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Factors associated with blood pressure and nutritional status among adolescents: a cross-sectional study

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ABSTRACT

Introduction: The association between obesity and hypertension in adolescents necessitates the identification of potential predictors at an early stage. This study aimed to examine the association of sex and place of residence with nutritional status and blood pressure in adolescents aged 10-18 years.

Methods: A sample of 198 subjects aged 10-18 years was included in this study. Data on demographic characteristics were collected using a structured questionnaire, whereas nutritional status and blood pressure were measured using standardized measures. Statistical analyses, including the independent t-test, Pearson and Spearman correlation test, and linear regression, were conducted to identify potential risk factors, with statistical significance set at $p < 0.05$.

Results: The study revealed a high prevalence of overweight-obesity (24.7%) and hypertension (11.1%) among the subjects. Significant correlations were observed between body weight, height, age, and blood pressure ($p < 0.05$). Boys exhibited higher mean body height and Systolic Blood Pressure (SBP) than girls. Nutritional status was positively associated with Body Mass Index (BMI) and blood pressure, with nutritional status emerging as the primary predictor in both private houses and boarding schools ($p < 0.05$). Furthermore, age at menarche was found to be a predictor of blood pressure in boys, whereas age was a predictor in girls.

Conclusions: BMI predicts nutritional status and blood pressure, whereas age and menarche age are crucial factors that depend on sex. Based on these findings, it is critical to manage obesity and hypertension by considering characteristics such as nutritional status, sex, and age.

Keywords: adolescents, blood pressure, good health and well-being, nutritional status

Introduction

Adolescence plays an essential role in connecting children's health to adult well-being. This transitional phase introduce challenges, including emotional, health, and health-related behavioral concerns, with potential long-term impact on an individual's life (Best & Ban, 2021). The World Health Organization (WHO) has reported that adolescents contribute to 30% of preventable morbidity and mortality due to noncommunicable diseases (NCDs) (WHO, 2022), causing 38 million of 57 million deaths annually (Dick & Ferguson, 2015). Despite these statistics, adolescents remain largely overlooked in global NCD burdens, especially in low- and middle-income countries (LMICs) (Akseer *et al.*, 2020).

Extensive research has attested to the pivotal role of adolescence as a formative period for health outcomes. Notably, risk factors such as unhealthy diet, obesity, high blood pressure, and tobacco use significantly contribute to premature mortality and suboptimal adult health (Institute of Medicine and National Research Council, 2015). Research involving over two hundred thousand subjects reveals that 80% of obese adolescents face a persistent risk of retaining obesity into adulthood, with nearly 70% remaining obese over three decades (Simmonds *et al.*, 2016). Effective prevention of obesity and hypertension requires consideration of both lifestyle and inherent individual characteristics. Sex is one such variable associated with obesity and hypertension. Sex differences manifest in the regulation of key biomarkers, such as leptin, which signifies uncontrolled eating in overweight and obesity, and adiponectin, which is inversely linked to body fat mass and visceral adiposity (Benbaibeche, Bounihi, & Koceir, 2021). A study in China also underscores that hypertension in adolescence is primarily determined by sex, age, and body mass index (BMI) (Zhao, Mo, & Pang, 2021). In addition, another study revealed that metabolic syndrome is more prevalent in boys among children and adolescents, whereas it is more common in females among adults (Choi *et al.*, 2021). This highlights the significance of considering both age and sex when devising effective prevention strategies.

Thus, the impact of environmental factors on health is undeniable. A study in Central Poland revealed that socioeconomic conditions, maternal education, and place of residence significantly influenced the occurrence of diet-related diseases (Zadka, Pałkowska-Goździk and Rosołowska-Huszcz, 2019; Astutik *et al.*, 2021). While families generally play a crucial role in shaping children's diets, school food also contributed daily intake among children (Farapti *et al.*, 2019). Furthermore, boarding schools offer unique experiences that impact lifestyles and health outcomes. African studies indicate that boarding students have lower energy adequacy and nutritional status than do non-boarding students (Sunday Ekanah, 2017; Olugbemi *et al.*, 2019). Conversely, in China, boarding students exhibit significantly better nutritional status than their non-boarding counterparts (Wang *et al.*, 2016). In Indonesia, conflicting findings have been reported regarding nutrition knowledge and practices of boarding school students. While some studies indicated poor knowledge and inappropriately balanced nutrition practices (Indriasari *et al.*, 2020), others suggested that students had implemented good nutrition practices, even though the provision of lunch programs and nutrition education was found to improve knowledge, attitude, and practice (Rimbawan *et al.*, 2023). This disparity is attributed not only to consumption patterns, but also to the environment's role in providing appropriate food to adolescents, underscoring the need for a comprehensive analysis of societal factors and their impact on adolescent health.

The interplay of nutritional status, blood pressure, inherent characteristics, and environmental factors in adolescents is a complex and multifaceted issue. Although some studies have been conducted, it is important to thoroughly study how inherent individual characteristics and community factors influence adolescent health, especially in Indonesia. Therefore, this study was conducted to investigate the correlation between sex and place of residence with nutritional status and blood pressure in adolescents aged 10-18 years. Overall, understanding this linkage is crucial for designing interventions addressing individual and environmental factors, leading to evidence-based strategies to reduce noncommunicable disease risk and enhance adolescent well-being.

Materials and Methods

Subjects and Study Design

This was an observational analysis with a cross-sectional study design, conducted from the end of 2020 to 2022 in Surabaya, Indonesia. As many as 198 subjects from 500 populations (aged 10-18 years, both sexes), including those living in private homes and boarding schools, were recruited using the formula proposed by Lemeshow et al. (1990), a well-established method for determining sample sizes in health-related studies. The prevalence of obesity and hypertension among adolescents used in this calculation was 31.3% (Syah *et al.*, 2020) with a desired precision level of 5%. The study was postponed due to the peak of the COVID pandemic in 2021 but continued to recruit subjects directly in 2022. This study used two ethical clearances from the Ethics Committee of the Faculty of Dentistry, Universitas Airlangga, with approval number 409/HRECC. FODM/IX/2020 and 143/EA/KEPK/2022 by the Health Research Ethics Committee of the Faculty of Public Health, Universitas Airlangga. Prior to the study, the teacher and headmaster provided students with informed consent through a clear protocol obtained from both parents and guardians, ensuring that ethical standards were met, and their participation was voluntary.

Anthropometic Measurement

This study examined several independent variables, including age, age at menarche, and place of residence, while the dependent variables were nutritional status and blood pressure. According to the Centers for Disease Control and Prevention, obesity and hypertension in adolescents result from a multifaceted interplay of behavioral, environmental, and genetic factors (CDC, 2018). Age, particularly pubertal age, significantly influences the hormonal profile that governs adolescent growth and maturation (Zhao, Mo and Pang, 2021), while environmental factors such as residence altitude influence optimal growth and development (Zadka, Pałkowska-Goździk and Rosołowska-Huszcz, 2019). Data were collected using a structured questionnaire encompassing demographic information, anthropometric data, and blood pressure. Body weight measurements were acquired by Bioelectrical Impedance Analysis (BIA) using the Karada Scan HBF-375 (OMRON Healthcare Co., Kyoto, Japan), with an accuracy 0.1 kg. Body height was measured using a SECA 213 GEA portable stadiometer (SECA GmbH & Co. KG, Hamburg, Germany) accurate to 0.1 cm and were calibrated by the laboratory staff from the Department of Nutrition at Universitas Airlangga, Indonesia. Body mass index (BMI) was calculated using the WHO AnthroPlus version 1.0.4 as. software to monitor the growth of school-age children and adolescents aged 5-19 years old. Based on age- and sex-specific BMI cut-offs from the Indonesian Ministry of Health in 2020 for ages 5–18 years, subjects were categorized as underweight (-3 SD to <-2 SD), normal (-2 SD to +1 SD), overweight (+1 SD to +2 SD), and obese (>+2 SD) (Indonesian Ministry of Health, 2020).

Blood Pressure Measurement

Blood pressure was measured using an OMRON HEM-7201 digital sphygmomanometer (OMRON Healthcare Co., Kyoto, Japan). Prior to measurements, subjects were instructed to relax for five minutes before initiation of the measurements. The blood pressure was measured twice consecutively, with a two-minute interval between the measurements. If a difference of > 10 mmHg was observed between the first and second measurements, a third measurement was recorded. Blood pressure classifications adhered to the guidelines of the American Academy of Pediatrics (AAP) for children and adolescents, with values categorized as normal (<120/<80 mmHg), pre-hypertension (120/<80 to 129/<80 mmHg), and hypertension (≥130/≥80 mmHg) (Flynn *et al.*, 2017).

Table 1. Characteristics of subjects

Characteristics	Mean ± SD/ n (%)
Sex	
Girl	116 (58.6)
Boy	82 (41.4)
Age (years)	13.08 ± 2.37
Children	61 (30.8)
Early adolescence	77 (38.9)
Late adolescence	60 (30.3)
Puberty (years)	8.15 ± 5.80
Not pubescent	65 (32.8)
Pubescent	133 (67.2)
Place of Residence	
Private house	101 (51.0)
Boarding school	97 (49.0)
Nutritional Status (SD)	0.16 ± 1.38
Underweight	12 (6.1)
Normal	137 (69.2)
Overweight	25 (12.6)
Obese	24 (12.1)
SBP (mmHg)	107.07 ± 14.19
Normal	170 (85.8)
Pre-hypertension	16 (8.1)
Hypertension	12 (6.1)
DBP (mmHg)	72.02 ± 10.47
Normal	156 (78.8)
Pre-hypertension	28 (14.1)
Hypertension	14 (7.1)
Hypertension Status	
Normal	141 (71.2)
Pre-hypertension	35 (17.7)
Hypertension	22 (11.1)
Obesity related Hypertension	
Normal	136 (68.7)
Obesity only	40 (20.2)
Hypertension only	13 (6.6)
Both obesity and hypertension	9 (4.5)

Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 25 (IBM Corp., New York, USA). Categorical variables are presented as frequencies and percentages, and continuous variables as means and standard deviations. Univariate analysis was performed to determine the frequency distribution of subject characteristics (sex, age, age at menarche, place of residence), nutritional status, and blood pressure data. Independent t-test was

Table 2. Baseline characteristics stratified by sex and place of residence

Variables	Sex: Boys Mean ± SD	Sex: Girls Mean ± SD	p	Residence: Private House Mean ± SD	Residence: Boarding School Mean ± SD	p
Age	13.33 ± 2.57	12.91 ± 2.20	0.228	11.44 ± 1.85	14.79 ± 1.45	0.000*
Age at Menarche	8.32 ± 5.98	8.03 ± 5.69	0.737	4.49 ± 6.08	11.46 ± 2.97	0.000*
Body Weight	47.95 ± 16.27	44.49 ± 13.26	0.102	38.65 ± 13.07	53.49 ± 12.19	0.000*
Body Height	152.36 ± 14.08	147.43 ± 9.92	0.007*	142.36 ± 11.06	156.88 ± 7.82	0.000*
BMI/A	0.29 ± 1.30	0.07 ± 1.42	0.267	-0.014 ± 1.51	0.34 ± 1.19	0.064
SBP	111.60 ± 15.12	103.87 ± 12.59	0.000*	106.96 ± 12.89	107.19 ± 15.48	0.907
DBP	70.85 ± 10.36	72.85 ± 10.50	0.187	76.51 ± 10.79	67.35 ± 7.75	0.000*

Independent t-test, significant at *p < 0.05.

Table 3. Correlation of baseline characteristics with nutritional status and blood pressure

Variables	Nutritional Status	Blood Pressure	
		SBP	DBP
	r (p-value)	r (p-value)	r (p-value)
Age	0.073 (0.308)	0.155 (0.029)*	-0.216 (0.002)**
Age at Menarche	0.075 (0.296)	0.082 (0.248)	-0.155 (0.029)*
Body Weight	0.442 (0.000)††	0.408 (0.000)††	-0.023 (0.751)
Body Height	0.161 (0.023)*	0.338 (0.000)**	-0.162 (0.023)*
BMI/A	1	0.142 (0.046)†	0.000 (0.995)

Pearson correlation, significant at †p < 0.05 and ††p < 0.01.
Spearman correlation, significant at *p < 0.05 and **p < 0.01.

performed to evaluate the differences of subject characteristics, nutritional status, and blood pressure stratified by sex and place of residence. The goodness-of-fit of the quantitative variable data to a normal distribution was evaluated using the Kolmogorov-Smirnov test with the Lilliefors correction. Normally distributed data were analyzed using the Pearson correlation test for body weight and BMI/A, while non-normally distributed data were analyzed using the Spearman correlation test (age, age at menarche, and body height). Multiple linear regression was performed to obtain the estimation formula for the most associated risk factors of nutritional status and blood pressure among adolescents defined by sex and place of residence with backward elimination method. A likelihood of error of less than 5% ($p<0.05$) was considered statistically significant for all statistical analyses, and the confidence interval was set at 95%.

Results

Subjects Characteristic

This study enrolled 198 subjects (116 girls and 82 boys) with a mean age of 13.08 ± 2.37 years, placing them in the early adolescence category (38.9%). Puberty was experienced by 67.2% of the subjects when 8.15 ± 5.80 years. Regarding place of residence, subjects were fairly split between those living in a private house (51.0%) and those living in a boarding school (49.0%). Nutritional status revealed that 24.7% of the subjects were classified as overweight and obese (OW-OB). In terms of blood pressure profile, the mean of systolic blood pressure (SBP) was 107.07 ± 14.19 mmHg and diastolic blood pressure (DBP) was 72.02 ± 10.47 mmHg. Notably, approximately 4.5% of subjects had both obesity and hypertension (Table 1).

Baseline characteristics stratified by sex and place of residence

In addition to health indicators, the sex analysis revealed significant differences in only two variables, height and SBP, between boys and girls (Table 2). Boys had higher mean heights (152.36 ± 14.08 cm) and SBP (111.60 ± 15.12 mmHg) compared to girls (147.43 ± 9.92 cm and 103.87 ± 12.59 mmHg), respectively. Subjects living in boarding schools had different mean values from those living in private houses across several variables, including age, age at menarche, body weight, and height ($p < 0.05$). Specifically, subjects living in boarding schools had lower DBP values (67.35 ± 7.75 mmHg vs. 76.51 ± 10.79 mmHg) than their counterparts living in private houses (p=0.000).

Correlation of baseline characteristics with nutritional status and blood pressure

Moreover, the study found a positive correlation between nutritional status and anthropometric indicators such as weight (r = 0.442, p = 0.000) and height (r = 0.161, p = 0.023). Additionally, there was a positive correlation between SBP and age, body weight, body height, and BMI/A. In contrast, DBP was negatively correlated with age, age at menarche, and height although the correlation was determined to be very weak (r < 0.025). The correlation of baseline characteristics with nutritional status and blood pressure are presented in Table 3.

Multiple linear regression analysis

The results of the multiple linear regression analysis presented in Table 4 identify the final model that

Table 4. Final model of nutritional status and blood pressure associated factor

Variables		B	SE	Beta	t	p-value
BMI/A	Constant	-2.949	0.367		-8.029	0.000
	BMI	0.154	0.018	0.528	8.695	0.000*
SBP	Constant	100.151	4.248		23.574	0.000
	Age at Menarche	-0.620	0.193	-0.254	-3.210	0.002*
	Body Weight	1.007	0.160	1.040	6.301	0.000*
	BMI	-1.695	0.448	-0.564	-3.788	0.000*
DBP	Constant	82.076	4.453		18.433	0.000
	Age	-1.290	0.322	-0.292	-4.008	0.000*
	BMI	0.337	0.161	0.152	2.089	0.038*

B: parameter estimates, SE: standard error, Beta: standardized estimates, significant at *p < 0.05.

Table 5. Final model of nutritional status and blood pressure associated factor based on sex

Variables		B	SE	Beta	t	p-value
Nutritional Status						
Boys	Constant	-0.786	0.985		-0.798	0.428
	BMI	0.149	0.033	0.511	4.499	0.000*
	SBP	-0.017	0.010	-0.199	-1.757	0.083
Girls	Constant	-2.497	0.689		-3.624	0.000
	Age	-0.091	0.050	-0.141	-1.833	0.069
	BMI	0.184	0.022	0.636	8.240	0.000*
SBP						
Boys	Constant	99.722	7.426		13.429	0.000
	Age at Menarche	-1.050	0.322	-0.416	-3.259	0.002*
	Body Weight	1.250	0.804	1.344	4.844	0.000*
	BMI	-1.954	0.258	-0.578	-2.430	0.017*
Girls	Constant	49.886	18.093		2.757	0.007
	Age	-1.659	0.698	-0.290	-2.377	0.019*
	Body Height	0.511	0.156	0.402	3.269	0.001*
	BMI/A	1.319	0.794	0.149	1.663	0.099
DBP						
Boys	Constant	70.289	3.435		20.460	0.000
	Age at Menarche	-0.809	0.233	-0.467	-3.467	0.001*
	Body Weight	0.152	0.086	0.239	1.771	0.080
Girls	Constant	86.002	5.713		15.053	0.000
	Age	-1.019	0.436	-0.214	-2.335	0.021*

B: parameter estimates, SE: standard error, Beta: standardized estimates, significant at *p < 0.05.

determines the factors associated with nutritional status and blood pressure in this study. The equation for nutritional status is BMI/A = -2.949 + 0.154 (BMI), while the equations for blood pressure are SBP = 100.151 - 0.620 (Age at Menarche) + 1.007 (Body Weight) - 1.695 (BMI) and DBP = 82.076 - 1.290 (Age) + 0.337 (BMI). When stratifying the analysis by sex, it was evident that BMI was the strongest predictor factor of nutritional status in both boys and girls ($p < 0.05$). In boys, age at menarche was the main predictor of BP, whereas in girls, age was negatively associated with BP (Table 5). Moreover, considering the analysis by place of residence, age and anthropometric indices emerged as the primary predictors of nutrition status for subjects residing in private houses, unlike those in boarding schools. In private houses, BMI/A is the most influential predictor of SBP, whereas in boarding schools, it is BMI. The positive association between BMI/A and BP contrasts with the negative association observed between BMI and BP (Table 6).

Discussions

Subject characteristics

Adolescent overweight and obesity (OW-OB) represent an ongoing public health concern in Indonesia, with a prevalence of 23.9% among children (Farapti *et al.*, 2019) and 28.1% among adolescents (Kandinasti & Farapti, 2019), as indicated in both prior and current studies. However, the prevalence of OW-OB in this study was 24.7%, similar to previous study (23.7%) among adolescents in Surabaya Indonesia (Syifadhiya & Farapti, 2023). OW-OB highlights multifactorial factors, with food being a significant

Table 6. Final model of nutritional status and blood pressure associated factor based on place of residence

Variables		B	SE	Beta	t	p-value
Nutritional Status						
Private House	Constant	-10.525	2.926		-3.597	0.001
	Age	-0.212	0.043	-0.259	-4.895	0.000*
	Body Weight	-0.098	0.038	-0.843	-2.595	0.011*
	Body Height	0.048	0.021	0.348	2.252	0.027*
	BMI	0.532	0.081	1.586	6.525	0.000*
Boarding School	Constant	0.345	0.121		2.842	0.005
SBP						
Private House	Constant	44.919	14.932		3.008	0.003
	Body Height	0.436	0.105	0.374	4.169	0.000*
	BMI/A	2.107	0.764	0.247	2.756	0.007*
Boarding School	Constant	85.291	6.200		13.756	0.000
	Body Weight	1.477	0.552	1.163	7.401	0.000*
	BMI	-2.616	0.200	-0.744	-4.735	0.000*
DBP						
Private House	Constant	66.296	4.494		14.753	0.000
	BMI/A	0.547	0.234	0.229	2.339	0.021*
Boarding School	Constant	58.300	3.409		17.104	0.000
	Body Weight	0.176	0.634	0.277	2.835	0.080
	BMI	-1.120	0.062	-0.173	-1.767	0.006*

B: parameter estimates, SE: standard error, Beta: standardized estimates, significant at *p < 0.05.

contributor. Research also shows that students consume high-calorie food on weekends (Kandinasti & Farapti, 2019), although school food still doesn't meet their nutrition requirements (Farapti *et al.*, 2019). Several studies also reported a significant increase in OW-OB among adolescents in Asian countries during the COVID-19 pandemic (Chin, Woon, & Chan, 2022; He et al., 2022; Kim, Lee, & Yoo, 2022; UNICEF, 2022). In Indonesia, UNICEF found that the prevalence of OW-OB has increased across all age groups and income levels during the COVID-19 pandemic, with limited access to healthy foods and reduced physical activity being the primary contributing factors (UNICEF, 2022).

In addition to OW-OB, this study found a high prevalence of hypertension (HT) among adolescents, with 11.1% affected and about 4.5% having both OB and HT. This study showed that the mean SBP and DBP were 107.07 ± 14.19 mmHg and 72.02 ± 10.47 mmHg, respectively. This is higher than previous studies in the same age group in Palembang, Indonesia (Kurnianto *et al.*, 2020) and Central Jakarta, Indonesia (Pardede & Setyanto, 2017), which found prevalence rates of 8% and 9.6%, respectively, but lower than those in Yunnan, China (13.45%) (Yang *et al.*, 2021). The difference may be due to reference, whereby this study used the American Academy of Pediatrics (AAP), and Pardede and Setyanto (2017) used the Fourth Report (2004) that has a lower prevalence of hypertension in stage 1 and 2 (Park & Shin, 2021).

Disparities in subject characteristics based on sex and place of residence

Sex differences can affect physiological conditions, with boys and girls showing significant differences in body height and SBP. A study in Aceh, Indonesia, revealed that boys had an average height 2.3 cm greater than girls (Yusni & Meutia, 2019), and an almost 5 cm height differential between the sexes in this study. Generally, boys tend to have higher mesomorph values, indicating musculoskeletal strength, while girls tend to exhibit higher endomorph values, suggesting greater subcutaneous fat accumulation (Rahmawati & Hastuti, 2021). As a result, boys generally outgrow girls during puberty. Notably, a large-scale study in Bogotá found that girls tend to be taller than boys between the ages of 9 and 11, but this trend reverses as they enter later stages of development (Cossio-Bolaños *et al.*, 2021). Girls typically reach their age at peak height velocity (APHV) approximately 2.2 years earlier than boys, while boys experience peak height velocity (PHV) about 0.4 cm/year earlier than girls during puberty, which is consistent with studies in both Asian and Western populations (Cossio-Bolaños *et al.*, 2021). As nearly 70% of the subjects had already undergone puberty at the time of measurement, this study found that boys had a higher stature than girls and also affected SBP. During puberty, both girls and boys experience a rapid increase in BP, but boys tend to have higher increases in SBP (Poh *et al.*, 2022). In another study, it was found that papilla fungiform density influences blood pressure, being higher in girls, and 4.2% of boys with high saltiness threshold had a higher SBP and DBP (Syifadhiya and Farapti, 2023). However, examining genetics, pregnancy experiences (mediated by birth length and weight), nutritional quality, and environment despite puberty are important for obtaining more comprehensive results (Rodriguez-Martinez *et al.*, 2020).

The environment significantly influences health through health behaviors, with factors like place of residence, family income, and maternal educational level influencing optimal development and growth (Zadka, Pałkowska-Goździk, & Rosołowska-Huszcz, 2019). This study found that adolescents living in boarding schools had higher nutritional status than those living in private houses, despite both being at normal nutritional status and not statistically significant. This aligns with a Nigerian study that found no nutritional status disparity between adolescents from two residences, suggesting adequate school feeding for boarding students (Bolajoko *et al.*, 2014). When examining anthropometric indicators, such as body weight and height, it was observed that boarding school adolescents had higher values, possibly due to the older age of the adolescents and the onset of puberty. Private house adolescents were three years younger, with most not yet reaching puberty. Age at menarche is significantly associated with anthropometric indicators, with adolescents who experience menarche having a 0.30 times higher risk of OW-OB (Asrullah *et al.*, 2022). An Asian study also reported that the average APHV occurs at the age of 13-14 years (Tsutsui *et al.*, 2022), which may explain the differences observed between adolescents living in the two residences. This difference may also have been due to sampling. Adolescents living in private houses were drawn from evening Islamic schools, which tend to have a wider age range than boarding schools with age qualifications.

Correlation between subject characteristics with nutritional status and blood pressure

This study revealed a positive correlation between body weight, height, and BMI/A in adolescents. Similarly, a large-scale study in England, Scotland, and Wales also demonstrated a strong correlation between body weight and nutritional status, while a weak correlation existed between body height and nutritional status in adolescents aged 11–15 years, turning negative at 16 years (Johnson *et al.*, 2020). While BMI/A measurement is widely accepted as an appropriate indicator for determining the nutritional status of adolescents, other body composition measurements, such as body fat, muscle mass, and body water, are also important for understanding body composition distribution. The study found that body composition is similar between boys and girls before age 12, but differences emerge after 12 years (Kobylińska *et al.*, 2022). Therefore, the BIA method needs to be employed for an in-depth assessment of body mass, particularly in adolescents during puberty, to enhance the understanding of the correlation between anthropometric indicators, nutritional status, and physical growth, enabling targeted intervention measures.

In terms of blood pressure, this study demonstrated that age and body height were significantly correlated with both SBP and DBP, consistent with previous studies conducted in Malaysia (Poh *et al.*, 2022), Nigeria (Kobylińska *et al.*, 2022), and Maryland (Devonshire *et al.*, 2016). Furthermore, sex, age, and height are recognized as indicators of blood pressure percentile assessment in children under 13 years old (Galescu *et al.*, 2012; Flynn *et al.*, 2017), and more than 30% of the subjects in this study in these categories. Indian studies have also highlighted that the ratio of blood pressure to height (either SBP/height or DBP/height) is a feasible and accurate method for diagnosing prehypertension in adolescents, considering racial differences (Kurane *et al.*, 2015). In addition to age and height factors, Chinese schoolchildren aged 7-12 years showed a correlation between pubertal development and blood pressure, specifically an increase in SBP and DBP in children experiencing puberty earlier. Children experiencing puberty showed a 3.84 mmHg increase in SBP and 2.24 times increase in DBP (Li *et al.*, 2021), although, in this study, it was more significant in DBP ($r = -0.155$, $p = 0.029$). This inverse correlation indicates that adolescents who experience puberty earlier have a higher risk of higher blood pressure, particularly DBP (62% vs. 53% for SBP) (Li *et al.*, 2021). In contrast, this study found that body weight and BMI/A had a linear correlation with SBP but not with DBP. This finding is consistent with a Nigerian study of primary school students, which stated that body weight was the main predictor of SBP (24.8%) and had minimal impact on DBP (1.5%) (Kobylińska *et al.*, 2022). A Korean study evaluating the correlation between high BMI values and blood pressure in adolescents aged 10-19 years showed that changes in body weight correlated with changes in blood pressure (Song, 2014). This study confirmed that a high BMI/A value significantly enhanced the probability of having an elevated SBP (>90th percentile) in both normal and overweight adolescents. This finding implies that changes in nutritional status can influence blood pressure, regardless of initial body weight or the presence of hypertension.

Factors predicting nutrition status and blood pressure

This study revealed that BMI is the most reliable predictor of nutritional status in both private homes and boarding schools for both males and females. However, it is essential to consider that BMI is a key indicator of adolescent nutritional status when interpreted relative to age and sex, as it differs from that of adults. This study utilized age- and sex-specific BMI cut-offs recommended by the Indonesian Ministry of Health and aligned with the World Health Organization (WHO) Z-score criteria for the early detection of nutritional issues. Nonetheless, study in Poland (Słowik *et al.*, 2019) suggests that bioelectromagnetic impedance analysis should be employed to measure adipose tissue content and location, particularly in sports-oriented adolescents. Therefore, evaluating the correlation among BMI, body fat percentage, and nutritional status (BMI/A) is of utmost importance.

This study found that BMI/A was the main predictor of BP in adolescents aged 10-18 years, with a positive association with SBP and DBP. Another study in Malaysia found that nutritional status is a good predictor of hypertension, with an increase in nutritional status contributing to increased SBP and DBP in adolescents (Poh *et al.*, 2022). Previous studies have also identified a correlation between nutritional status and hypertension, as well as the significant impact of elevated sodium intake on both conditions (Furqonia, Farapti and Notobroto, 2023). In China, children with hypertension have higher levels of triglycerides, blood glucose, insulin, and homeostatic index for insulin resistance (HOMA-IR), particularly among those with obesity (Xu *et al.*, 2011). In this study, nutritional status was identified as the main predictor of BP in adolescents living in a private house and those in boarding schools. Previous research has also outlined nutritional status and abdominal circumference as significant risk factors (Tjahjono et al., 2021, 2023), and ABSI (derived from BMI and waist circumference) showed better sensitivity in predicting adolescent BP. ABSI considers the accumulation of visceral fat, and a higher value indicates a higher risk of metabolic syndrome, including increased blood pressure (Mameli *et al.*, 2018). Additionally, age has been identified as a key predictor of BP in girls, whereas age at menarche is a predictor for boys. A study in Malaysia found that age was inversely correlated with SBP and DBP (Poh *et al.*, 2022), and differences in pubertal development between the sexes contributed to a higher prevalence of hypertension in boys. A longitudinal study in southwest England revealed that, during puberty, boys had a 10.19 mmHg higher SBP than girls, but follow-up observations (3 – 5 years after puberty) showed that girls had a higher mean SBP than boys (O'Neill *et al.*, 2022). This study established that early puberty in boys leads to increased blood pressure, as indicated by the negative relationship between age at menarche and blood pressure.

This study has the strength of ensuring a representative sample size and diverse dataset for adolescents in this region. In addition, the study comprehensively explored subject characteristics, including sex, place of residence, and their association with nutritional status and blood pressure. Although the cross-sectional design of this study cannot establish cause-and-effect relationships, the findings may provide guidance for future studies and intervention considerations related to nutritional issues, especially in the context of sex and place of residence. Although the BMI/A was used to measure the nutritional status of adolescents, this study recognized the importance of considering body composition measurements to obtain more comprehensive results. In addition, the lack of information regarding potential confounding factors, such as economic status, dietary habits, birth weight and length, and physical activity, may have affected the relationship between variables. Therefore, other factors associated with nutritional status and blood pressure in adolescents should be investigated in future studies.

Conclusion

This study found that obesity and hypertension were more prevalent among adolescents than among the national average. These findings emphasize the role of BMI as a significant predictor of nutritional status and explain the importance of monitoring nutritional status as a main predictor of blood pressure. These health issues affect both sexes and adolescents who live in private homes and boarding school. Sex differences, such as age at menarche, may influence anthropometric growth and development of hypertension. The place of residence also plays a role in the differences in age, anthropometric indicators, and blood pressure. These findings suggest the need for tailored health interventions like implementation of regular health screening and monitoring (especially nutritional status and blood pressure) for both groups, including nutrition education program into the school curriculum for boarding school adolescents and parental involvement to provide balanced nutrition in private house adolescents. Some practical recommendations, such as providing school lunch programs, conducting health check-ups, promoting physical activity in the school setting, collaborating with community centers to provide sports and recreational activities that are accessible to adolescents living in private homes, and conducting community workshops to educate parents about the importance of promoting healthy lifestyles for their adolescents, seem to warrant consideration. From this result, future studies also should consider variables, such as socioeconomic conditions, dietary habits, physical activity, and maternal experience, to make more accurate predictions. The longitudinal and comparative study designs provide comprehensive insights. Overall, urgent action such as school health campaigns, parental empowerment, and community involvements is needed by school authorities and educators, health professionals, parents and guardians, and community organizations to address the high prevalence of obesity and hypertension in adolescents.

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Conflict of interest

The authors declare that they have no conflict of interest.

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