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Research Article

Anthropometric Measures of Adiposity and Their Associations with Blood Pressure among Malay Adolescents Aged 18 to 19 Years Old in Terengganu

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ABSTRACT

This study aims to explore association of anthropometric adiposity measures with blood pressure among Malays aged 18 to 19 years. Participants comprised 309 university students of Malay ethnicity residing in Kuala Nerus, Terengganu. This cross-sectional research study was done in April 2021 to August 2023. A total of 40.7% of participants were overweight/obese, 42.1% normal weight, and 17.5% underweight based on World Health Organisation (WHO)-Asian Body Mass Index (BMI) classification. Among this population, 15.5% of the students was considered as Hypertension (HPT) and 21.4% had Elevated Blood Pressure (EBP). Proportions of male students with HPT (35.7%) and EBP (29.8%) were significantly higher compared to female students (18% and 18.2%, respectively). Linear regression analysis indicated that BMI was a significant factor that influenced Systolic Blood Pressure (SBP), especially among female participants. Obese adolescents had 7.0 times higher odds of developing EBP/HPT compared to those in other BMI categories (aOR=6.97; 95% CI:2.92–16.6; $p<0.05$). The high prevalence of HPT and EBP raises concern, as the study also confirmed an association between obesity and blood pressure. In conclusion, anthropometric measures of adiposity were associated with increased odds of HPT. Thus, early identification of individuals with high-risk anthropometric adiposity is crucial to facilitate timely intervention and mitigate associated risks.

INTRODUCTION

The increasing prevalence of Hypertension (HPT) among older adolescents can persist and progress into HPT in adulthood (Kurnianto *et al.* 2020). EBP often leads to organ damage and cardiovascular complications, including early endothelial dysfunction, arterial stiffness, and left ventricular hypertrophy in later life, which gives grave concern in healthcare (Wang *et al.* 2019). For adolescents aged 13 years and above, EBP is defined as Systolic Blood Pressure (SBP) of 120 to 129 mmHg and Diastolic Blood Pressure (DBP) of less than 80 mmHg, while blood pressure reading at ≥130/80 mmHg is considered as HPT According to the Clinical Practice Guidelines (CPG), for the diagnosis, evaluating, and treating children and adolescents from the American Academy of Paediatrics (AAP) in 2017, those aged ≥3 years with HPT are recommended to undergo annual screening for blood pressure abnormalities during preventative visits (Flynn *et al.* 2017).

Several countries have reported a high prevalence of HPT among late adolescents and adults that can be even more severe among those who are obese. Data from a meta-analysis of Chinese children and adolescents indicate a pooled prevalence of 9.8%, with variation based on weight status (Wang *et al.* 2019). Findings from a cohort study, also revealed that HPT during adulthood correlates with the high blood pressure monitored during their adolescence (Azegami *et al.* 2021). During adolescence, it is challenging to distinguish between natural growth and increased adiposity due to rapid changes in body composition and sex hormones. Studies suggest that to assess adiposity and its relation to vascular diseases, more detailed phenotyping methods, such as DEXA, should be used to break down the weight components (Dangardt *et al.* 2019; Bennett 2023; Fedewa *et al.* 2019).

In addition, although various studies have shown strong association between body composition and increased blood pressure among children and adolescents, no studies have focused specifically on the adolescent population in Malaysia. The only study involving Malay adolescents was conducted in Sarawak, and examined only anthropometric measurements but not body adiposity in relation to blood pressure (Cheah *et al.* 2018). The present study focused on Malays aged 18−19 years old, as research has shown that late adolescents have a higher prevalence of HPT compared to early adolescents (Daniel *et al.* 2020; Mohan *et al.* 2019; Chandrashekarappa *et al.* 2022).

Therefore, this study was conducted to investigate the relationship of various anthropometric adiposity, including BMI, Waist Circumference (WC), Waist-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Fat Mass Index (FMI), Fat-Free Mass Index (FFMI), Fat-to-Fat Free Mass Ratio (FFFMR), and Body Fat (BF) percentage with blood pressure, focusing specifically on Malays aged 18 to 19 years old. This research focused on this age group as it is a crucial transition period from childhood to adulthood. During this time, many adolescents begin entering higher education institutions and living away from the family, which impacts their independence and lifestyle adaptation, further influencing health outcome.

METHODS

Design, location, and time

This study was conducted between April 2021 to August 2023 using cross-sectional study design. Participants were students aged between 18 to 19 years old from a public university in Terengganu who were enrolled in foundation and diploma programmes. Students who were of non-Malay ethnicity, those with medical history of chronic diseases, on medication, pregnant or breastfeeding, elite athletes involved in competitive sports, or COVID-19 positive patients, were exlucded. Ethical approval for this study was obtained by UniSZA Human Research Ethics Committee (UHREC) (RACER/1/2019/SKK06/UniSZA/3).

Sampling

This study employed probability sampling. Based on the student list from the academic section of the university, the total number of undergraduate students in both diploma and foundation programs in the university was 2,357. Subjects were choosen at random. Single proportion formula of Krejcie and Morgan (1970) was used to determined the sample size (Morgan 1970) :

$$s = \frac{X^2NP(1-p)}{d^2(N-1)} + X^2P(1-p)$$

where the X-score for a 95% confidence interval is 1.96, population size for this research is 2,357 students (N), for the population proportion (p) (0.17, as the prevalence of HPT among those 18 years and older in Malaysia is 17.3% (Omar *et al.* 2016)), and margin of error (d) is 0.05. Considering a 20% drop-out rate, the final sample size was calculated to be 266 participants.

Data collection

Based on the student list, 419 students (17.8%) were precluded for being ≥20 years old or non-Malay. Given the challenging circumstances of COVID-19 during the data collection period, participants recruitment was conducted through social media. For each student who met all the inclusion criteria, an appointment was scheduled and data collection was done at the agreed-upon date and time. The timeline between an interview and data collection averaged within 3 months due to movement restrictions imposed during COVID-19. Consent forms were also distributed to participants using online questionnaires, which were shared via social media to minimise contact.

Anthropometric measurements. Height was measured using SECA Model 217 stadiometer (SECA, Germany) to the nearest 0.1 cm, and weight was measured using Electronic Weighing Scale SECA 880 (SECA, Germany) to the nearest 0.1 kg. Measurements were taken twice, and the average of both weight and height were calculated and taken as the final value. If the difference between the 2 readings is more than 10%, a third measurement will be taken. Weight (kg) is divided by height meters squared (m^2) to get BMI. BMI of adolescents were categorised according to the WHO-Asian guidelines: low normal (<18.5 kg/m^2), normal (18.5−22.9 kg/m^2), overweight (23−24.9 kg/m^2) and obese (≥25 kg/m^2) (Saha *et al.* 2021).

Waist and hip circumferences were measured using Rosscraft Anthrotape (USA). The measurements were taken while the participant stood erect with bared waist, after exhaling, with both feet together and both arms relaxed and hanging freely at their sides. Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, according to WHO Regional Office for the Western Pacific (2008). The fullest part of the buttocks were measured for hip circumference. The measurements were taken twice and were recorded in centimetres (cm) to the closest 0.1 cm. The average reading is then calculated. WHR was calculated using WC (cm) divided by hip measurement (cm), whereas WHtR was calculated using WC (cm) divided by height (cm).

The cut-off values for waist circumference used in this study, based on the International Diabetes Federation (2007) guidelines for Asian individuals aged ≥18 years old, are ≥80 cm and ≥90 cm for women and man respectively (Xi *et al.* 2019). The cut-off values were WHR 0.891 (Widjaja *et al.* 2023) and WHtR 0.49 (Eslami *et al.* 2023) for both males and females.

Body composition measurement. Body composition was measured using Bioelectrical Impedance Analysis (BIA) technique with the Bodystat Quadscan 4000 (Bodystat Ltd, Isle of Man, British Isles). For this measurement, two electrodes were placed on the right hand and 2 electrodes on the right foot (Froon-Torenstra *et al.* 2024) . Students needed to fast overnight and avoid exercise a day prior to data collection date. During the measurement, the participant must be in a supine position, with arms abducted at least 30°C and legs abducted at approximately 45°C (Fowler 2019). Based on the BIA measurement, Fat Free Mass (FFM) (kg) and Fat Mass (FM) (kg) data were extracted.

Fat Mass Index (FMI), Fat-Free Mass Index (FFMI) and Fat-to-Fat Free Mass Ratio (FFFMR) were then calculated (Xiao *et al.* 2018) :

$$FMI = \frac{Fat\ mass\ (kg)}{Height(m)^2}$$

$$FFMI = \frac{Fat\ free\ mass\ (kg)}{Height(m)^2}$$

$$FFFMR = \frac{Fat\ mass\ (kg)}{Fat\ free\ mass\ (kg)}$$

Blood pressure measurement. Blood pressure was measured using Omron Digital Blood Pressure Monitor HEM 7203 (Omron, Japan). Measurement was taken in the morning, with participant asked to sit comfortably and remain silent during the measurement process. Blood pressure was recorded twice and mean blood pressure was calculated (Kallioinen *et al.* 2017). The HPT cut-offs employed was based on the American Academy of Paediatrics (AAP 2017), among adolescents aged ≥13 years old EBP is defined as having blood pressure 120−129/<80 mmHg, while HPT is defined as ≥130/≥80 mmHg (Flynn *et al.* 2017).

Data analysis

IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, New York, USA) was used to analyse the data. For descriptive statistics analysis, data are written as mean and Standard Deviation (SD). For this research, multiple linear regression between blood pressure and other anthropometric adiposity indicators was done, with $p<0.05$ set as a significant level. Analysis for associations between the anthropometric adiposity measures with blood pressure employed linear regression analysis. Selected anthropometric variables were then analysed to estimate the adjusted odds ratio and 95% confidence interval for their association with blood pressure using multiple logistic regression.

RESULTS AND DISCUSSION

In this study, 309 students aged between 18 and 19 years old participated, with 27.2% (84) males and 72.8% (225) females. The mean and Standard Deviation (SD) of anthropometric adiposity parameters and blood pressure are presented in Table 1. There were significant differences ($p<0.05$) between male and female students in all measurements, except for WHtR and BMI. Male students had significantly heavier, taller, high BMI, WC, HC, WHR, WHtR, FFM, FFMI, SBP and DBP. Females had higher fat mass and body fat percentage than male students.

The frequency of obese adolescents (23.1%) was triple the prevalence announced in the

National Health and Morbidity Survey (NHMS) in 2019 (8%) (Ganapathy *et al.* 2019).This data was similar to findings among adolescents in the United States (22.2%) (Ganapathy *et al.* 2020). The dissimilarity in results may be ascribed to the different classification BMI systems used to categorize participants' body weight status, this study employed the WHO-Asian BMI classification which has lower cut-off values for obese (BMI ≥25 kg/m²) and overweight (BMI ≥23 kg/m²) compared to the WHO criteria for White, Hispanic and Black populations (WHO Regional Office for the Western Pacific 2000). This classification for the Asian population has been shown to have better sensitivity in predicting comorbid dysmetabolic conditions, particularly HPT, among North Indian populations (Verma *et al.* 2019).

Studies have comprehensively demonstrated that gender plays an important role in blood pressure, where females are likely to have lower SBP than males (Alhawari *et al.* 2018; Tebar *et al.* 2018). This trend was observed in this study as males have significantly higher blood pressure than females. This difference is seen not only in adolescents but also in adult populations (Soo *et al.* 2020). The primary contributors to blood pressure differences between genders include the sympathetic nervous activity, immune system, endothelin-1, renin-angiotensin system, and also sex hormones (Song *et al.* 2020). Males and females also differ in vascular function, hence, effecting their renal sodium handling capacity, which contributes to differences in blood pressure (Drury *et al.* 2024).

The data suggests that females have a tendency to have lower WC compared to males. This result aligns with existing evidence that males generally have larger waist circumference due to sexual development (Taxová Braunerová

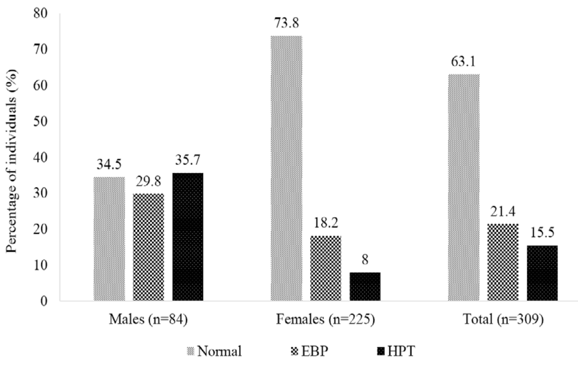
Table 1. Mean differences in anthropometric adiposity and blood pressure by gender

Anthropometric/ Body composition parameters	Males (n=84) Mean±SD	n (%)	Females (n=225) Mean±SD	n (%)	p^*	Total (N=309) Mean±SD	n (%)
Weight (kg)	66.59±18.15		55.40±13.54		<0.001	58.44±15.72	
Height (cm)	1.69±0.06		1.56±0.05		<0.001	1.59±0.08	
BMI (kg/m²)	23.44±6.35		22.81±5.21		0.376	22.98±5.54	
Underweight (<18.5 kg/m²)		17 (20.2)		35 (15.6)			52 (16.8)
Normal (18.5−22.9 kg/ m²)		31 (36.9)		100 (44.4)			131 (42.4)
Overweight (23−24.9 kg/m²)		14 (16.7)		38 (16.9)			52 (16.8)
Obese (≥25 kg/m²)		22 (26.2)		52 (23.1)			74 (23.9)
WC (cm)	78.33±14.07		71.74±11.21		<0.001	73.53±12.39	
HC (cm)	95.06±11.84		95.01±9.58		<0.001	95.02±12.39	
WHR	0.82±0.06		0.75±0.07		<0.001	0.77±0.07	
WHtR	0.46±0.08		0.46±0.07		0.693	0.46±0.07	
FM (kg)	11.59±9.43		16.85±8.10		<0.001	15.42±8.79	
FFM (kg)	55.32±10.16		38.62±6.42		<0.001	43.16±10.64	
BF (%)	15.9±6.9		29.2±6.20		<0.001	25.6±8.7	
FMI (kg/m²)	4.08±3.30		6.95±3.28		<0.001	6.17±3.51	
FFMI (kg/m²)	19.46±3.40		15.90±2.20		<0.001	16.86±3.03	
FFFMR	0.20±0.12		0.42±0.14		<0.001	0.36±0.17	
SBP (mmHg)	124±12		112±11		<0.001	116±12	
DBP (mmHg)	76±8		74±8		0.032	75±8	

*An Independent t-test test significantly at p<0.05; Mean and SD were reported or n (%): SD: Standard Deviation; BMI: Body Mass Index; WC: Waist Circumference; HC: Hip Circumference; WHR: Waist-Hip Ratio; WHtR: Waist-Height Ratio; FFM: Fat Free Mass; FM; Fat Mass; BF: Body Fat Percentage; FMI: Fat Mass Index; FFMI: Fat Free Mass Index; FFFMR: Fat-to-Fat Free Mass Ratio; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure *et al.* 2021). A cross-sectional study conducted among Korean adolescents similarly found that WC among males was significantly higher with noticeable differences between genders (Kim *et al.* 2018). These differences serve as indicators, as studies have revealed that higher WC is linked with abdominal fat, which is a crucial factor in the development of vascular and cardiac impairment (Trandafir *et al.* 2020).

Although females tend to have smaller WC, data showed that females have higher BF percentages due to notable differences in body fat composition and distribution between the genders, which are influenced by changes in sex hormone level (Yao *et al.* 2023). Supporting this finding, a cross-sectional study in Terengganu also shared a similar perspective that males have lower body fat percentage than females at the same pubertal status (Khair & Wee 2021). Studies have shown that factors, such as motor skills, environment, eating habits, health knowledge, lifestyle and socioeconomic status, play a significant role in adolescent body fat percentage (Ab Rahman *et al.* 2020; Martha Sari *et al.* 2021; Egg *et al.* 2020).

As shown in Figure 1, most of the participants (63.1%) had normal blood pressure, followed by EBP (21.4%) and HPT (15.5%). The prevalence of EBP and HPT among males (65.5%) was much higher compared to females (26.2%). The prevalence of HPT among this population (15.5%) is higher than that found in a study conducted among adolescents in Putrajaya (11.6%) and is significantly higher than recent studies conducted in Kuala Lumpur (4.7%) (Poh *et al.* 2022; Rampal *et al.* 2011). This disparity in results could be attributed to differences in data distribution related to body weight status,



EBP: Elevated Blood Pressure; HPT: Hypertension

Figure 1. Proportion of participants by blood pressure categories

as blood pressure varied based on weight status (Wang *et al.* 2019). This population had a higher percentage of obese and overweight students, which likely contributed to the high numbers of HPT.

Overall, the prevalence of HPT and EBP was very high in this community (36.9%), signalling a major concern that requires focused attention from primary care providers. In Malaysia, research linking anthropometric indices with blood pressure among adolescents remains limited. As obesity continue to rise and increasing affects not only among adult populations but also children and adolescents, it is crucial to monitor blood pressure regularly to prevent future health disease.

On regressing anthropometric adiposity parameters on blood pressure (Table 2 and Table 3), among all participants, BMI revealed a significant association with SBP, while WHR was significantly related with DBP. WC was the only anthropometric indicator revealed to possess a significant association with both blood pressure readings among all participants.

The result from logistic regression analysis of the risk of HPT across different factors is shown in Table 4. In these analyses, after adjusting for gender, weight status was identified as a significant predictor for the risk of HPT among adolescents particularly among obese participants (OR=6.97; 95% CI:2.92–16.60; $p<0.05$). However, a large WC was not a significant predictive for the risk of HPT with aOR of 1.07 (95% CI:1.04–1.09). Based on the result, obese adolescents had a 7.0 times higher risk of developing EBP/HPT compared to other BMI categories. Also, adolescents who had abdominal obesity had a 1.0 times higher risk for developing EBP/HPT.

Overall, this study shows that obesity, as measured by BMI, is linked with increased odds of HPT and EBP compared to other anthropometric adiposity parameters, making it the best predictor of HPT among Malay late adolescents in Terengganu. Logistic regression revealed that obese adolescents had 7.0 times the odds of developing EBP/HPT compared to other BMI ranges (aOR=6.97; 95% CI:2.92–16.60; $p<0.05$). This finding is in line with a previous study that emphasised obesity as a contributor to the increased odds (aOR=8.97; 95% CI:3.16–25.48; $p<0.05$) of EBP/HPT and served as the strong predictor blood pressure (Poh *et al.* 2022). Similarly, data from Chinese adolescents

Table 2. Linear regression of anthropometric adiposity parameters on systolic blood pressure

Model	Coefficients (Dependent variable: Systolic blood pressure in all participants) (N=309)				*p*
	Unstandardized coefficients		95% CI for *B*		
	B	SE	Lower bound	Upper bound	
(Constant)	71.42	8.82	54.07	88.77	<0.001
BMI	1.05	0.42	0.22	1.89	<0.05
WC	0.56	0.10	0.36	0.75	<0.001
HC	-0.15	0.12	-0.38	0.09	0.215
WHR	20.57	13.05	-5.11	46.25	0.116
WHtR	-8.35	18.88	-45.49	28.80	0.659
FMI	-0.44	1.17	-2.74	1.86	0.708
FFMI	1.02	0.63	-0.22	2.25	0.106
FFFMR	-16.88	19.25	-54.76	21.00	0.381

CI: Confidence Interval; BMI: Body Mass Index; WC: Waist Circumference; HC: Hip Circumference; WHR: Waist-Hip Ratio; WHtR: Waist-Height Ratio; FMI: Fat Mass Index; FFMI: Fat-Free Mass Index; FFFMR: Fat-To-Fat Free Mass Ratio; SE; Standarad error

Table 3. Linear regression of anthropometric adiposity parameters on diastolic blood pressure

Model	Coefficients (Dependent variable: Diastolic blood Pressure in all participants) (N=309)				*p*
	Unstandardized coefficients		95% CI for *B*		
	B	SE	Lower bound	Upper bound	
(Constant)	53.65	7.07	39.73	67.58	<0.001
BMI	0.63	0.34	-0.04	1.30	0.065
WC	0.21	0.07	0.07	0.35	<0.05
HC	0.03	0.09	-0.14	0.20	0.726
WHR	22.84	10.47	2.23	43.45	0.97
WHtR	-18.22	15.15	-48.03	11.59	0.230
FMI	0.24	0.94	-1.60	2.09	0.796
FFMI	-0.19	0.50	-1.18	0.81	0.712
FFFMR	-2.33	15.45	-32.73	28.06	0.880

CI: Confidence Interval; BMI: Body Mass Index; WC: Waist Circumference; HC: Hip Circumference; WHR: Waist-Hip Ratio; WHtR: Waist-Height Ratio; FMI: Fat Mass Index; FFMI: Fat-Free Mass Index; FFFMR: Fat-To-Fat Free Mass Ratio; SE; Standarad error

have shown a pooled prevalence of HPT at 9.8%, which rise to 34.1% among obese and 15.5% among overweight adolescents (Wang *et al.* 2019). Additionally, a study in Central Java found an increased risk of metabolic syndromes among obese adolescents, with over half already having HPT (53%) (Sukmasari *et al.* 2019).

The results suggest no significant association between HPT and WC. Logistic regression showed that adolescents with high WC had only a slightly increased odds of developing HPT, with an aOR of 1.07 (95% CI:1.04–1.09). However, global findings suggest that high WC is associated with 2 to 3 times greater risk of HPT compared to a normal WC (Mohammed Nawi *et al.* 2021). Larger WC was related with elevated visceral fat, which is associated with arterial stiffness potentially leading to higher SBP (Guimarães Filho *et al.* 2022). A large-scale observational study among Brazilian adolescents

Table 4. Odds ratio between selected anthropometric adiposity variables and high blood pressure

Variable	Normal BP n (%)	HPT n (%)	Multiple logistic regression	
			aOR (95 % CI)	*p*
BMI status				
Obese (≥25 kg/m)	51 (68.9)	23 (31.1)	6.97 (2.92−16.60)	<0.001
Overweight (23−24.9 kg/m²)	42 (80.8)	10 (19.2)	1.97 (0.78−4.99)	0.152
Normal (18.5−22.9 kg/ m²)	120 (91.6)	11 (8.4)	1.00	
WC category				
Abdominal obesity	4 (36.4)	7 (63.6)	1.07 (1.04−1.09)	<0.001
≥90 cm for males				
≥80 cm for females				
Normal WC	257 (86.2)	41(13.8)	1.00	

BMI: Body Mass Index; Obese is 25 kg/m² or higher; Overweight is between (23−24.9 kg/m²); Normal weight is between (18.5−22.9 kg/ m²); Underweight is below 18.5 kg/m²; Abdominal Obesity criteria is ≥90 cm for males and ≥80 cm for females; CI: Confidence Interval; aOR: Gender-adjusted Odds Ratios; *Multiple logistic regression significantly p<0.05; WC: Waist Circumference; BP: Blood Pressure; HPT: Hypertension

showed that larger WC, even with normal BMI, increased the risk of EBP (Pazin *et al.* 2020).

Notably, this study did not find a strong association between WHtR, FMI and BF percentage and risk of HPT. These findings support a study on Chinese children and adolescents, which indicates that BMI and WC are more accurate predictors of HPT compared to the other anthropometric indices (Li *et al.* 2020). Nevertheless, a cohort study of children and adolescents aged 9 to 17 found that high FM during adolescence, period was linked with a higher risk for arterial stiffness, which is related to advanced SBP (Dangardt *et al.* 2019). Also, research in Beijing involving children and adolescents suggests that a higher body fat percentage might negatively affect blood pressure among children (Chen *et al.* 2021).

This research only focused on one population in the same area which reduced the results' usage to a wider range of the adolescent population. A nationwide study that includes all ethnic groups in Malaysia, focusing on individuals aged 18 to 19 years old population to provide an overview of HPT in the country. Additionally, as this study focused on late adolescents the data may not fully represent the whole adolescent age group. However, the findings offer an overview of adolescents' current blood pressure trends. Importantly, this study highlights a more accessible approach to identifying adolescents in danger of EBP and HPT, which could serve as a routine measurement for all adolescents.

CONCLUSIONS

In conclusion, approximately one-third of 18−19 years old were found to have HPT or EBP, with males disproportionately affected – two-thirds of male participants had HPT and EBP. BMI demonstrated the strongest association with HPT, reinforcing the significant correlation between obesity and blood pressure. The findings underscore the critical need for routine blood pressure monitoring and early screening in late adolescents to identify and mitigate high blood pressure risks. Targeted intervention programs aimed at raising awareness and promoting healthy lifestyles are essential to prevent obesity and reduce the burden of HPT in this age group.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest in conducting or publishing this study.

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