifestyle and dietary interventions aimed at preventing progression to chronic cardiovascular disease.

Strengths and Limitations

This study's strength lies in its focus on an underexplored Kashmiri pediatric population and use of a simple, cost-effective TG/HDL-C ratio. However, its cross-sectional design, small sample size, and lack of direct insulin resistance assessment limit causal inference. Unmeasured factors such as diet, physical activity, and genetics may also have influenced the results.

CONCLUSION

The TG/HDL-C ratio appears to be a sensitive marker for detecting cardiometabolic risk in overweight and obese Kashmiri children. It identifies early metabolic abnormalities even in normotensive children and overcomes limitations of BMI alone. Routine use of this simple, cost-effective marker is recommended for early risk stratification and intervention.

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