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Associations between body fat percentage, waist-to-hip ratio, physical activity, and elevated blood pressure among junior high school adolescents in Jakarta

Hubungan persen lemak tubuh, rasio lingkar pinggang-panggul, aktivitas fisik, dan peningkatan tekanan darah pada remaja SMP di Jakarta

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Abstract

Elevated blood pressure affects approximately three out of ten Indonesian adolescents aged ≥15 years, increasing their risk of adult hypertension. Adiposity indicators, including Waist-to-Hip Ratio (WHR) and body fat percentage (BF%), are biologically linked to insulin resistance, while high fat intake may increase vascular resistance. However, evidence regarding adolescents in metropolitan settings, such as Jakarta, remains limited. This study examined the associations between fat intake, WHR, BF%, physical activity, and elevated blood pressure among adolescents. A cross-sectional study was conducted among 219 ninth-grade students at State Junior High School 182 Jakarta, selected using stratified random sampling. Blood pressure was categorized as normal (<120/80 mmHg) or elevated (≥120/80 mmHg). Data were collected through interviews and completion of the SQ-FFQ, PAQ-C/PAQ-A, anthropometric measurements, and Bioelectrical Impedance Analysis. Ethical approval was obtained (No. 037/KEPK/UNPRI/V/2025). Chi-Square analysis revealed that abdominal obesity (WHR) and high BF% were significantly associated with elevated blood pressure (p=0,017 and p<0,001), whereas fat intake (p=0,132) and physical activity (p=0,694) were not. Multivariate logistic regression identified BF% as the strongest determinant (p<0,001; OR=7,393; 95% CI=3,748-14,581) of elevated blood pressure. In conclusion, adiposity, particularly an elevated BF%, is a key driver of elevated blood pressure in urban adolescents, underscoring the need for early obesity-focused interventions.

Keywords: Elevated blood pressure, adolescent health, body fat percentage, Waist-to-Hip Ratio, obesity

Abstrak

Sekitar 3 dari 10 remaja di Indonesia yang berusia ≥15 tahun memiliki tekanan darah yang meningkat, sehingga memperbesar risiko remaja mengalami hipertensi di masa dewasa. Indikator adipositas, seperti Rasio Lingkar Pinggang-Panggul (RLPP) dan persentase lemak tubuh, berhubungan secara biologis dengan resistensi insulin, sementara asupan lemak tinggi berpotensi meningkatkan resistensi vaskular. Namun, bukti pada remaja di wilayah metropolitan seperti Jakarta masih terbatas. Penelitian ini bertujuan menganalisis hubungan antara asupan lemak, RLPP, persen lemak tubuh, aktivitas fisik, dan peningkatan tekanan darah pada remaja. Penelitian *cross-sectional* dilakukan pada 219 siswa kelas IX SMP Negeri 182 Jakarta yang dipilih melalui *stratified random sampling*. Tekanan darah diklasifikasikan sebagai normal (<120/80 mmHg) dan meningkat (≥120/80 mmHg). Data dikumpulkan melalui wawancara SQ-FFQ, PAQ-C/PAQ-A, pengukuran antropometri, dan pengukuran dengan *Bioelectrical Impedance Analysis*. Telah

diperoleh persetujuan etik (No. 037/KEPK/UNPRI/V/2025). Analisis *Chi-Square* menunjukkan bahwa obesitas abdominal (RLPP) dan persen lemak tubuh yang tinggi berhubungan signifikan dengan peningkatan tekanan darah (p=0,017 dan p<0,001), sedangkan asupan lemak dan aktivitas fisik tidak. Regresi logistik multivariat mengidentifikasi persen lemak tubuh sebagai determinan terkuat (p<0,001; OR=7,393; 95% CI=3,748-14,581). Kesimpulan, adipositas, khususnya persen lemak tubuh yang tinggi, merupakan factor utama peningkatan tekanan darah remaja perkotaan dan memerlukan intervensi dini berbasis pencegahan obesitas.

Kata Kunci: Peningkatan tekanan darah, kesehatan remaja, persen lemak tubuh, Rasio Lingkar Pinggang-Panggul, obesitas

Introduction

Hypertension, a leading non-communicable disease (NCDs), remains a serious health concern globally and nationally. Risk factors for hypertension begin to accumulate early in life, making adolescence a crucial stage for blood pressure regulation (Neves et al., 2021). The 2023 Indonesian Health Survey (SKI) reports that 29,2% of Indonesians aged ≥ 15 years had hypertension (Kementerian Kesehatan RI, 2023). This prevalence is substantially higher than that reported in other Southeast Asian countries, such as Thailand (9,4%) and Malaysia, where a study in Kuala Lumpur reported 4,7% of adolescents had hypertension (Pirojsakul et al., 2022; Poh et al., 2022). The SKI survey also documented a hypertension prevalence of 29,5% among Jakarta residents in the same age group, ranking Jakarta as the seventh-highest province in Indonesia based on measured blood pressure (Kementerian Kesehatan RI, 2023). Longitudinal research indicates that individuals with hypertension in adulthood often exhibit elevated blood pressure during childhood and adolescence (Azegami et al., 2021). Globally, the prevalence of hypertension in 2015 peaked at 7,89% among adolescents aged 14 years, which was higher than the prevalence observed at the age of 6 (4,32%) and 19 (3,28%) years (Song et al., 2019). This finding indicates that mid-pubertal adolescents have a higher prevalence of elevated blood pressure than those in early or late puberty, underscoring the importance of early identification and management of blood pressure in this age group. The lack of appropriate lifestyle changes at an early stage places adolescents with elevated blood pressure at a greater risk of developing chronic conditions, including diabetes mellitus, renal failure, and cardiovascular diseases, later in life (Qurbo, 2024).

Hypertension development is markedly influenced by adverse lifestyle patterns, including high-fat dietary intake, abdominal obesity, and physical inactivity. Intake of foods with high total fat content has been shown to increase the risk of cardiovascular disease, including hypertension, as demonstrated in a study of children and adolescents aged 8-17 years in the United States (Maffeis et al., 2021; Li et al., 2023). Similarly, research in Semarang found that 71,4% of hypertensive adolescents aged 13–18 years consumed excessive dietary fat (Qurbo, 2024). These findings indicate a significant contribution of dietary fat intake to blood pressure regulation among adolescents. An observational study in South Jakarta found that adolescents had the highest fat intake (61,2 g/person/day) compared with children and adults, with the largest contributions coming from street foods, restaurants, and fast food (Andarwulan et al., 2021). High-fat consumption also contributes to visceral fat accumulation, which is a key contributor to obesity (Sukmawati & Sarbini, 2024).

Numerous studies have identified obesity as a major contributor to elevated blood pressure. In 2023, Jakarta ranked third among Indonesia's 38 provinces for adolescent overweight prevalence, at 16,5% among those aged 13-15 years and 14,4% among those aged 16-18 years (Kementerian Kesehatan RI, 2023). The Waist-to-Hip Ratio (WHR) is a widely used anthropometric indicator for assessing abdominal obesity and is considered effective in detecting visceral fat associated with hypertension (Widjaja et al., 2023; Rusydi et al., 2024). A study conducted in Malaysia found that WHR was significantly and positively associated with adolescents' blood pressure, indicating that individuals with greater WHR values may have a heightened likelihood of developing hypertension (Poh et al., 2022; Kusuma et al.,

2021). In addition to WHR, Body Fat Percentage serves as another important indicator for evaluating adiposity and its link to elevated blood pressure.

A high Body Fat Percentage (BF%) can contribute to increased systolic and diastolic blood pressure in children and adolescents, as excess body fat is believed to reflect the presence of insulin resistance, which elevates blood pressure through systemic vascular resistance due to various mechanisms, such as altered calcium transport, sympathetic nervous system activation, and increased sodium retention (M. Chen et al., 2021). A cohort study among Brazilian children and adolescents found that BF% was positively correlated with both systolic and diastolic blood pressure. The study also reported that adolescents with a high BF% had a 2,49-fold greater probability of developing hypertension within three years (Welser et al., 2023; Brand et al., 2022).

High adiposity is often a consequence of physical inactivity, which can disrupt blood pressure regulation and elevate the likelihood of hypertensive outcomes. National data show a rising trend in physical inactivity among Indonesians, increasing from 26,1% in 2013 to 33,5% in 2018 and reaching 37,4% in 2023 (Kementerian Kesehatan RI, 2023). A study in Surabaya found that 29,6% of adolescents aged 15–17 years with low physical activity levels had elevated blood pressure. This finding demonstrates that inadequate physical activity is related to greater severity of hypertension (Kusparlina, 2022). In parallel, research involving adolescents in Canada reported that engaging in any physical activity more intense than light provides a protective effect against the development of hypertension (Wellman et al., 2020).

Located in South Jakarta, State Junior High School 182 Jakarta demonstrated a relatively high prevalence of elevated blood pressure (26,6%) among students based on a preliminary study. The widespread availability of street food around schools may increase students' exposure to high-fat diets and obesity. Moreover, studies examining blood pressure among adolescents in Jakarta, particularly those analyzing adiposity indicators (fat intake, WHR, and BF%) using multivariate approaches, are still limited, with most research focusing on older adults and sodium intake. Therefore, this study aimed to analyze and confirm the relationship between fat intake, WHR, BF%, and physical activity with elevated blood pressure among adolescents at SJHS 182 Jakarta and to examine the proportion of adolescents with elevated blood pressure in Jakarta.

Methods

This quantitative cross-sectional study was conducted at State Junior High School 182 Jakarta between January and July 2025, with a preliminary study in January, main data collection in May, and data analysis completed in July 2025. The study population consisted of ninth-grade students in South Korea. The inclusion criteria required participants to be aged ≥ 13 years. Participants with underlying medical conditions, including a history of congenital cardiovascular disease, type 1 diabetes mellitus, and/or renal disorders requiring antihypertensive medication were excluded from the study. The sample size was determined using the Lemeshow formula for a two-proportion difference hypothesis, which yielded a minimum sample size requirement of 214 respondents. Participants were selected using a stratified random sampling technique based on class distribution. In this study, fat intake, Waist-to-Hip Ratio (WHR), body fat percentage (BF%), and physical activity level were designated as independent variables, whereas elevated blood pressure was designated as the dependent variable. Although the cross-sectional design enables the evaluation of relationships among these variables at a single time point, it is important to note that this design precludes the ability to infer causal relationships.

Blood pressure data were obtained using a digital sphygmomanometer. Measurements were recorded three times consecutively on each participant's right arm, separated by one-minute rest periods to enhance the reliability of the measurements. The means of the second and third readings were subsequently used for analysis. Blood pressure was classified according to the American Academy of Pediatrics guidelines (Flynn et al., 2017) but was simplified into two categories: normal (<120/80 mmHg) and elevated (≥120/80 mmHg).

Dietary fat intake data were collected through interviews using a validated Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) that has been shown to be reliable (r=0,15–

0,60, Cronbach's Alpha=0,715). The SQ-FFQ assessed the participants' daily fat intake over the past month, with the food fat content estimated using the 2020 Indonesian Food Composition Table. As the SQ-FFQ relies on the memory of the respondents, potential recall bias should be acknowledged. The average daily fat intake was compared with the Indonesian Recommended Dietary Allowance (RDA), adjusted for age and sex. Fat intake was classified as adequate (≤110% of the RDA) or excessive (>110% of the RDA) (Daniartama et al., 2021). Waist circumference was assessed using a flexible tape placed at the midpoint between the lower edge of the last palpable rib and the upper margin of the iliac crest, whereas hip circumference was recorded at the point of the greatest prominence of the buttocks (Daniartama et al., 2021). WHR was calculated by dividing the waist circumference by the hip circumference. A WHR cut-off value ≥0,891 (sensitivity 47,1% and specificity 35,6%) has been shown to predict metabolic syndrome in Indonesian adolescents, including elevated blood pressure (Widjaja et al., 2023). Therefore, this study classified adolescents with WHR ≥0,891 as exhibiting abdominal obesity, while those with WHR <0,891 were identified as not presenting abdominal obesity. BF% was measured using a Bioelectrical Impedance Analysis (BIA) device. Although BIA is a noninvasive and practical method for assessing body composition in adolescents, its accuracy may be influenced by hydration status and menstrual cycle-related fluctuations that affect total body water and electrical conductivity. Nevertheless, standardized cut-offs were applied to classify participants as having normal BF% (<19% for males and <26% for females) or high BF% (≥19% for males and ≥26% for females), indicating an increased level of adiposity (Lisnawati et al., 2023).

Physical activity was assessed using the Physical Activity Questionnaire for Older Children (PAQ-C) and adolescents (PAQ-A). Participants aged 8-14 years completed the PAQ-C, while those aged 15-20 years completed the PAQ-A. The mean of the final score was used to classify participants into low (≤2,0), moderate (2,1–3,9), or high (>3,9) physical activity levels (Haryadi et al., 2023). Statistical processing of the dataset was performed using IBM SPSS Statistics version 25. Analytical procedures included univariate analysis for descriptive evaluations, bivariate analysis using the chi-square test, and multivariate analysis using multiple logistic regression. Ethical clearance for this research was granted by the Health Research Ethics Committee of Universitas Prima Indonesia (No. 037/KEPK/UNPRI/V/2025).

Result and Discussion

Table 1 presents the descriptive profiles of the participants' characteristics, as well as the distribution of fat intake, WHR, BF%, and physical activity levels. A total of 227 students met the inclusion criteria and participated in the study; however, eight were excluded due to incomplete data. As a result, 219 ninth-grade students were included in the final analysis, predominantly females (56,6%) and mostly aged 15 years (74,9%).

Most participants (75,8%) were exposed to cigarette smoke, either through active or passive smoking, with passive exposure originating from the household or external environments. Similar findings were reported by Pratiwi and Yuliwati (2022), where 56,7% of adolescents smoked and 53% had parents who smoked. According to the Global Youth Tobacco Survey (WHO, 2019), 19,2% of Indonesian adolescents aged 13–15 years were active smokers and 40,6% reporting prior smoking experience, with household exposure increasing from 57,3% in 2014 to 57,8% in 2019. Prolonged exposure to tobacco smoke is a contributing factor to the development of hypertension (Siregar et al., 2020). This is supported by a study in the United States showing that children and adolescents exposed to tobacco, either passively or actively, had a 1,31-fold higher risk of elevated blood pressure (p=0,01; 95% CI=1,06–1,61) compared with their unexposed peers (Levy et al., 2021).

Approximately two-thirds of the participants (67,6%) reported receiving a high daily allowance, defined as ≥Rp20.000 based on the median value. Research conducted by Rahman et al. (2021) discovered that nearly half of the high school students in Jakarta spent their allowance on snacks and transportation fees. A higher daily allowance is assumed to provide greater purchasing freedom, potentially increasing snack consumption and influencing adolescents' overall dietary patterns (J. Rahman et al., 2021).

Table 1. Frequency distribution of participants' characteristics, fat intake, WHR, BF% and physical activity level (n=219)

Characteristics & Variables	n	%	Mean ± SD	Median
Age (years)				
14	16	7,3		
15	164	74,9	15,11 ± 0,504	15,0
16	38	17,4		
17	1	0,5		
Sex				
Female	124	56,6	-	-
Male	95	43,4		
Exposure to cigarette smoke				
Not exposed	53	24,2	-	-
Exposed	166	75,8		
Allowance money (Rp)				
Low	71	32,4	22.054 ± 11616,8	20.000,0
High	148	67,6		
Elevated blood pressure (mmHg)				
Normal	156	71,2	110,8 ± 11,99* 70,88 ± 8,14**	110,5* 71,0**
Elevated	63	28,8		
Fat intake (g)				
Adequate	160	73,1	72,76 ± 69,75	50,89
Excessive	59	26,9		
WHR (cm)				
Non-abdominal obesity	196	89,5	0,82 ± 0,61	0,81
Abdominal obesity	23	10,5		
BF%				
Normal	139	63,5	24,66 ± 29,56	22,0
High	80	36,5		
Physical activity				
Low	79	36,1	-	-
Moderate	139	63,5		
High	1	0,5		

*systolic blood pressure, **diastolic blood pressure

As presented in Table 1, most participants had normal blood pressure (71,2%), while a notable percentage (28,8%) were classified as having elevated blood pressure. Similar findings were reported by Erlena and Cahyaningsih (2022), who found a greater proportion of students with normal blood pressure (67,3%) than those with hypertension (32,7%). A contrasting pattern was observed in Semarang, where Qurbo et al.(2024) reported a higher proportion of adolescents aged 13–18 years presenting with hypertension (64%). Elevated blood pressure at a young age may increase the likelihood of developing hypertension and cardiovascular diseases in subsequent stages of life (Wellman et al., 2020). The majority of participants had an adequate fat intake (73,1%), while fewer reported excessive fat consumption. Consistent results were observed by Sukmawati and Sarbini (2024), who reported that a higher proportion of adolescents had a good level of fat intake (55,3%) compared to those with poor intake (44,6%).

WHR measurement in this study showed that most of the students (89,5%) did not exhibit abdominal obesity. A similar pattern was reported by Ilmi and Utari (2020), who found that 53,6% of university students were categorized as non-obese and 46,4% as obese based on WHR assessment. An elevated WHR is widely recognized as a marker of increased adipose tissue distribution in the upper body region, reflecting a higher risk of abdominal fat accumulation (Angesti, 2020). Consistent with the WHR findings, the majority of participants had a normal BF% (63,5%), while 36,5% were classified as having a high BF%. Similar results were reported by Rahman et al. (2021), who

found that most students (72%) had normal BF compared to 28% with excess BF. Elevated total fat mass and percentage among children and adolescents have been associated with obesity and metabolic disorders (F.et al.. Chen et al., 2019). Additionally, a substantial proportion of participants reported engaging in physical activity at a moderate level (63,5%). Physical activity is an essential component in promoting overall physiological fitness, preventing bone density loss, and mitigating anxiety and psychological stress (Wahyudi & Albary, 2021).

The Relationship between Fat Intake with Elevated Blood Pressure

In the present study, no significant relationship was observed between dietary fat intake and elevated blood pressure within the adolescent population at State Junior High School 182 Jakarta, as indicated by the results of the chi-square test (p≥0,05) showed in Table 2. This result aligns with the observations reported by Ekaningrum (2021), who similarly found that fat consumption did not exhibit a statistically meaningful association with hypertension (p=0,323). However, contrasting evidence was observed in studies by Salsabila et al. (2023), who reported significant associations linking fat intake with elevations in both systolic (p=0,016) and diastolic (p=0,047) blood pressure, and by Pherenis et al. (2023), who found that fat consumption was significantly associated with the occurrence of hypertension (p<0,001).

Excessive intake of fats, especially saturated fats, has been shown to elevate low-density lipoprotein (LDL) cholesterol levels, thereby promoting atherosclerotic plaque formation, reducing blood flow, and increasing vascular resistance, which collectively contribute to elevated blood pressure (Ekaningrum, 2021; Salsabila et al., 2023). The absence of an association between fat intake and elevated blood pressure in this study may be attributed to the fact that most participants consumed fat within the recommended levels, and even those with higher intake generally maintained normal blood pressure. This suggests that fat intake does not exert an immediate effect on adolescent blood pressure, as its impact on the cardiovascular system typically requires long-term exposure to manifest clinically. Moreover, fat intake does not reflect circulating lipid levels, which may be more directly related to blood pressure, and approximately 5% of ingested fat remains unabsorbed in the intestinal lumen (Michalski et al., 2021). Therefore, elevated blood pressure is more likely to be associated with the cumulative effects of long-term diet and lifestyle, such as adiposity accumulation captured by anthropometric measurements, rather than short-term fat intake.

Table 2. Chi-Square test of fat intake, WHR, BF%, and physical activity with elevated blood pressure

Variable	Elevated Blood Pressure				Total		p-value
	Normal		Elevated				
	N	%	n	%	n	%	
Fat intake							
Adequate	109	49,8	51	23,3	160	73,1	0,132
Excessive	47	21,5	12	5,5	59	26,9	
Waist-to-Hip Ratio (WHR)							
Non-abdominal obesity	145	66,2	51	23,3	196	89,5	0,017
Abdominal obesity	11	5,0	12	5,5	23	10,5	
Body fat percentage (BF%)							
Normal	118	53,9	21	9,6	139	63,5	<0,001
High	38	17,4	42	19,2	80	36,5	
Physical activity							
Low	58	26,5	21	9,6	79	36,1	0,694
Moderate	97	44,3	42	19,2	139	63,5	
High	1	0,5	0	0,0	1	0,5	

The Relationship between Waist-to-Hip Ratio with Elevated Blood Pressure

Table 2 demonstrates a significant correlation between WHR and elevated blood pressure among adolescents (p=0,017; <0,05). This result aligns with the research conducted by Poh et al. (2022) on Malaysian adolescents aged 10–16 years, which reported a moderate correlation

between WHR and systolic blood pressure (p<0,001). Comparable results were also observed by Kusuma et al. (2021), who indicated a significant relationship (p<0,001) between WHR and hypertension in both sexes, and by Rusydi et al. (2024), who identified a significant correlation (p<0,001) between WHR and blood pressure levels. The prevalence of elevated blood pressure was 52,1% (12 out of 23) in adolescents with abdominal obesity, compared with 26,0% (51 out of 196) in those without abdominal obesity, yielding a prevalence ratio (PR) of 2,0. This indicates that adolescents with abdominal obesity had a twofold higher prevalence of elevated blood pressure than their nonabdominally obese peers.

Excess fat accumulation in the abdominal region may reduce insulin sensitivity, as adipose tissue releases higher levels of free fatty acids into circulation through lipolysis (Sukmawati & Sarbini, 2024). This process can trigger the secretion of pro-inflammatory cytokines, such as TNF-α and IL-6, leading to systemic inflammation and subsequent insulin resistance (Rusydi et al., 2024; Sukmawati & Sarbini, 2024). Insulin resistance impairs the vasodilatory function of insulin, promotes vasoconstriction, and contributes to endothelial dysfunction, thereby diminishing vascular responsiveness to hemodynamic demands and disrupting the balance of vascular tone (Rusydi et al., 2024). In addition, the accumulation of adipose cells in the abdominal region enhances angiotensinogen production and local renin-angiotensin system activity, which further amplifies its systemic effects and contributes to elevated blood pressure (Angesti, 2020).

The Relationship between Body Fat Percentage with Elevated Blood Pressure

The present study found that adolescents with higher body fat percentages tended to have higher blood pressure levels. Statistical analysis using the chi-square test in Table 2 demonstrated that body fat percentage was significantly associated with elevated blood pressure in adolescents (p<0,001). The current result supports prior research conducted among high school adolescents by Angesti (2020), which reported a statistically meaningful association between body fat percentage and systolic blood pressure with p-value = 0,016. Similarly, Chen et al. (2021) observed that adolescents with higher body fat percentages had significantly greater systolic and diastolic blood pressure (p<0,05). Supporting evidence was also provided by Kusuma et al. (2021), who identified a significant association (p<0,001) between body fat percentage and the degree of hypertension in both male and female participants.

Research conducted in Korea reported that the risk of hypertension increased significantly with higher BF%, even among individuals with a normal Body Mass Index (BMI), highlighting BF% as an important indicator of hypertension risk independent of weight status (Park et al., 2019). Excess adiposity, as reflected by a high body fat percentage, is a key determinant of the onset and progression of hypertension across different stages of life. This occurs through complex metabolic, hemodynamic, and inflammatory mechanisms that may contribute to cardiovascular complications, such as left ventricular hypertrophy (Brand et al., 2022). Elevated leptin levels in obese individuals can trigger afferent signaling to the central nervous system, activating the sympathetic nervous system via melanocortin release. The interaction of melanocortin with melanocortin-4 receptors (MCR4) promotes sympathetic nerve activity, leading to increased norepinephrine secretion, vasoconstriction, and stimulation of the renin-angiotensin system, which collectively contribute to the elevation of blood pressure (Litwin, 2024; Scheen, 2019).

The Relationship between Physical Activity with Elevated Blood Pressure

This study found no association between physical activity levels and elevated blood pressure among adolescents, as reflected in the chi-square analysis results in Table 2 (p≥0,05). This finding aligns with Malik and Syahrul (2022), who also reported an absence of a statistical correlation between physical activity levels and blood pressure in adolescents (p=1,00). In contrast, Kusparlina (2022) observed an association with a negative pattern, indicating that lower physical activity levels were correlated with higher degrees of hypertension (p=0,047). Similarly, Saputri et al. (2021) found a strong statistical association (p<0,001) between physical activity and hypertension among adolescents.

Engaging in regular physical activity contributes to improved smooth muscle

strength, enhanced cardiac output, stronger and more consistent heart contractions, and greater vascular elasticity (Wahyudi & Albary, 2021). Consistent exercise also increases parasympathetic nerve activity, promoting vasodilation and lowering vascular pressure, which helps prevent hypertension (Saputri et al., 2021). Moreover, regular physical activity facilitates sodium excretion through sweat, thereby reducing blood sodium levels and peripheral resistance, leading to lower blood pressure (Rosdiana & Elizar, 2022). Increasing weekly physical activity from 30 to 120 min has been shown to reduce the risk of hypertension by 20–60% compared to inactivity (Wellman et al., 2020). Conversely, adolescents with low physical activity and sedentary habits experience decreased energy expenditure, especially when combined with excessive calorie intake, promoting fat accumulation (Kusparlina, 2022).

Although regular physical activity is theoretically associated with increased parasympathetic activity and vasodilation through improved vascular elasticity, the findings of this study suggest that other factors are more influential in this population. Adiposity, reflected by BF%, may promote insulin resistance and sympathetic nervous system activation via the leptin-melanocortin pathway, exerting a stronger and more direct effect on systemic vascular resistance than the protective effects of physical activity. Moreover, the PAQ-C and PAQ-A assess physical activity over the preceding seven days only, limiting the evaluation of long-term habitual activity, which is thought to contribute to lower blood pressure.

The Most Influential Determinant of Elevated Blood Pressure

Table 3. Final model of multivariate analysis of factors associated with elevated blood pressure

Variable	p-value	OR	95% CI	
			Lower	Upper
Body fat percentage (BF%)	<0,001	7,393	3,748	14,581
Sex	0,003	2,761	1,401	5,443

Multivariate analysis using multiple logistic regression only included variables with p-value <0,25 from the bivariate analysis, including fat intake, WHR, BF%, and sex. Following variable elimination, the final model retained BF% and sex as variables. The results demonstrated a significant association between BF% and elevated blood pressure, with this variable exhibiting the highest odds ratio among all predictors (p<0,001; OR=7,393; 95% CI=3,748-14,581). These findings indicate that BF% is the most influential determinant of elevated blood pressure among adolescents at State Junior High School 182 Jakarta. Adolescents with increased BF% exhibited a 7,3 times higher risk of experiencing elevated blood pressure relative to peers with normal BF%. Consistent evidence was also reported by Ningrum et al. (2019) in Purbalingga, where BF% emerged as the primary determinant correlated with hypertension, and those categorized as obese exhibited a 5,8-fold greater likelihood of developing the condition.

The multivariate analysis further indicated that male adolescents were 2,7 times more likely to exhibit elevated blood pressure than females. This result is consistent with physiological evidence indicating that systolic blood pressure in males aged 13-15 years is approximately 4 mmHg higher than that in females, with the gap widening to 10-14 mmHg by ages 16-17. Such variations are often attributed to differences in body size and hemodynamic function, as women generally have smaller body dimensions and lower arterial flow rates, leading to lower blood pressure levels (Kusparlina, 2022). Consistently, Li et al. (2020) reported that men with higher BF% had a 3,3-fold higher probability of developing hypertension, whereas the risk among women was only 2,66 times higher. These findings support the results of the present study, indicating that BF%, when adjusted for sex, serves as a pivotal factor in the elevation of adolescents' blood pressure.

This study demonstrated notable strength through its relatively large sample size, which enhanced the representativeness of the target population. However, certain limitations of this study should be acknowledged. The analysis did not account for other potential determinants of elevated blood pressure among adolescents, such as growth acceleration and hormonal changes that are commonly observed during puberty. Moreover, the study was limited to ninth-grade students at State Junior High School 182 Jakarta, which may have restricted the variability in age and overall distribution of the study data.

Conclusion

This study successfully achieved its objective by examining and confirming the associations between fat intake, WHR, BF%, physical activity, and elevated blood pressure in urban adolescents in Jakarta. The findings of this study indicate that adiposity, particularly body fat percentage and Waist-to-Hip Ratio, plays a crucial role in the development of elevated blood pressure among adolescents at State Junior High School 182 Jakarta. Among the examined variables, body fat percentage emerged as the most influential determinant, indicating that higher adiposity substantially increases the risk of elevated blood pressure in adolescents. The analysis also revealed that male adolescents were 2,7 times more likely to develop elevated blood pressure than their female counterparts. Conversely, fat intake and physical activity were not significantly associated with the blood pressure status.

These results underscore the importance of early monitoring and management of obesity and body fat accumulation as part of school-based and community-level strategies to prevent adolescent hypertension and other cardiovascular risks, as well as their development in adulthood. Schools may incorporate routine anthropometric and body composition screening, including periodic BF% assessment, into annual health examinations conducted by trained health personnel. At the community level, collaboration with primary health centers can support follow-up monitoring, individualized counseling for at-risk adolescents, and parental education to reinforce healthy behavior at home. Collectively, such coordinated interventions may reduce the long-term burden of hypertension and cardiovascular diseases, beginning in adolescence.

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