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FAT INTAKE, NATRIUM INTAKE, AND SLEEP DURATION ARE STRONGLY ASSOCIATED WITH PRE-METABOLIC SYNDROME IN ADOLESCENTS

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ABSTRACT

Introduction: The prevalence of pre-metabolic syndrome components, such as abdominal obesity and elevated blood pressure, in teenagers is increasing yearly. One of the modifiable risk factors to pre-metabolic syndrome is lifestyle, including dietary intake, physical activity, and sleep duration. Based on preliminary study, 80% (12 of 15) students were found to have high blood pressure. **Aims:** The objective of this study was to evaluate the relationship between nutrition and lifestyle factors with pre-metabolic syndrome in high school students. **Methods:** This study was cross-sectional design with 90 adolescents as respondents. Instruments used in this study were sphygmomanometer and waist ruler to measure blood pressure and waist circumference; 3x24 hours of food record and SQ-FFQ to observe dietary intake; modified PSQI to assess sleep duration; and modified IPAQ to know physical activity score in respondents. All data were statistically analyzed with Spearman correlation test. **Results:** The findings of this study were fat intake, fulfillment of fat requirement (% of fat requirement), natrium intake, and sleep duration were significantly associate with pre-metabolic syndrome occurrence in adolescents ($p<0.05$). Coefficient correlation showed positive for fat intake, % of fat requirement, and natrium intake (respectively 0.705; 0.511; 0.854) and negative for sleep duration (-0.819). **Conclusion:** there are association between fat intake, fulfillment of fat requirement (% of fat requirement), natrium intake, and sleep duration with pre-metabolic syndrome in adolescents. This study findings may be used as evaluation for government nutrition programs for adolescents.

Keywords: adolescent, eating, life style, metabolic syndrome

INTRODUCTION

The adolescent era (10-19 years) is a period of transition into adulthood in which various biological changes occur, including changes in body composition. Weight gain is one of the changes in body composition. Uncontrolled weight gain can lead to obesity. Since half of the optimal adult body weight is acquired during adolescence, it is crucial to monitor teens' nutritional status (Brown, 2011; Mahan and Raymond, 2017). Aside from biological changes, the adolescent period is also generally associated with the formation of food preferences, when teenagers start choosing food independently (Mukanu *et al.*, 2022). According to many studies, the majority of teenagers tend to consume high-fat diets (fast food, snacking) and high-sugar food (sugar-sweetened beverages) (Neta *et al.*, 2021; Sinai *et al.*, 2021). Previous study also explained that more than half of teenager respondents ate while watching TV and prefer to eat away from home. Thus fast food had the most percentage of energy contribution in teenagers (Ramírez-López, Flores-Aldana and Salmerón, 2019).

Teenagers are more likely to have higher body mass index when their diets have high levels of sugar, fat, and calorie density. The occurrence of adolescents' overweight and obesity is increasing every year. In 2013, the prevalence of overweight and obesity among Indonesian adolescents (10-18 years) was 18.1%, while in 2018 it increased to 29.5% (Ministry of Health Republic Indonesia,

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2013; 2018). Obesity is associated with higher risk of pre-metabolic syndrome. Pre-metabolic syndrome is defined as the presence of two of the five metabolic syndrome characteristics, which include central obesity, high blood pressure, elevated triglyceride levels, elevated fasting blood glucose levels, and reduced high-density lipoprotein (HDL) levels (Purandar and Ganesan, 2022). The prevalence of pre-metabolic syndrome and/or metabolic syndrome in teenagers are assumed to increase every year. Based on a study in 2013, the prevalence of metabolic syndrome in adolescents was 16.47%, while previous study conducted in 2021 stated that the prevalence increased to 41.4% (Singh *et al.*, 2013; Asghari *et al.*, 2021). According to preliminary study on 15 students at the location, 80% of students had pre-metabolic syndrome, which consisted of seven students having high waist circumference and 12 students having high blood pressure. Compared with previous studies, the pre-metabolic syndrome prevalence in the study location was higher. Pre-metabolic syndrome can be used to predict the likelihood of metabolic syndrome, which is strongly linked to degenerative diseases including diabetes, dyslipidemia, coronary heart disease, and others (Kaur, 2014).

Previous study has identified risk factors for metabolic syndrome in adults, such as sedentary lifestyle, bad eating habits, lack of sleep, and obesity (Kaur, 2014). Light physical activity and unhealthy eating patterns lead to negative energy balance, resulting in obesity. Stress and lack of sleep also lead to hormonal imbalances that contribute to obesity and increased inflammatory markers (Cabej, 2019). Obesity can cause increased oxidative stress in the body, leading to insulin resistance, which results in glucose being unable to enter cells and accumulating in the blood (hyperglycemia). Insulin resistance also leads to increased fatty acid secretion from adipose tissue and hepatic triglyceride synthesis, resulting in increased blood triglyceride levels and decreased high-density lipoprotein (HDL) levels. Hyperinsulinemia resulting from insulin resistance can also cause natrium retention, leading to increased blood pressure (Cho *et al.*, 2017).

Several previous studies have analyzed these factors separately. However, there is no research, especially in Indonesia, that addresses all these factors in relation to the occurrence of pre-metabolic syndrome in teenagers. The prevalence of obesity, known as a risk factor for metabolic disorder, in adolescents also increases each year. Therefore, it is important to conduct a study that analyzes these various lifestyle factors as influencers of pre-metabolic syndrome in teenagers. The results of this study are expected to provide additional information and serve as a basis for planning or evaluating government nutrition programs for adolescents.

METHODS

This study was an analytical observational study with cross-sectional design conducted at a high school in Sidoarjo, East Java, Indonesia. The sample size was determined using stratified sampling formula by Lemeshow et al. (1990), which suggests a minimum sample size of 90 respondents. The sampling technique used stratified random sampling, with inclusion and exclusion criteria. The inclusion criteria for this study included physically and mentally healthy students (without ascites, edema, or injuries to the legs or arms) and who were willing to participate as respondents. The exclusion criteria were students who were taking medication for degenerative diseases (such as hypertension, diabetes, or dyslipidemia), students following specific disease diets, and students taking sleep medication. This study has been reviewed and approved by the Health Research Ethic Committee of Universitas Nahdlatul Ulama Surabaya (reg. number: No.0031/EC/KEPK/UNUSA/2023). All the respondents who met the inclusion criteria were explained about the procedures of data collection, then those who agreed to be respondents were asked to complete an informed consent document.

The instruments used to measure pre-metabolic syndrome in this study were waist ruler (Onemed OD 235 with the nearest 0,1 cm) for measuring waist circumference and digital sphygmomanometer (Onemed TensiOne 1A with precision 3 mmHg) for measuring blood pressure. Waist circumference was measured midway between the last rib and the iliac crest of respondent. Measurement of waist circumference was done by a nutritionist. Blood pressure measurement was taken by a nurse in relaxed sitting condition with measurement twice at a two minutes interval. Both waist circumference and blood pressure measurement were conducted twice and then the average calculated. The respondents were asked to record their physical activity, including intensity and length of activity, for one week using a modified version of the International Physical Activity Questionnaire (IPAQ) (Suyoto *et al.*, 2016). The respondents were also asked to list their daily consumption with the food record questionnaire over three days (2 weekdays and 1 weekend) to assess their energy and macronutrient intake (protein, fat, and carbohydrate), while fiber and natrium intake were enquired with Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) (Adhi, 2012; Shabrina, Mulyani and Perdana, 2019). SQ-FFQ was used to assess respondents' source of fiber and natrium food consumption for a month. This study used modified Pittsburgh Sleep Quality Index for assessing the respondents' sleep duration over a week (Jumarsih, 2021). All the instruments used in this study have been used in Indonesian population. All procedures were monitored by a qualified enumerator (nutritionist).

All the data collected were then categorized. Based on Indonesian Pediatric Society (2014), blood pressure was considered high when the average measurement results were >128/83 mmHg in girls and >130/83 mmHg in boys, while waist circumference was considered at-risk when the average results were >76 cm in girls and >77 cm in boys. Pre-metabolic syndrome was defined when respondents had high blood pressure and/or at-risk waist circumference (Indonesian Pediatric Society, 2014). Based on the length and intensity of the activities completed by respondents, physical activity was calculated using the IPAQ calculation criteria, and then classified as high physical activity (IPAQ score >3000 METs-minutes/week), moderate (≥600-3000 METs-minutes/week), and low (<600 METs-minutes/week) (Sember *et al.*, 2020). Nutrisurvey software was used to analyze dietary consumption data. This study also calculated energy requirement for each respondent with Schofield formula for 10-18 years old (Fuentes-Servín *et al.*, 2021). Protein, fat, and carbohydrate needs were then calculated as respectively 15%, 25%, and 60% of the total energy requirement (Yujin *et al.*, 2020). To determine the respondents' fulfillment of nutrient requirement, comparison of the respondents' needs with the respondents' average intake data was calculated. Sleep duration was classified as inadequate (<7 hours per day) and sufficient (8-10 hours per day) (Muhammad *et al.*, 2020).

All collected data were analyzed using the Statistical Packages for the Social Sciences (SPSS). The data analysis involved univariate and bivariate analysis. The univariate analysis aimed to explore the descriptive analysis (frequencies, mean, and standard deviation) of the respondents' characteristics, while the bivariate analysis aimed to examine the relationship between these various lifestyle factors with pre-metabolic syndrome in teenagers. The bivariate analysis used Spearman correlation test. Significance values (p-value) lower than 0.05 were considered statistically significant, while coefficient correlations (r-value) were analyzed to know the strength and direction of the correlation.

RESULT

The general characteristics of the study respondents are described in Table 1. Of the 90 participants, 61.1% were girls and 38.9% were boys. The mean (SD) age of respondents was 17 (1) years old. Based on measurements, Table 1 shows that mean (SD) of waist circumference was 75 (11.5) cm, while systolic and diastolic blood pressure respectively was 120 (12.7) and 73 (88) mmHg. Daily intakes were reported with mean of 3x24 hours food record. The results of intake analysis were 1445 ± 435.1 kcal for energy, 57 ± 12.4 gram of protein, 66 ± 14.9 gram of fat, and 172 ± 62.8 gram. The majority of respondents had moderate physical activity (66.7%) and sufficient sleep duration (56.7%). Table 1 also shows that 32.2% respondents had overweight and obesity z-score. According to waist circumference and blood pressure measurement, 58.9% respondents were classified to pre-metabolic syndrome.

Table 1. Respondents' Characteristics

Variable	N	%	Mean ± SD
Age (years old)			17 ± 1
Waist circumference (cm)			75 ± 11.5
Systolic blood pressure (mmHg)			120 ± 12.7
Diastolic blood pressure (mmHg)			73 ± 8.8
Dietary intake			
Energy (kcal)			1445 ± 435.1
Protein (gram)			57 ± 12.4
Fat (gram)			66 ± 14.9
Carbohydrate (gram)			172 ± 62.8
Fiber (gram)			14 ± 6.8
Natrium (milligram)			1474 ± 544.2
Sex			
Girls	55	61.1	
Boys	35	38.9	
Physical activity (METs-minutes/week)			2726 ± 1512.,9
Moderate	60	66.7	
High	30	33.3	
Sleep duration category			
Insufficient	39	43.3	
Sufficient	51	56.7	
Nutritional status (Body Mass Index/Age)			
Thinness	2	2.2	
Normal	59	65.6	
Overweight	24	26.7	
Obese	5	5.5	
Waist circumference category			
Normal	47	52.2	
At risk	43	47.8	

Variable	N	%	Mean ± SD
Blood pressure category			
Normal	61	67.8	
High	29	32.2	
Pre-metabolic syndrome category			
Non-pre-metabolic syndrome	37	41.1	
Pre-metabolic syndrome	53	58.9	

Table 2. Characteristics of the Respondents according to Pre-Metabolic Syndrome Status

Variable	Non Pre-Metabolic Syndrome (Mean ± SD)	Pre-Metabolic Syndrome (Mean ± SD)
Waist circumference (cm)	65.6 ± 6.1	79.9 ± 10.3
Systolic blood pressure (mmHg)	110.9 ± 6.4	127.0 ± 9.9
Diastolic blood pressure (mmHg)	67.1 ± 6.6	76.6 ± 6.5
Physical activity (METs-minute/week)	2554.3 ± 1388.2	2797.0 ± 1359.7
Energy intake (kcal)	1379.9 ± 364.9	1546.4 ± 535.2
Fulfillment of energy (% requirement)	72.9 ± 20.4	74.3 ± 25.2
Protein intake (gram)	54.4 ± 10.6	61.3 ± 14.1
Fulfillment of protein (% requirement)	76.5 ± 16.4	78.1 ± 19.2
Fat intake (gram)	54.3 ± 9.3	74.9 ± 13.5
Fulfillment of fat (% requirement)	103.9 ± 22.7	127.8 ± 17.4
Carbohydrate intake (gram)	169.9 ± 51.9	183.9 ± 74.1
Fulfillment of carbohydrate (% requirement)	59.7 ± 18.1	58.9 ± 23.3
Fiber intake (gram)	15.1 ± 6.6	13.7 ± 7.1
Natrium intake (milligram)	1092.0 ± 1710.8	1710.8 ± 382.5
Sleep duration (hours/day)	8 ± 0.9	5.2 ± 1.3

Table 3. Coefficient Correlation for Pre-Metabolic Syndrome and its Determinant Factor

Variable	Pre-Metabolic Syndrome (p-value; r-value)
Physical Activity	0.151; -0.153
Energy Intake	0.103; 0.334
% of Energy Need	0.855; -0.020
Protein Intake	0.086; 0.182
% of Protein Need	0.997; 0.000
Fat Intake	0.000*; 0.705
% of Fat Need	0.000*; 0.511
Carbohydrate Intake	0.913; -0.012
% of Carbohydrate Need	0.276; -0.116
Fiber Intake	0.836; -0.022
Natrium Intake	0.000*; 0.854
Sleep Duration	0.000*; -0.819

Note: % of need indicate percentage of fulfillment need from respondents' intake. Spearman's correlation test was used to analyze the correlation between pre-metabolic syndrome and its factor. * explains that these variables were significant with $p < 0.05$.

Table 2 shows lifestyle characteristics according to status of pre-metabolic syndrome. This study found that, compared to respondents with non-pre-metabolic syndrome category, those with pre-metabolic syndrome had slightly higher waist circumference and both blood pressure measurements. All dietary intake, including energy, macronutrient, and natrium, also showed higher in respondents with pre-metabolic syndrome. The fulfillment of each macronutrient and energy also reported higher among pre-metabolic syndrome respondents. On the other hand, lower natrium intake was shown in non-pre-metabolic syndrome. Consistently with natrium intake, longer sleep duration was observed in non-pre-metabolic syndrome.

An interesting finding in this study was lower score of physical activity found in non-pre-metabolic syndrome. This might be because the IPAQ questionnaire used in this study covered length of activity in four domains, including leisure time (sitting), domestic activities (daily activities/household chores), work-related, and transport-related (walking) physical activity (Sember *et al.*, 2020). Previous study explained that IPAQ relevance with moderate-vigorous physical activity was due to its scoring system, thus respondents tended to have active physical activity even though being inactive (overestimated) (Al-Bachir and Ahmad, 2021) Table 3 explains Spearman's coefficient correlation for pre-metabolic syndrome and its factor. It indicates that fat intake, fulfillment of fat requirement (% of fat need), natrium intake, and sleep duration were significantly associated with pre-metabolic syndrome occurrence in adolescents. Coefficient correlation showed similar result with Table 2. Positive r-value in fat intake, % of fat need, and natrium intake (respectively 0.705; 0.511; 0.854) represented strong association which means that higher fat and natrium intake are associated with elevation of pre-metabolic syndrome occurrence. Conversely, negative r-value (sleep duration with -0.819) informed that longer sleep duration inversely correlated with pre-metabolic syndrome occurrence.

DISCUSSION

Global progression of metabolic syndrome prevalence has been associated with several lifestyles including diet. Inadequate physical activity, prolonged consumption of high fat diet, smoking habit, heavy alcohol consumption, prolonged time of sleep inadequacy, and stress have been identified as the risk factors of metabolic syndrome (Mohamed *et al.*, 2023; Rus *et al.*, 2023). To tackle inappropriate diet, Indonesia's government published dietary guidelines called Balanced Nutrition Guideline (*Pedoman Gizi Seimbang*). One of the messages mentioned is to limit consumption of sweet (glucose/sucrose), salty (natrium), and fatty food (fat) (FAO, 2015; Khusun *et al.*, 2023). This study aimed to investigate the relationship between various lifestyle factors as influencers of pre-metabolic syndrome in teenagers.

The current study found that prevalence of overweight and obese were higher than thinness, similar with previous study which stated that nutritional status problems in teenagers were dominantly by overweight and obese (Sinai *et al.*, 2021). This study used waist circumference as anthropometry indicator to diagnose obesity. Waist circumference can be a predictor of metabolic syndrome since waist circumference is able to measure excess body fat, mainly abdominal obesity (de Oliveira *et al.*, 2023). Many studies showed that waist circumference and/or waist hip ratio measurement were better predictors to cardiometabolic risk than body mass index (Ren *et al.*, 2023).

This study's results explained that the majority of respondents had excessive fat intake. Prior study found that more adolescents had diet-related obesity and non-communicable diseases than previously. A few studies also explained that adolescents rarely follow dietary guidelines, such as consumed a lot of processed food (Daly, O'Sullivan and Kearney, 2022). Several factors contributing to food selection in teenagers were sensory appeal, price, convenience, and health.

This study finding was in accordance with previous study that total fat intake inversely associated with abdominal obesity in Mediterranean population. That study stated that the highest total fat consumption had the greatest risk of abdominal obesity. Subjects in the lowest quintile of total fat intake had lower abdominal obesity. Subjects in the lowest quintile of total fat intake had lower abdominal obesity (95.2%) than subjects in the highest quintile (96.7%) (Julibert *et al.*, 2019). Another study suggested that increasing high-fat consumption (fast food, chicken skin, fat meat) may raise risk of metabolic syndrome components, such as abdominal obesity (OR 5.11), high blood pressure (OR 3.58) and insulin resistance in adolescents (OR 6,66) (Ramírez-López, Flores-Aldana and Salmerón, 2019). Our study found that adolescents had poor dietary intake, specifically high fat food. The respondents in this study reported many fried foods (fried chicken, fritters (*bakwan*, *tahu isi*) and snacks (crackers, chips).

According to prior study, adolescents have greater preference of sweet and savory taste. Sensory components, like taste, consistently determine food choice in adolescents. Additionally, high fat food tends to be cheaper and convenient to adolescents who have a busy schedule. Adolescents also related to poor diet, since they lack of skills to cook or prepare healthy eating (Daly, O'Sullivan and Kearney, 2022).

High fat food has been related to energy-dense food. High energy-dense intake may increase adipose tissue, mainly at abdominal subcutaneous and visceral fat, that can be measured by waist circumference (Konieczna *et al.*, 2019). Accumulation of abdominal fat may alter natrium regulation, promote insulin resistance and inflammation; therefore, those mechanisms may affect the vascular function and induce elevated blood pressure (Kotsis *et al.*, 2010; Wang *et al.*, 2020). A theory has been postulated that adipose tissue is a mandatory element of metabolic syndrome's pathophysiology since adipose tissue has dynamic remodeling capability, including hypertrophy, hyperplasic, apoptosis, extensive vascularization, and extracellular matrix remodeling. Those mechanisms are associated with inflammation and metabolic complications (Cai, Huang and He, 2022).

In this study, natrium intake was shown higher in pre-metabolic syndrome respondents and significantly positively associated with pre-metabolic syndrome. Similar to this study, Fang *et al.* (2021) presented that abdominal obesity (11.8%) was more prevalent in the highest tertile of natrium intake compared to lower tertile natrium intake (7.5%). A meta-analysis study also found that dietary natrium intake was positively associated with obesity outcome, such as body weight and waist circumference) (Lee *et al.*, 2023). Several studies also found that higher urinary natrium excretion was related with an increased risk of weight gain and central obesity (Lee *et al.*, 2018). Higher level of natrium can lead to increasing the volume of extracellular water, which is associated with weight gain. A possible mechanism to explain these positive associations is that natrium intake may induce lipogenesis and insulin-stimulated glucose uptake. High natrium intake also stimulates leptin production and the white adipose tissue mass (Cai, Huang and He, 2022). Previous study also found that high natrium diet may contribute to increasing fasting ghrelin. Ghrelin and leptin have been identified as appetite and fat deposition regulators. Those studies showed that natrium might alter body fat metabolism, thus natrium may contribute to obesity.

Another plausible mechanism was dietary natrium intake causes thirst, which might lead to increased consumption both of sugar-sweetened beverage and total fluid (Zhu *et al.*, 2021; Lee *et al.*, 2023). Those mechanisms, in turn, may enhance development of hypertension in adolescents. Similar with this study's finding, beside high natrium intake, sugar-sweetened beverages (carbonated drink, canned coffee/tea) were also frequently recorded in the food record questionnaire. Sugar-sweetened beverages contain high simple sugar, including fructose. Fructose metabolism leads to increasing serum uric acid (Farhangi, Nikniaz and Khodarahmi, 2020). Hyperuricemia is mainly correlated with nicotinamide adenine dinucleotide phosphate (NADPH) oxidase stimulation, which increases oxidative stress in vascular smooth muscle (Parvanova *et al.*, 2024). High-sugar consumption also stimulates salt absorption in the small intestine and renal, thus it contributes to progression of high blood pressure.

Lastly, another significant result found in the current study was that sleep duration negatively related with pre-metabolic syndrome. Sufficient duration of sleep (8 ± 0.9 hours/day) was observed in non-pre-metabolic syndrome compared with pre-metabolic syndrome group (5.2 ± 1.3 hours/day). This finding is consistent with previous study explanation that better sleep duration has negative correlation with body mass index, waist circumference, and hip circumference (Muhammad *et al.*, 2020). Shorter sleep duration also significantly increased relative risk of metabolic syndrome as much as 1.15 fold greater (Che *et al.*, 2021). A theory was proposed that sleep deprivation or late bedtime might involve behavioral factors, such as less physical activity, enhanced screen time/electronic device usage, and night eating syndrome in adolescents (Liu *et al.*, 2021).

Based on previous study, less physical activity contributes to negative energy balance and significantly increases risk of higher waist circumference and metabolic disorders (Harraqui *et al.*, 2023). Enhancing screen time/electronic device usage contributes to increasing blue-green light at night. These exposures decrease melatonin level, therefore contributing to metabolic dysregulation. Longer screen time is also associated with reduced time spent outside, thus affecting to decrease sunlight exposure which can impact circadian alignment (Chaput *et al.*, 2023). Night eating syndrome in adolescents is related with higher fat intake and lower fruits-vegetables intake in adolescents (Farhangi, 2019). Beside those sleep deprivation induced obesity mechanisms, shorter sleep duration is also associated with imbalance of melatonin and ghrelin hormones, which contributes to dysregulation of appetite and hunger (de Oliveira *et al.*, 2023). Thus, that mechanism may cause metabolic syndrome in adolescents.

All relationships between lifestyle factor and metabolic syndrome are mainly related with hormonal disturbance. Higher intake of energy, carbohydrate, fat, and natrium may stimulate dysregulation of leptin and ghrelin hormones due to accumulation of adipose tissue. Impaired leptin signaling pathways may alter hunger and satiety signaling, thus it may affect appetite and food intake (Yeung and Tadi, 2023). Ghrelin hormones, known as hunger hormone, have a role in stimulating appetite, regulating sleep-wake pattern, and metabolism. Previous study showed that people with overweight or obesity suffered from leptin resistance (higher level of leptin in serum), thus it resulted in significantly higher leptin/ghrelin ratio (Adamska-Patruno *et al.,* 2018). Both circulating ghrelin and leptin also have impact on energy balance regulation. Lower leptin and higher ghrelin was found in respondents with low resting metabolic rate compared with normal resting metabolic rate (Hajishizari *et al.*, 2022). Similar mechanism was also found in sleep deprivation. Increasing leptin levels lead to induced gluconeogenesis, thus it may affect to insulin resistance and type 2 diabetes mellitus. Inversely, lower level of ghrelin may affect to impaired fat utilization which stimulates adiposity, reduced insulin sensitivity, and dysregulation of blood pressure (Mohamed, Hassanien and Abokhosheim, 2014; Sitar-Tăut *et al.*, 2021). Those mechanisms lead to type 2 diabetes and cardiovascular disease development.

In this study, pre-metabolic syndrome was classified based on waist circumference as indicator of abdominal obesity and blood pressure as indicator of hypertension. As stated above (Table 1), the majority of respondents were classified as pre-metabolic syndrome due to their abdominal obesity (elevated waist circumference). Abdominal or visceral fat was considered as a main pool of white adipose tissue. White adipose tissue is known as passive depot for energy storage and can secrete a variety of pro-inflammatory substances such as tumor-necrosis-factor α (TNF- α), and interleukin-6 (IL-6) (Shoelson, Herrero and Naaz, 2007; Parvanova *et al.*, 2024). Thus, in line with previous study, increased abdominal fat was associated with increasing risk of cardiometabolic risk, including elevating blood pressure. Excessive fat induces sympathetic nervous system (SNS) overactivation, renin-angiotensin-aldosterone (RAA) system stimulation, change in adipose cytokines, and functional renal change (Shariq and McKenzie, 2020; El Meouchy *et al.*, 2022). Obesity also leads to structurally disturbance in endothelial tissue and flow-induced vasoconstriction.

Several limitations in this study were a) causal effect between variables could not explained due to cross-sectional design; b) considered its calculating procedure, modified IPAQ tends to result in higher score of physical activity; c) this study also did not observe intake of sugar/glucose, which may affect pre-metabolic syndrome in adolescents. However, this study has considered various lifestyle and dietary factors which might be related to pre-metabolic syndrome in teenagers. Moreover, even with a small number of respondents, interesting relationships between fat intake, natrium intake, sleep duration, and pre-metabolic syndrome have been found in this study. Further research is needed with larger sample size to assess other variables, mainly nutrient intake, and its relationship with metabolic syndrome in adolescents.

CONCLUSIONS

This study concludes that fat intake, natrium intake, and sleep duration statistically associate with pre-metabolic syndrome in adolescents. Therefore, dietary and education intervention for adolescents are required to improve their food preference and lifestyle as an obesity preventive program.

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