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Central obesity and its association with metabolic syndrome in adolescent students of Aceh Sport High School: A cross-sectional study

Obesitas sentral dan hubungannya dengan sindrom metabolik pada siswa remaja di Sekolah Olahraga Aceh: Studi potong lintang

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Abstract

Obesity remains a significant nutritional issue in the pediatric population and is closely linked to metabolic disorders. According to the World Health Organization (2022), 160 million individuals aged 5–19 years are classified as obese. This study aimed to evaluate the association between central obesity and metabolic syndrome (MetS) in sports students. This cross-sectional study was conducted at Aceh Sports High School from May to August 2024, involving 43 students selected through simple random sampling. Although the sample size was relatively small, these findings offer valuable preliminary insights. The data collected included demographics, anthropometric measurements, blood pressure, and blood tests (glucose, HDL cholesterol, and triglycerides). Central obesity was assessed using waist circumference and MS was evaluated based on the NCEP ATP III criteria. Data were analyzed descriptively, followed by the chi-square test. The majority of the participants were not at risk of MS (51,2%). However, chi-square analysis revealed a statistically significant association between waist circumference and MetS (p<0,001, OR = 3,75 95% CI = 2,072– 6,788). In conclusion, while most participants were not at risk of MetS, central obesity emerged as a strong predictor. These findings underscore the need for early screening and intervention, even in physically active adolescents.

Keywords: Central obesity, metabolic syndrome, adolescents, sport students

Abstrak

Obesitas tetap menjadi masalah gizi yang signifikan pada populasi pediatrik dan sangat berkaitan dengan gangguan metabolik. Menurut Organisasi Kesehatan Dunia (WHO) pada tahun 2022, sebanyak 160 juta individu berusia 5-19 tahun diklasifikasikan sebagai obesitas. Penelitian ini bertujuan untuk menilai hubungan antara obesitas sentral dengan sindrom metabolik (SM) pada siswa sekolah olahraga. Penelitian potong lintang ini dilakukan di Sekolah Khusus Olahraga Aceh pada Mei–Agustus 2024, melibatkan 43 siswa yang dipilih melalui *simple random sampling*. Meskipun ukuran sampel relatif kecil, temuan ini memberikan informasi awal yang penting. Pengumpulan data meliputi identitas dasar, pengukuran antropometri, tekanan darah, serta pemeriksaan darah (glukosa, kolesterol HDL, dan trigliserida). Obesitas sentral diukur menggunakan lingkar pinggang, dan MS dievaluasi berdasarkan kriteria NCEP ATP III. Data dianalisis secara deskriptif, kemudian dilanjutkan dengan uji Chi-square. Mayoritas peserta tidak berisiko mengalami MS (51,2%). Namun, analisis Chi-square menunjukkan adanya hubungan yang signifikan antara lingkar pinggang dan SM (p<0,001, OR = 3,75, CI 95% = 2,072–6,788). Kesimpulannya, meskipun sebagian besar peserta tidak berisiko mengalami MS, obesitas sentral muncul sebagai prediktor kuat. Temuan ini menekankan pentingnya skrining dan intervensi dini, bahkan pada remaja yang aktif secara fisik.

Kata Kunci: Obesitas sentral, sindrom metabolik, remaja, siswa sekolah olahraga

Introduction

Metabolic syndrome (MetS) is a group of metabolic conditions that elevate the risk of cardiovascular diseases, including high blood pressure, central obesity, and dyslipidemia. The prevalence of MetS has been steadily increasing even among children, making it a pressing public health concern. This rise in prevalence mirrors the growing rates of obesity affecting children and adolescents globally, including in Indonesia (Zhu et al., 2020; Magge et al., 2017). The study analyzing data from the 2013 Riskesdas reported a 5,93% prevalence of MetS among adolescents aged 15–24 years, based on the NCEPATP III criteria (Pratiwi ZA et al., 2017). In a targeted study of obese adolescents aged 13–16 years, 45,8% (27 subjects) had metabolic syndrome (Prihaningtyas et al., 2020).

According to Health 2022 WHO data, over 390 million children and adolescents aged 5-19 are affected by excess nutrition, of which 160 million are classified as obese. The obesity rate has surged dramatically, from 8% in 1990 to 20% in 2022 (Vaamonde & Álvarez-Món, 2020). A UNICEF report highlights a significant rise in overweight and obesity rates between 2010 and 2018 in Indonesia across nearly all age groups, from 9,2% to 20% among children aged 5–12 years, 1,9% to 14,8% among adolescents aged 13–18 years, and 21,7% to 35,4% among adults aged > 18 years (United Nations Children's Fund, 2022). Adolescents with obesity are more likely to develop obesity in adulthood. This trend is supported by the increase in obesity rates during the transition from adolescence to early adulthood, which rose from 10,9% to 22,1% between 2010 and 2015 (Dieny et al., 2015).

Obesity is also prevalent among student athletes, with a Philadelphia study reporting that 20% were overweight and 24% were obese (Kropa et al., 2016). Although physically active, student athletes are still at risk of obesity due to several factors, such as poor eating habits, low cardiorespiratory fitness, sedentary behavior outside of training, Relative Energy Deficiency in Sport (RED-S), and lifestyle changes during the off-season (Cleven et al., 2022; Oliveira & Guedes, 2016). Although physical activity is essential, it does not provide complete protection against obesity. A comprehensive approach, including balanced nutrition, regular aerobic activity, and reduced sedentary behavior, is required to minimize the risk of obesity in student athletes.

Obesity develops when energy consumption from food exceeds energy expenditure. This issue has become more common in society due to a phenomenon in which physical activity levels decline while children continue to consume high-calorie foods (Wu et al., 2016; Al Rahmad et al., 2020). Abdominal (central) obesity refers to the accumulation of fat in the skin of the abdominal wall and in the abdominal cavity (Soleha & Azzaky Bimandama, 2016).

Waist circumference is a basic, practical, and sensitive measure of central obesity. It was measured at the midpoint between the lower rib and iliac crest using a fixed tape measure (0.1 cm, taken horizontally at the end of exhalation (Bahar et al., 2012). As stated by the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III), a waist circumference at or above the 90th percentile for adolescents is considered abdominal obesity. This measurement is commonly used to screen for metabolic syndrome. Waist circumference is often preferred over Body Mass Index (BMI) for detecting central obesity because it directly measures fat accumulation around the abdomen, an area closely associated with metabolic risk. In contrast, BMI only reflects weight relative to height and does not differentiate between fat, muscle, and bone, nor does it indicate fat distribution (Ross et al., 2020).

The accumulation of intra-abdominal fat is more strongly linked to insulin resistance and hyperlipidemia than overall body fat. This build-up leads to an increase in the free fatty acids released during lipolysis, which can impair insulin sensitivity (Gregory, 2019). Furthermore, progressive accumulation of abdominal fat is a significant predictor of the risk of hypertension, type 2 diabetes, cardiovascular diseases, and other metabolic complications (Macpherson et al., 2016; Powell-Wiley et al., 2021).

Preventing obesity in the young population reduces the risk of MetS (Gregory, 2019). This can be achieved by promoting an active lifestyle from an early age and ensuring consistent physical activity throughout childhood and adolescence (Carson et al. 2016). This approach aligns with the principles of sports schools, which integrate physical activity into their educational curricula. In sports

schools, students engage in both academic and non-academic subjects with a focus on selecting a sport in which they receive intensive physical training. However, despite high levels of physical activity, studies have shown that student athletes are not immune to metabolic risk. Factors such as poor dietary habits, sedentary behavior outside training hours, and low cardiorespiratory fitness can contribute to a higher risk of MetS, even among physically active youth. Therefore, attending sports school does not necessarily guarantee a lower risk of metabolic syndrome. This study aimed to evaluate the relationship between central obesity, as determined by waist circumference, and metabolic syndrome in adolescents in Sports High School Aceh.

Methods

This analytical observational study was conducted at Aceh Sports High School from May to August 2024. The study focused on student athletes, a population of interest due to the paradoxical risk of central obesity and metabolic syndrome despite regular training, highlighting the importance of comprehensive health screening, even among active adolescents.

This cross-sectional study was conducted to evaluate the association between central obesity and metabolic syndrome in student athletes. Cross-sectional studies are efficient and practical study designs that provide a snapshot of a population at a specific point in time, making them ideal for assessing the prevalence of health conditions or behaviors. Conducting these studies is cost-effective and relatively quick, as they collect data only once and do not require follow-up. Additionally, they are valuable for identifying associations between variables. However, it is important to note that cross-sectional studies cannot establish causality owing to their observational nature (Capili, 2021).

The sample consisted of high school students who met the inclusion criteria and were selected using simple random sampling via lottery. The minimum sample size was calculated using the following formula:

$$n = \left(\frac{Za^2\ (PQ)}{d}\right)$$

$$n = \left(\frac{1{,}96^2\ (0{,}13 \times (1-0{,}13))}{0{,}1}\right) = 42$$

Za = standard deviation of the error rate (1,96)
P = disease proportion (0,13)
Q = 1-P
d = margin of error (10%)

The sample size was determined using a standard formula to estimate the population proportion with a specified level of precision. Based on a previous study, the estimated prevalence of metabolic syndrome among adolescents was 0,13 (Zhu et al., 2020). With a 95% confidence level (Z = 1,96) and a margin of error of 10% (0,10), the calculated minimum required sample size for this study was 42 participants. Participants aged 15–18 years enrolled at Aceh Sport School were eligible for inclusion if they provided written informed consent and completed all phases of the study. Students were excluded if they actively participated in a sports competition during the study period or were absent from school at the time of data collection. After applying the inclusion and exclusion criteria, 43 students were selected as study participants.

Data collection included name, age, and sex, followed by anthropometric measurements, such as height, weight, and waist circumference. Height and weight were measured using a calibrated stadiometer and digital scale, respectively, whereas waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest using a non-stretchable measuring tape. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Blood pressure was measured using a calibrated digital sphygmomanometer after the participant rested for at least five minutes in a seated position. Venous blood samples were collected by a trained phlebotomist to assess random blood glucose, HDL cholesterol, and triglyceride levels using standardized laboratory kits and procedures. Waist circumference was used as an indicator of central obesity, whereas blood pressure and laboratory test results were used to assess the risk of metabolic syndrome. All data were collected by trained health personnel who had undergone prior instructions to ensure consistency in measurement techniques and adherence to standardized protocols.

Metabolic syndrome was defined based on the NCEP ATP III criteria. Participants were classified as having metabolic syndrome if they

met at least three of the following five conditions: waist circumference ≥ 90th percentile, blood pressure ≥ 90th percentile, triglycerides ≥ 110 mg/dL, HDL cholesterol ≤ 40 mg/dL, and blood glucose ≥ 200 mg/dL. Individuals meeting at least one of these criteria are considered at risk for metabolic syndrome (Bekel & Thupayagale-Tshweneagae, 2020; DeBoer et al., 2019; Lung NH, 2002).

All data were electronically tabulated and analyzed using SPSS version 23. Descriptive analysis was used to summarize the participants' characteristics. A chi-square (χ^2) test was conducted to assess the association between waist circumference and metabolic syndrome. Before performing the test, the assumptions were checked, including the requirement that the expected frequencies in each cell should be at least 5. Since the Chi-square test does not provide the strength of association, odds ratios (OR) with 95% confidence intervals (CI) were calculated to quantify the relationship. For continuous variables, normality was assessed using the Shapiro–Wilk test prior to any comparative analysis. This study was approved by the Ethics Committee of the Faculty of Medicine at Syiah Kuala University (approval number. 020/EA/FK/2024).

Result and Discussion

Table 1 shows that the study participants were predominantly male, comprising 58,1%, with most being aged 16 years (48,8%). This gender distribution contrasts with national education statistics, where 64,45% of general high school students are female (Badan Pusat Statistik, 2023) but aligns with trends observed in sports schools, which typically enroll more male students. This male predominance is relevant given that boys are generally more physically active than girls, potentially influencing body composition and obesity risk (Marques et al., 2016) (Hyde et al., 2020).

Furthermore, dietary habits differ by sex and influence obesity risk. Male tend to consume more red and processed meats, salty foods, and diets high in fats and sugars, with irregular eating patterns and lower overall diet quality. Females generally eat more vegetables and fiber-rich foods but are more prone to emotional or impulsive eating. These differences suggest that males are at risk due to poor diet quality, whereas females may be affected by disordered eating behaviors. Sex-specific strategies are essential for effective obesity prevention (Feraco et al., 2024).

Table 1. Characteristics of respondents (n=43)

Characteristic	n	%
Gender		
Male	25	58,1
Female	18	41,9
Age (years)		
15	2	4,7
16	21	48,8
17	13	30,2
18	7	16,3
BMI		
Underweight	5	11,6
Normal	32	74,5
Overweight	5	11,6
Obese	1	2,3
Waist Circumference		
Normal (<percentile 90)	30	69,8
Abnormal (>percentile 90)	13	30,2
Blood Pressure		
Normal (< percentile 90)	43	100
Elevated	0	0
Random Blood Glucose		
Normal (<200 mg/dl)	43	100
Elevated (≥200 mg/dl)	0	0
HDL Cholesterol		
Normal (≥40 mg/dl)	39	90,7
Elevated (<40 mg/dl)	4	9,3
Triglycerides		
Normal (<110 mg/dl)	32	74,4
Elevated (≥110 mg/dl)	11	25,6
Metabolic Syndrome Risk		
0 risk	22	51,2
1 risk	15	34,9
2 risk	5	11,6
3 risk	1	2,3

The vast majority of participants (74,5%) had a normal nutritional status, while underweight, overweight, and obese categories represented a smaller portion. This distribution is more favorable compared to the national adolescent data in Indonesia, where the prevalence of overweight and obesity among adolescents aged 13–18 years was 148% (United Nations Children's Fund, 2022). The lower prevalence observed in this study may be

attributable to students' regular participation in structured physical training, a characteristic of sports school curricula. Similar findings have been reported in athlete populations, where regular exercise is associated with healthier BMI ranges and improved metabolic profiles (Zhu et al., 2020) (Silva et al., 2017). Despite high physical activity levels, 30,2% of the participants had waist circumferences above the 90th percentile, suggesting central obesity. This rate is higher than the 21,8% prevalence reported among Chinese adolescents, possibly due to contextual factors, such as diet, training intensity, or differences in measurement criteria (Zhu et al., 2020).

The majority of study participants were not at risk for metabolic syndrome (51,2%). However, 46,5% had one or two risk factors and one student (2,3%) met the full diagnostic criteria. This result aligns with a previous study conducted in China reported that 2,62% of the pediatric population was diagnosed with metabolic syndrome (Zhu et al., 2020). Similarly, according to a 2016 Korean study, 2.1% of 2,330 adolescents aged 10–19 years fulfilled the requirements for metabolic syndrome (Kim & So, 2016). These findings underscore that even physically active adolescents may face metabolic risks, especially in the presence of central obesity.

The results of bivariate analysis of waist circumference and metabolic syndrome are presented in Table 2.

Table 2. Chi Square test between waist circumference (WC) and metabolic syndrome

Variable	At Risk	No Risk	OR	P value	CI 95%
	n (%)	n (%)			
Abnormal	13 (61,9)	0 (0,0)	3,75	<0,001	2,072– 6,788
Normal	8 (38,1)	22 (100,0)			

Table 2 indicates a strong association between waist circumference and the prevalence of metabolic syndrome in teenagers at sports high schools in Aceh Province, with a p-value of <0,001. According to the findings, students with a larger waist circumference are 3,75 times more inclined to develop metabolic syndrome than those with a normal waist circumference. Notably, 13 of the 21 students identified as being at risk for metabolic syndrome had elevated waist circumference, while none of the students with normal waist circumference measurements exhibited any of the metabolic risk factors. This pattern underscores the critical role of central obesity in the pathogenesis of MetS. Waist circumference is a reliable marker of visceral fat, which is strongly linked to insulin resistance, dyslipidemia, and hypertension, which are the key components of metabolic syndrome. Even among physically active students, a normal waist circumference appears to offer a protective effect against metabolic abnormalities. This emphasizes the importance of monitoring abdominal fat, rather than relying solely on general body weight or BMI, to assess metabolic risk (Darsini et al., 2020; Silva et al., 2017).

A 2021 study in Saudi Arabia found that teenagers with a waist circumference greater than the 90th percentile had significantly more risk factors for metabolic syndrome (≥2 risk factors, 64,87%), whereas those with a normal waist circumference typically had only one risk factor (Alowfi et al., 2021). The study in East Java with 208 obese teenagers found a strong association between waist circumference and metabolic syndrome (Widjaja et al., 2023). These studies validate the current findings and highlight the importance of monitoring waist circumference as a critical marker for metabolic syndrome, even among physically active students with a normal BMI. Central obesity can exist independently of general obesity, and may be the earliest and most consistent indicator of cardiometabolic risk.

Approximately one-third of the total body fat can be measured using subcutaneous fat. The size of subcutaneous fat represents fat deposits beneath the skin, providing an approximation of the overall body fat. This anthropometric assessment is highly accurate in assessing obesity in children and adolescents (Nuraini & Murbawani, 2019). The NCEP ATP III recommends waist circumference at or above the 90th percentile as the cutoff for defining abdominal obesity in children and adolescents (Lung, 2002). Although Body Mass Index (BMI) and waist circumference are the two most widely used parameters for examining overall and abdominal obesity, previous studies have

shown that people with the same BMI can have significant variances in abdominal fat mass. Some individuals may have a normal BMI but still exhibit central obesity, as shown in the Bogalusa Heart Study, which found that 9,22% of individuals aged 4–18 years with a normal BMI had central obesity (Mokha et al., 2010; Song et al., 2019).

Although students at sports schools are generally assumed to be physically fit, several factors can contribute to abnormal waist circumference in this population. During adolescence, natural growth and hormonal changes can lead to increases in waist, which may not always reflect poor health (Aars et al., 2019). Inconsistent physical activity due to injuries or academic demands, along with unhealthy dietary habitssuch as consumption of processed foods and sugary drinks, can lead to central fat accumulation despite regular training (Błaszczyk-Bębenek et al., 2019). Moreover, psychological stress may elevate cortisol levels, which is linked to increased abdominal fat (Ma et al., 2022). These factors emphasize that regular physical activity alone may not be sufficient to prevent central obesity, thus underscoring the need for a more comprehensive approach to lifestyle habits.

Abnormal waist circumference is linked to a higher risk of metabolic syndrome components, including hypertension, hypercholesterolemia, and type 2 diabetes. Excess intra-abdominal fat disrupts blood pressure regulation and lipid metabolism, lowers adiponectin levels, and increases free fatty acids, all of which impair insulin function. These changes can lead to insulin resistance, initially causing hyperinsulinemia, and eventually progressing to type 2 diabetes if glucose regulation fails (Darsini et al. 2020). While these mechanisms explain the biological link, this study's cross-sectional design, small sample size, and lack of dietary, genetic, and psychosocial data limit the causal interpretation. Nonetheless, the findings underscore the importance of waist circumference as a screening tool in adolescent health programs, particularly for student athletes. Tailored school-based interventions focusing on nutrition, stress management, and routine waist circumference monitoring could help mitigate future cardiometabolic risk in Indonesian adolescents.

Conclusion

This study found a significant association between central obesity—measured by waist circumference above the 90th percentile—and the risk of metabolic syndrome among adolescents in a sports high school. While obesity is a key predictor of metabolic and cardiovascular complications, these findings highlight the urgent need for routine screening of waist circumference and other metabolic indicators, even in physically active student populations.

Schools should implement periodic health assessments and consider modifying training programs to address not just performance, but also long-term metabolic health. Additionally, integrating targeted nutrition education and stress management strategies could enhance preventive efforts. However, due to the study's small sample size and cross-sectional design, further longitudinal research is needed to explore causal relationships and evaluate the effectiveness of intervention programs.

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