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TG/HDL-C ratio as a risk marker for metabolic syndrome and atherosclerosis in adolescents aged 15-18 years in Indonesia

Rasio TG/HDL-C sebagai penanda risiko sindrom metabolik dan aterosklerosis pada remaja usia 15-18 tahun di Indonesia

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Abstract

Metabolic syndrome is characterized by high levels of triglycerides, blood glucose, and blood pressure, along with low high-density lipoprotein cholesterol (HDL-C) and central obesity. The TG/HDL-C ratio is a quick and cost-effective marker of dyslipidemia and insulin resistance, increasing the risk of atherosclerosis. However, most studies on TG/HDL-C ratio in Indonesia have been limited to adolescent populations with distinct metabolic profiles and health risks. This study aimed to assess the correlation between metabolic syndrome risk and TG/HDL-C ratio as a marker of atherosclerosis risk in adolescents. This cross-sectional study was conducted at Batik 1 Senior High School Surakarta from October 2023 to March 2024. A total of 65 adolescents were selected using simple random sampling. The observed data included body mass index (BMI), waist circumference, blood pressure, fasting blood glucose, triglycerides, HDL-C, metabolic syndrome risk, and atherosclerosis risk. Pearson and Spearman correlation tests were used for statistical analysis. The results showed A significant correlation was observed between TG/HDL-C ratio and atherosclerosis risk (p= 0,000), waist circumference (p= 0,009), systolic blood pressure (p= 0,001), and diastolic blood pressure (p= 0,000). However, no significant correlation was found between fasting blood glucose level (p= 0,905) and BAZ (p= 0,405). In conclusion, TG/HDL-C ratio can serve as a valuable indicator for assessing metabolic syndrome risk in adolescents, allowing for early intervention to reduce the risk of atherosclerosis.

Keywords: Adolescents, atherosclerosis, MetS, TG/HDL-C ratio

Abstrak

Sindrom metabolik ditandai dengan trigliserida, glukosa darah, dan tekanan darah yang tinggi, serta HDL-C yang rendah dan obesitas sentral. Rasio TG/HDL-C adalah penanda yang cepat dan hemat biaya, yang mengindikasikan dislipidemia dan resistensi insulin, yang meningkatkan risiko aterosklerosis. Namun, sebagian besar penelitian tentang rasio TG/HDL-C terbatas pada populasi remaja di Indonesia dengan profil metabolik dan risiko kesehatan yang berbeda. Tujuan penelitian untuk mengetahui korelasi risiko *metabolic syndrome* terhadap rasio TG/HDL-C sebagai penanda risiko aterosklerosis pada remaja. Penelitian *cross sectional* telah dilakukan di SMA Batik 1 Surakarta pada bulan Oktober 2023 – Maret 2024. Sampel merupakan 65 remaja diambil secara *simple random sampling*. Data yang diobservasi meliputi body mass index, lingkar perut, tekanan darah, glukosa darah puasa, trigliserida, HDL-C, risiko MetS dan risiko aterosklerosis. Analisis statistik menggunakan uji pearson dan spearman. Hasil menunjukkan terdapat hubungan rasio TG/HDL-C dengan risiko aterosklerosis (p= 0,000), lingkar perut (p= 0,009), tekanan darah sistolik (p= 0,001) dan diastolik (p= 0,000), sedangkan pada glukosa darah puasa (p= 0,905) dan IMT/U (p= 0,405) tidak signifikan. Kesimpulan, rasio TG/HDL-C dapat digunakan sebagai indikator penilaian risiko sindrom metabolik pada remaja sehingga risiko aterosklerosis dapat ditangani sejak dini.

Kata Kunci: Aterosklerosis, MetS, rasio TG/HDL-C, remaja

Introduction

Metabolic syndrome is a group of metabolic dysregulation that can trigger non-communicable diseases such as cardiovascular disease and type diabetes mellitus 2 (Alamnia et al., 2021). In adolescents aged 10-18 years, the prevalence of metabolic syndrome shows an increasing trend globally, in line with the increasingly high rates of obesity and sedentary lifestyles in adolescents (Bekele & Thupayagale-Tshweneagae, 2020). Although data regarding cases of metabolic syndrome in adolescents in Indonesia are still limited, the prevalence of non-communicable diseases in adolescents can indicate that metabolic syndrome occurs at a young age. According to the 2018 Basic Health Research data, the prevalence of diabetes mellitus and hypertension among those aged 15 years and over in Indonesia was 2% and 34,11%, respectively, while in Central Java, it reached 2,1% and 37,57%, respectively (Kemenkes RI, 2018). The higher rate of non-communicable diseases in Central Java compared with the national case rate indicates that there are serious metabolic problems at the regional level.

Data from the World Health Organization in 2016 stated that more than 340 million children and adolescents were obese (WHO, 2021). According to basic health research data in 2018, the number of cases of abdominal obesity among those aged 15 years and over in Indonesia reached 31% and in Central Java reached 28,8% (Kemenkes RI, 2018). Central obesity in adolescents as measured by waist circumference is a significant early indicator because the accumulation of visceral fat triggers systemic inflammation and insulin resistance (Maharani et al., 2024).

Unhealthy dietary factors, such as consuming foods high in saturated fat from junk food, added sugar, high in salt, and low in fiber, have been shown to increase the risk of obesity, insulin resistance, and hypertension in adolescents, which contributes to the development of metabolic syndrome (Bekele & Thupayagale-Tshweneagae, 2020; Nurzakiah et al., 2021; Ahmad et al., 2023). In addition, lack of physical activity due to sedentary behavior and excessive use of gadgets can exacerbate the risk of metabolic syndrome in adolescents by increasing visceral fat and reducing insulin sensitivity (Mahumud et al., 2021; Anriyani et al., 2024; Agbaje, 2024). Bad sleep habits such as lack of sleep in both quantity and quality found among adolescents with metabolically unhealthy obesity (MUO) have been proven to increase insulin resistance by reducing HOMA-IR (Leksono et al., 2022; Kurube et al., 2023). The combination of these three factors can create a cycle that accelerates the occurrence of metabolic disorders in obese adolescents, namely insulin resistance, high blood pressure and an increase in lipid profiles (triglycerides, total cholesterol and LDL cholesterol) although a significant reduction in HDL cholesterol has not been confirmed (Shaumi & Achmad, 2019; Nurhidayati et al., 2022).

The triglyceride to HDL cholesterol (TG/HDL-C) ratio has been identified as a powerful indicator for assessing the risk of metabolic syndrome compared to other lipid ratios (Rezapour et al., 2018). Apart from that, the TG/HDL-C ratio also provides a clearer picture of an individual's lipid profile, where an increase in this ratio can indicate abnormalities in lipid metabolism in the blood (dyslipidemia) (Kosmas et al., 2023).

Increased triglyceride and cholesterol levels can trigger plaque buildup on the walls of blood vessels, which results in narrowing and hardening of the blood vessels or atherosclerosis, and an increased risk of coronary heart disease (Kong et al., 2022). Previous studies have shown that increased TG/HDL-C ratio in obese adolescents correlates significantly with increased risk of insulin resistance and other metabolic dysfunctions (Radetti et al., 2022; Iwani et al., 2022). However, studies on the use of this ratio to detect metabolic syndrome and atherosclerosis risk in the adolescent population in Indonesia are still limited, especially in the context of early intervention to prevent cardiovascular disease in adulthood.

A preliminary survey of 32 students at Batik 1 Senior High School Surakarta showed that 72% of students were at risk of central obesity, 72,18% had high fat intake due to a diet dominated by fried processing, and 75% had low physical activity. The results of this preliminary survey showed that the risk of metabolic syndrome and atherosclerosis in adolescents in this environment is quite high. Therefore, this study aims to measure the effect of triglyceride and HDL cholesterol ratio on the risk of MetS as a marker of atherosclerosis risk in adolescents.

Methods

This observational study used a cross-sectional approach by identifying and analyzing the independent variables, namely the risk of metabolic syndrome, and the dependent variables, namely the risk of atherosclerosis and the TG/HDL-C ratio, at the same time. This study was conducted at Batik 1 Senior High School Surakarta from October 2023 to March 2024. Considering the preliminary survey results that showed a high risk of metabolic syndrome and atherosclerosis in the adolescent population at that school.

The research population consisted of 248 grade 11 students at Batik 1 Senior High School, Surakarta. Sixty-five teenagers participated in this research was 65 teenagers. The sample size was obtained based on the Lameshow (1997) formula, as follows:

$$n = \frac{N\, Z^2_{1-\alpha/2}\, p\,(1-p)}{d^2\,(N-1) + Z^2_{1-\alpha/2}\, p\,(1-p)}$$

$$n = \frac{248 \times 1{,}96^2 \times 0{,}72\,(1-0{,}72)}{0{,}1^2 \times (248-1) + 1{,}96^2 \times 0{,}72\,(1-0{,}72)}$$

$$n = 59{,}25$$

The sample size was increased at a follow-up of 10%. $\frac{n}{1+f}$

$$n = \frac{59{,}25}{1-0{,}1}$$

$$n = 65$$

Information:
n = Sample size
N = Total population (248)
Z2 1-α/2 = 95% level of significance (1,96)
d = Absolute precision of sample size estimation (0,1)
f = large follow-up
P = Proportion of adolescents at risk of metabolic syndrome (preliminary survey results namely 72% have central obesity)

The inclusion criteria for this research sample were being 15-18 years old, willing to become a research participant (informed consent), able to communicate well, having a BMI in the obesity/overweight category, not taking weight loss drugs, hypertension, hypercholesterolemia, and hyperglycemia. The exclusion criteria for this study were participants who changed schools during the study period.

The sample collection used a simple random sampling method through a drawing process. Each student in the class, which is the research population, is given a unique number according to the official attendance list. This number is then written on a small paper of uniform size and folded such that the identity of the number cannot be seen. The number of lottery papers used differed for each class according to the number of students in that class. Classes XI-1, XI-2, and XI-3, and this difference in number aims to ensure that the sample proportion can be balanced based on the number of students in each class without reducing the random nature of the selection process. Participants were selected according to the lottery serial number chosen.

This research procedure began when informed consent was signed by all subjects or guardians after receiving an explanation regarding the research, such as advantages, disadvantages, and side effects that may occur after the research is completed by the subjects or guardians. Next, interviews were conducted on participant identity, anthropometric examinations (abdominal circumference, body weight, and height), blood pressure examinations, and blood laboratory examinations (fasting blood glucose and lipid levels). After all the required data were collected, they were processed and analyzed.

The instruments used included a willingness to participate (informed consent) form, a participant identity form, and a blood laboratory examination form (glucose and lipid levels). The self-identity form consists of age, sex, mother's employment status, father's employment, family income, nutritional status, abdominal circumference, and blood pressure.

Adolescent nutritional status was determined using the Body Mass Index (BMI) z-score formula for age (BAZ). BMI was calculated as body weight (kg) / height squared (m^2). The risk of MetS was determined based on five criteria: central obesity, high blood pressure, high triglyceride levels, low HDL-C levels, and high fasting blood glucose levels.

Height was measured using a stadiometer; weight, using a scale; and abdominal circumference, using a metline. The blood pressure was measured using a blood pressure monitor. Glucose and lipid levels (HDL-C and Triglycerides) were obtained by taking venous blood samples using a blood examination kit. Blood samples were analyzed using a spectrophotometer at the UMS FIK Biochemistry Laboratory. The examination used the enzymatic method of cholesterol oxidase-p-amino phenazone (CHOD-PAP) for HDL cholesterol levels and glycerol phosphate dehydrogenase (GPO-PAP) for blood glucose and triglyceride levels.

Data were processed by categorizing the collected data. Nutritional status (BAZ) is categorized as Underweight: -3 SD to <-2 SD; Normal -2 SD to +1 SD; Overweight: +1 SD to +2 SD; Obesity: >+2 SD (Kemenkes RI, 2020). Blood pressure is categorized as Abnormal/High: systolic blood pressure (SBP) ≥130 mmHg and diastolic (DBP) ≥85 mmHg; Normal: systolic blood pressure <130 mmHg and diastolic <85 mmHg (IDF, 2023). Abdominal circumference is categorized as Central obesity: abdominal circumference ≥90 cm for men and ≥80 cm for women; Normal: abdominal circumference <90 cm for men and <80 cm for women (IDF, 2023). fasting blood glucose (FBG) are categorized as Abnormal/High: FBG ≥110 mg/dL; Normal: FBG <110 mg/dL (PERKENI, 2021). HDL-C levels are categorized as Abnormal/Low: HDL-C ≤50 mg/dL for men and HDL-C ≤40 mg/dL for women; Normal: HDL-C >50 mg/dL for men and HDL-C >40 mg/dL (IDF, 2023). Triglyceride (TG) levels are categorized as Abnormal/High: TG ≥150 mg/dL; Normal: TG <150 mg/dL (IDF, 2023). Metabolic Syndrome (MetS) risk is categorized as At risk: MetS criteria ≥3 criteria; No Risk: MetS criteria <3 criteria (IDF, 2023). The cutoff TG/HDL-C ratio was categorized as very risky: >3, at risk: >2, and not at risk (low risk): <2. This cut-off refers to Chu et al., (2019) who established this cut-off as a sensitivity of 85,7% and specificity of 89,9% in detecting the risk of metabolic syndrome and cardiovascular disease in an East Asian adolescent population. The risk of atherosclerosis is categorized based on the Framingham Risk Factor, namely: risk: ⩾ 10%; no risk: <10% (Kasim et al., 2023).

The data were analyzed using SPSS for Windows version 21. Univariate analysis was used to describe the data so that they were easy to understand using frequency tables and percentages for each variable. The Kolmogorov–Smirnov test was used for data normality because the data were more than 50. Normally distributed data were tested for statistical correlation analysis using the Pearson test and abnormal data using the Spearman test with a significance level of 95%. Analysis of the relationship between the triglyceride ratio and HDL-C level on the risk of metabolic syndrome and the risk of atherosclerosis was performed using bivariate analysis, which was tested using the chi-square test with a significance level of 95%.

Ethical clearance was obtained from the UMS FIK Research Ethics Commission (ref. 198/KEPK-FIK/II/2024). Data collection was carried out after obtaining approval from the ethics commission and the subject or guardian of the research subject as well as witnesses (parents or teachers).

Result and Discussion

Table 1. Participant characteristics

Characteristics	Category	n	%
Gender	Male	34	52,3
	Female	31	47,7
Nutritional Status	Underweight	0	0
	Normal	44	67,7
	Overweight	13	20
	Obesity	8	12,3
Household Income	<RMW	0	0
	≥RMW	65	100
Abdominal Circumference	Normal	40	61,5
	Central Obesity	25	38,5
Blood pressure	Normal	46	70,8
	High	19	29,2
Glucose Levels	Normal	65	100
	Abnormal	0	0
HDL-C levels	Normal	55	84,7
	Abnormal	10	15,3
Triglyceride Levels	Normal	47	72,3
	Abnormal	18	27,7

Mets Risk	Risk	16	24,6
	No risk	49	75,4
Rasio TG/HDL-C	Very risk	6	9,4
	Risk	44	67,6
	No risk	15	23
Risiko Aterosklerosis	Risk	26	40
	No risk	39	60

Based on Table 1, the majority of the participants were male (52,3%). The nutritional status of most of the participants was normal (67,7%), and the entire family's income was above the Regional Minimum Wage or RMW (100%). This is because the location of this research was conducted in an urban area with the majority of employment in the informal sector and MSMEs and a higher standard of living costs (Khalida & Sjaf, 2021).

The clinical characteristics of the 65 participants were 38,5% had central obesity, 29,2% had high blood pressure and all participants were known to have blood glucose levels within the normal range (100%). This indicated that the risk of diabetes mellitus was not a major factor in the adolescent population in this study. These findings highlight the role of other factors, namely the lipid profile, in identifying the risk of metabolic syndrome. The results of this study showed that 15,3% of the patients had low HDL levels and 27,7% had high triglyceride levels.

Table 1 also shows that 26,4% of the participants were at risk of MetS, and 40% of the participants were at risk of atherosclerosis. The TG/HDL-C ratio showed that of 67,6% and very risk and 9.4% were at high risk. The relationship between the TG/HDL cholesterol ratio and MetS risk is shown in Table 2.

Table 2. TG/HDL cholesterol ratio with MetS

TG/HDL-C Ratio Category	MetS Risk				Total		p-value[a]
	No		Yes				
	n	%	n	%	n	%	
Low (No risk)	15	100,0	0	0,0	15	100,0	
Medium (Risk)	33	75,0	11	25,0	44	100,0	0,000
High (Very Risk)	1	16,7	5	83,3	6	100,0	

[a]Chi Square test

Table 3. TG/HDL cholesterol ratio with risk of atherosclerosis

TG/HDL-C Ratio Category	Risk of Atherosclerosis				Total		p-value[a]
	No		Yes				
	n	%	n	%	n	%	
Low (No risk)	15	100,0	0	0,0	15	100,0	
Medium (Risk)	24	54,5	20	45,5	44	100,0	0,000
High (Very Risk)	0	0,0	6	100,0	6	100,0	

[a]Chi Square test

The results of the chi-square statistical analysis showed a significant correlation between the ratio of triglycerides to HDL cholesterol and the risk of metabolic syndrome in adolescents at Batik 1 Senior High School Surakarta (p=0,000). According to retrospective cohort research by Radetti et al., (2022) in 1065 children and adolescents, it was proven that the TG/HDL-C ratio was able to identify a set of symptoms of metabolic disease in children and adolescents with severe obesity.

The correlation between the ratio of triglycerides to HDL cholesterol and metabolic syndrome can be explained by three mechanisms. The first and most important mechanism, namely the ratio of triglycerides to HDL cholesterol, is associated with the progression of cardiovascular disease, even though LDL cholesterol levels are low. Second, this ratio may reflect LDL cholesterol particles with a small density because these particles are more atherogenic than LDL cholesterol particles with a larger density. Finally, this ratio is considered to be a precise indicator of metabolic syndrome and insulin resistance that can lead to negative vascular transformation (Kosmas et al., 2023).

Table 3 shows the results of the analysis of the relationship between the TG/HDL-C ratio and risk of atherosclerosis. Based on the results of the chi-square statistical test, the TG/HDL cholesterol ratio category was significantly correlated with the risk of atherosclerosis in adolescents at Batik 1 Senior High School Surakarta (p=0,000). This research is supported by a statement (Iwani et al., 2022) which states that the ratio of triglycerides to HDL cholesterol (TG/HDL-C) has been shown to be strongly correlated with insulin resistance and central obesity, both of which are criteria for MetS and can increase the risk of cardiovascular disease. The clinical implications of these findings demonstrate the importance of monitoring the TG/HDL-C ratio as part of early screening for metabolic disorders in adolescents in early intervention to reduce the risk of atherosclerosis later in life. The TG/HDL cholesterol ratio may also be an additional tool to assist healthcare practitioners in monitoring the effectiveness of interventions in adolescents.

Table 3. Association of MetS risk with TG/HDL cholesterol ratio and atherosclerosis risk

Risk of MetS	TG/HDL-C ratio		Risk of Atherosclerosiss	
	R	p-value	R	p-value
Abdomen Circumference (cm)	0,323	0,009[a]	0,408	0,001[a]
Systolic Blood Pressure (mmHg)	0,408	0,001[b]	0,301	0,015[b]
Diastolic Blood Pressure (mmHg)	0,421	0,000[b]	0,297	0,016[b]
Fasting Blood Glucose (mg/dL)	-0,015	0,905[b]	0,099	0,431[b]
Triglycerides (mg/dL)	-	-	0,629	0,000[b]
HDL-C (mg/dL)	-	-	0,335	0,006[b]
BMI for Age Z-score (BAZ)	0,105	0,405[a]	0,080	0,525[a]

[a]Spearman test; [b]Pearson test

The results of the statistical analysis regarding the relationship between the risk of metabolic syndrome (MetS), the TG/HDL-C ratio, and the risk of atherosclerosis are presented in Table 4. This table shows a significant correlation between abdominal circumference and TG/HDL cholesterol ratio and the risk of atherosclerosis (p=0,009 and p=0,001, respectively). The correlation r values of 0,323 and 0,408 showed a moderate correlation and a positive relationship, respectively, where if there is an increase in abdominal circumference, the TG/HDL-C ratio and the risk of atherosclerosis will increase. These findings are in line with research Deusdará et al. (2022) who found the significance of abdominal circumference indicating central obesity with TG/HDL-C. This correlation suggests that increased visceral fat accumulation contributes to impaired lipid metabolism and insulin resistance, which is characterized by an increased TG/HDL-C ratio. This finding is also supported by Al-Domi & Al-Shorman (2019) which shows that an increase in abdominal circumference is related to an increase in the intima-media thickness of the common carotid artery (cIMT), dyslipidemia, and an increase in blood pressure which are included as risk factors for atherosclerosis.

Based on Table 4, the results of the Pearson test statistical analysis showed a significant correlation between diastolic (DBP) and systolic (SBP) blood pressure and the TG/HDL-C ratio and the risk of atherosclerosis ($p < 0,05$). The r value of 0,408 – 0,421 indicates a moderate level of correlation and is positive or in the same direction; thus, increasing TDD and TDS will increase the TG/HDL-C ratio and increase the risk of atherosclerosis, and vice versa. These findings are in line with research Yi et al. (2023) which shows that an increase in the TG/HDL-C ratio is positively correlated with higher systolic and diastolic blood pressure. This is due to the role of excess triglycerides in increasing renin-angiotensin-aldosterone activity and oxidative stress. These activities can affect vascular tone and cause hypertension. In addition, an increase in the TG/HDL-C ratio indicates a decrease in HDL, which has a protective function against blood vessel walls through anti-inflammatory and antithrombotic mechanisms. This condition accelerates the atherosclerosis process by forming lipid plaque in blood vessels (Rafsanjani et al., 2019).

In contrast, the relationship between the TG/HDL-C ratio and the risk of atherosclerosis with fasting blood glucose (FBG) levels was not significantly correlated (p=0,905 and p=0,431). The correlation values r=-0,015 and r=0,099 show that the relationship is very weak and the direction of the relationship is negative, where the higher the TG/HDL-C ratio, the lower the FBG. In contrast, the positive relationship between FBG levels and the risk of atherosclerosis shows that as FBG levels increase, the risk of atherosclerosis increases. This result is in line with Silvanni et al. (2024) which shows that the relationship between FBG and the TG/HDL-C ratio is not significant with a weak relationship and the direction of the relationship is also negative in prediabetes. This is caused by lipoprotein lipase activity in the early phase of insulin resistance which reduces triglycerides without affecting HDL (Bjornstad & Eckel, 2019). A high prevalence of insulin and glucose disorders has been shown to be found in the population of asymptomatic obese children and adolescents with fasting blood glucose that they can still control (Assuncao et al., 2018), in which impaired insulin triggers the risk of other metabolic syndromes and cardiovascular disease (Iwani et al., 2022). Instead, research Wang et al. (2022) showed a significant positive relationship between FBG, TG/HDL-C ratio in a population with metabolic syndrome and severe insulin resistance. This difference in results is influenced by different population samples, where this study was conducted on a population without a risk of diabetes mellitus based on FBG measurements, while the previous study population focused on people with type 2 diabetes mellitus. In addition, control variables and genetic factors were confounding factors that could bias the research results. These results indicate that the TG/HDL-C ratio is not strong enough as a single indicator of cardiovascular risk related to fasting blood glucose; thus, other factors, such as lipid profile, are needed for effective evaluation and prevention of atherosclerosis. The same finding was also found in the statistical analysis of the relationship between TG/HDL-C ratio and BAZ, which was not significant ($p>0,05$). This finding is in line with research Lumbantobing et al., (2022) which showed an insignificant relationship between the TG/HDL-C ratio and BMI in diabetes mellitus patients. Instead, research Nasruddin et al. (2022) explained that body mass index has a positive correlation with the ratio of TG/HDL cholesterol in fertile women with obesity. The results of statistical analysis from previous research state that a high TG/HDL cholesterol ratio can increase the risk of obesity and metabolic syndrome 3 times (Awujoola et al., 2024). These differences in findings are influenced by population characteristics, such as ethnicity, diet, and lifestyle, and uncontrolled confounding factors, such as blood pressure or physical activity, which may play a role in the relationship between BAZ and TG/HDL-C ratio. These findings indicate that BAZ is not sufficient for use as a sole predictor for assessing the risk of atherosclerosis in certain populations, such as adolescents. The combination of other risk factors, such as fat distribution or other lipid profile biomarkers, should also be considered.

Triglycerides and HDL cholesterol levels are associated with an increased risk of atherosclerosis. The basic mechanism of the relationship between triglycerides and HDL-C and atherosclerosis involves inflammatory processes and unbalanced fat metabolism, which can increase the formation of small, dense, and highly atherogenic LDL-C particles. Literature review by Kosmas et al. (2023) explained that residual metabolic risk may occur with various atherogenic processes that persist even after aggressive lowering of LDL-C cholesterol with statins. Residual metabolic risk may occur due to the important contribution of increased triglycerides and decreased HDL-C levels (Dhindsa et al., 2020). Therefore, monitoring and managing triglyceride and HDL-C levels are necessary to prevent and treat atherosclerosis.

Based on these findings, prevention efforts are needed through lifestyle modifications such as increasing physical activity, reducing consumption of saturated fats and added sugars and improving sleep patterns which have been proven to reduce BMI and cardiometabolic factors in obese adolescen (Vourdoumpa et al., 2024). Study by Tani et al. (2021) in the Japanese young adult male population, it was also proven that diet and exercise interventions could reduce the triglyceride/HDL cholesterol ratio. Study Sutrisna et al. (2016) regarding the antidiabetic and antioxidant effects of bay leaf extract, it can reduce blood glucose ($p<0,05$) so that its consumption can prevent an increased risk of metabolic syndrome. Study Sarbini et al. (2019) proved that giving rosella can improve insulin resistance by reducing fasting blood glucose levels ($p<0,05$). Therefore, rosella can be used to prevent the development of metabolic syndromes in adolescents. Other preventive efforts such as providing counseling can increase knowledge so that it can increase awareness to improve eating habits and avoid foods that cause metabolic disorders (Kusumawati, 2017). Efforts to provide education are supported by research results Kartika et al. (2024) which shows the influence of education regarding the importance of preventing non-communicable diseases and metabolic syndrome on increasing knowledge in the adolescent population (p<0,000).

This research has several limitations, namely, the small sample size and sampling method, which was only carried out at one school in Surakarta, affecting sampling bias and generalization of research results. The cross-sectional approach used in this study cannot show cause-and-effect relationships but only associations. Contemporary factors such as physical activity, diet, and family history were not assessed in this study, which may have influenced the bias of the findings regarding the TG/HDL-C ratio, risk of metabolic syndrome, and risk of atherosclerosis. The cutoff ratio of TG/HDL-C in this study uses international references because there is no cutoff ratio of TG/HDL-C for the Indonesian population that is relevant and validated so that it can affect the external validity of the results.

Conclusion

TG/HDL-C ratio is an important indicator for assessing the risk of metabolic syndrome and atherosclerosis. An increase in this ratio had a significant correlation with an increase in blood pressure, abdominal circumference, and cardiovascular risk, whereas a correlation with fasting blood glucose levels and BAZ was not significant.

The results of this study can be used as a consideration for public health policy in developing simple screening guidelines based on the TG/HDL ratio to be implemented in schools or primary health facilities. In addition, for further research, it is necessary to identify and control confounding variables, such as family history of metabolic disease, diet, level of physical activity, and smoking habits, which can influence the results of the analysis of the relationship between the TG/HDL ratio and metabolic syndrome. In addition, further research is required to validate the TG/HDL-C cut-off values based on local populations. Longitudinal studies are needed to determine whether changes in the TG/HDL-C ratio influence the risk of atherosclerosis over time.

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