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Original Article

Positive correlation between body weight and body mass index with blood pressure in young adults

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Abstract

Study assessing the correlation between body weight and body mass index (BMI) with blood pressure in young adults is still limited. The aim of this was to investigate the link between body weight and BMI with blood pressure, as well as to assess how much increasing of body weight and BMI contribute to raising blood pressure in young men and women. A cross-sectional study was conducted among 1,107 healthy young adults aged 18–22 years (women, n=705; men, n=402). Chi-squared test was used to assess the association between body weight and BMI with blood pressure. The Pearson correlation and linear regression analysis were used to determine the correlation and direction of the relationship between body weight and BMI with blood pressure. Our data indicated the associations between body weight and BMI with blood pressure (both had p=0.001). There was a strong correlation between body weight and systolic blood pressure (SBP) (r=0.709; p<0.001), whereas the correlation between body weight and diastolic blood pressure (DBP) was moderate (r=0.374; p<0.001). BMI moderately influenced SBP and DBP (r=0.488 and r=0.358; p<0.001). A linear correlation analysis revealed a positive correlation between body weight and BMI with blood pressure, where an increase in body weight of 1 kg resulted an increase in SBP of 0.725 mmHg and DBP of 0.318 mmHg. In addition, an increase in BMI of 1 kg/m^2 followed by an increase in SBP and DBP of 1.6 mmHg and 0.834 mmHg, respectively. This study highlights that nutritional status in young men and women is linked and has a positive correlation with blood pressure.

Keywords: Blood pressure, body mass index, hypertension, obesity, body weight

Introduction

Body mass index (BMI) is a metric used to assess body fat percentage and nutritional status [1,2]. A high BMI is linked to a higher risk of hypertension and other cardiovascular diseases (CVD) [2,3]. Obesity increases the risk of hypertension by 4.17 times and cardiovascular disease by 1.46 times, respectively [3]. Obesity and hypertension contribute to morbidity and mortality by causing comorbidities such as CVD and renal disease [4]. Obesity and high blood pressure accounted for 60% of the CVD burden [5]. Older age increases the risk of having high blood pressure. However, the prevalence of high blood pressure in young adults is concerning [6].

Obesity is not only a global epidemic concern in the 40s age group, but it is also a major public health issue at a young age [4]. Obesity prevalence in adults has increased dramatically since the coronavirus disease (COVID-19) pandemic [7]. Prior to the pandemic (before December 2019), the prevalence of obesity in men and women was around 11% and 15%, but this figure

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skyrocketed to 25.3% and 42.4%, respectively, during the COVID-19 pandemic (December 2019 to January 2023 [7]. In the United States, obesity prevalence grew by 3.2% from January 1, 2019 (40.7%) to March 12, 2020 (43.9%) [7,8]. In young adults, the increase in obesity reached 7.6% at the start of the COVID-19 pandemic (December 2019 to March 2020) when compared to before the pandemic (2017–2018) [8]. Based on data from the World Health Organization (WHO), since 1990, the prevalence of obesity in adults throughout the world has doubled, while in adolescents it has quadrupled [9]. In 2022, 1 in 8 people are obese [9]. It was found that 2.5 billion, or around 43%, of adults (18 years of age and older) are overweight, and as many as 890 million, or 16%, live with obesity globally [9]. An observational study reported that during the COVID-19 pandemic, from December 2019 to January 2023, more than two billion people were overweight, and more than 650 million adults (340 million teenagers and 39 million children) were obese [7]. The prevalence of obesity increased in line with the forced lockdown during the pandemic [7]. Even though obesity and overweight may be avoided, the prevalence of obesity is expected to rise, with an estimated 167 million adults and children experiencing health problems as a result of obesity and overweight by 2025 [7]. Based on a study in 34 provinces in Indonesia, the highest prevalence of obesity and overweight is in adults (18 years and over), ranging between 10.4–30.1% and 19.2–46.3%, respectively, followed by the 5–12 year age group (obesity: 2–15.0%, overweight: 6.1–30.3%) [10].

Obesity causes an increase in fat tissue, which will trigger blood vessel resistance, leading to an increase in the heart's workload to pump blood [11]. Obesity will also activate the sympathetic nervous system, resulting in peripheral resistance and arterial vasoconstriction, which leads to increased blood pressure and if it persists for a long time, it will cause hypertension [11]. Hypertension is a leading cause of mortality, accounting for around 13% of all fatalities (7.1 million) [12]. Obese women are three times more likely to suffer hypertension than non-obese women [12]. As obesity is closely associated with blood pressure, a rising BMI increases the chance of rising blood pressure and developing high blood pressure or hypertension [3]. According to the findings of our study in Wistar rats, there was a positive association between BMI and blood pressure, with an increase in BMI of 1 g/cm and an increase in blood pressure of 2.75 mmHg [14]. BMI is positively connected to blood pressure; rising BMI raises systolic blood pressure (SBP), and BMI is a risk factor for SBP elevation [3]. The higher the BMI value, the higher the risk of hypertension in adult men and women, including children [11]. The positive relationship between BMI and blood pressure in the elderly has been extensively studied. However, the correlation between body weight and BMI with SBP and diastolic blood pressure (DBP) in young adults is still unknown [14]. Therefore, the aim of this study was to determine the correlation between body weight and BMI with SBP and DBP in young adults.

Methods

Study design, participants, and sampling

This study used a cross-sectional design. The research data was collected from August to September 2023 at the student dormitories at Universitas Syiah Kuala, Darussalam, Banda Aceh, Indonesia.

The study participants were Universitas Syiah Kuala students from the Class of 2023 who lived in the student dormitories. The inclusion criteria included adult males and females aged 18 to 22 years, healthy, undiagnosed with hypertension, not practicing regular exercise (not athletes), not on a particular diet to regulate body weight, and not currently on hormonal therapy. The sampling criteria were set to ensure the homogeneity of the study participants, which, in this case, was within the premise that the individuals engaged in similar activities and had similar food consumption patterns.

The sample selection was carried out using the total population sampling method. A total of 1120 research participants were selected for this study. However, 13 subjects were excluded due to the sampling criteria. In total, 1107 study participants (402 male and 705 female subjects) were included in this study.

Blood pressure examination

The blood pressure was measured using an Omron digital sphygmomanometer between 8:00 and 10:00 am. Subjects were instructed not to exercise, not to consume coffee for at least four hours prior to the blood pressure test, to get enough sleep (7–8 hours), and not to use anti-hypertensive medication. Blood pressure was measured while sitting, and the average number was calculated after measuring the blood pressure twice. Blood pressure checks were performed by doctors who were not members of the research team in order to ensure the objectivity of the findings. SBP and DBP were classified as follows: normal blood pressure, 120/80 mmHg; elevated blood pressure or pre-hypertension, 120–129/80 mmHg; and hypertension if >130/>80 mmHg [15,16].

Body weight, height and BMI examination

Body weight measurements were taken in the morning between 8:00 and 10:00 am. Subjects were instructed not to eat breakfast before body weight measurements. Subjects were advised to remove all accessories and wear as light clothing as possible to ensure data accuracy. Body weight was measured using a manual scale in kilograms (kg). Before being used for body weight measurements, the scales were calibrated. Height was measured using a Microtoise (stature meter) in units of meters (m), while BMI was calculated using the BMI formula (BMI = weight/height squared) in units of kilograms per meter squared (kg/m^2). The BMI category used was in accordance with the Asia-Pacific reference BMI category for adults: underweight (<18.80 kg/m^2), normo-weight (18.50–22.90 kg/m^2), overweight (23.00–24.90 kg/m^2), obese (>25 kg/m^2) [17].

Statistical analysis

The data was analyzed using the independent Student t-test, Chi-squared test, Pearson correlation test and simple linear regression. The association between body weight and BMI with blood pressure was investigated using a Chi-squared analysis. Pearson correlation analysis was carried out to determine the close correlation between body weight and BMI with blood pressure. The Pearson correlation test value is correlation (r): 0.80 = very strong, 0.60–0.799 = strong; 0.40–0.599 = medium; 0.20–0.399 = weak; and 0.00–0.199 = very weak.

Simple linear regression was carried out to determine the direction of the relationship between the independent and dependent variables by creating a correlation equation. The direction of positive correlation means that if there is an increase in the independent variable, it will be followed by an increase in the dependent variable, and vice versa.

Results

The subject characteristics

This study included 1,107 participants, including 402 men (36.31%) and 705 women (63.69%). The men's mean body weight (58.53±10.18 kg) and height (165.76±5.12 cm) were significantly heavier and taller than those of the women's (weight: 52.25±10.18 kg, height: 154.80±5.09 cm) with a p=0.001 (**Table 1**). However, no significant difference in BMI was observed between men and women (p=0.487). The SBP value in men was higher than in women (p=0.003) and slightly higher (121.12±12.79 mmHg) than the normal range (90–120 mmHg). The mean DBP value in men and women was not significantly different (p=0.748) and was within the normal range (60–80 mmHg).

Table 1. Characteristics of the study participants and their comparison between male and female (n=1,107)

Variable	Gender	n	Mean±SD	Minimum	Maximum	p-value
Age (year)	Male	402	18.45±0.88	18	22	0.310
	Female	705	18.19±0.83	18	22	
Weight (kg)	Male	402	58.53±10.18	34	98	0.001*
	Female	705	52.25±10.18	36	94	
Height (cm)	Male	402	165.76±5.12	156	183	0.001*
	Female	705	154.80±5.09	142	169	
BMI (kg/m^2)	Male	402	21.33±3.95	13.81	47.17	0.487
	Female	705	21.79±10.50	15.54	40.02	

SBP (mmHg)	Male	402	121.12±12.79	90	166	0.003
	Female	705	109.33±11.41	83	163	
DBP (mmHg)	Male	402	77.45±9.47	61	108	0.748
	Female	705	75.50±9.09	57	107	

*Statistically significant at p=0.05

Comparison of body mass index and blood pressure between men and women

The findings of the BMI assessment of the study participants are presented **Table 2**. Men were more likely to be underweight, overweight, or obese than women (23.88% vs 15.17% and 17.16% vs 15.04%, 16.67%, and 15.61%). Meanwhile, women (54.18%) outnumbered men (42.29%) in terms of normal body weight. The BMI examination also showed that the highest percentage of nutritional status problems experienced by men and women are underweight (18.33%), obese (15.98%), and overweight (15.83%) (**Table 2**).

Table 2. Body mass index (BMI) categories for young men and women

BMI category	Gender		Total n (%)	p-value
	Male n (%)	Female n (%)		
Underweight	96 (23.88)	107 (15.17)	203 (18.33)	0.001*
Normo-weight	170 (42.29)	382 (54.18)	552 (49.86)	0.001*
Overweight	69 (17.16)	106 (15.04)	175 (15.83)	0.044*
Obese	67 (16.67)	110 (15.61)	177 (15.98)	0.001*
Total	402 (100)	705 (100)	1107 (100)	

*Statistically significant at p=0.05

The percentage of normal blood pressure (normotensive) in both men (53.73%) and women (81.84%) was higher (67.78%) than those with pre-hypertension (20.04%) and hypertension (12.18%) (**Table 3**). Men had a higher proportion of having pre-hypertension (25.88%) and hypertension (20.39) than women (14.19% and 3.97%, respectively). In the young adult population, there was a significant association between gender and pre-hypertension (p=0.016) and hypertension (p=0.038).

Table 3. Blood pressure categories in young men and women

Blood pressure category	Gender		Total n (%)	p-value
	Male n (%)	Female n (%)		
Normotensive	216 (53.73)	577 (81.84)	793 (67.78)	0.001*
Pre-hypertension	104 (25.88)	100 (14.19)	204 (20.04)	0.016*
Hypertension	82 (20.39)	28 (3.97)	110 (12.18)	0.038*
Total	402 (100)	705 (100)	1107 (100)	

*Statistically significant at p=0.05

Association between body weight, body mass index (BMI), and blood pressure

There was a substantial association between nutritional status and blood pressure (p<0.001) (**Table 4**). Obese young adults were more likely to have pre-hypertension and hypertension than overweight individuals (38.73% and 50% vs 36.76% and 20%). Additionally, data indicated that 31.1% (55/177) of obese individuals also have hypertension.

Table 4. Association between obesity and high blood pressure at a young age

BMI category	Blood pressure category			Total n (%)	p-value
	Normal n (%)	Pre-hypertension n (%)	Hypertension n (%)		
Underweight	197 (24.84)	3 (1.47)	3 (2.72)	203 (9.67)	<0.001*
Normal	475 (59.89)	47 (23.04)	30 (27.28)	552 (36.74)	
Overweight	78 (9.84)	75 (36.76)	22 (20.00)	175 (22.20)	
Obese	43 (5.43)	79 (38.73)	55 (50.00)	177 (31.39)	
Total	793 (100)	204 (100)	110 (100)	1107 (100)	

After establishing a significant association between BMI and blood pressure categories, a Pearson correlation analysis was conducted to evaluate not only the direction of the association

but also the strength of the relationship between the BMI and blood pressure. The correlations between body weight, BMI with blood pressure in young men and women are presented in **Table 5**. According to these data, an increase in body weight and BMI was followed by an increase in blood pressure. These findings also show a significantly strong correlation between body weight and SBP (r=0.699, p<0.001), but only a significantly weak correlation between body weight and DBP (r=0.374, p<0.001). Similarly, BMI had a moderate correlation to SBP and a weak correlation with DBP (r=0.488 and r=0.358, respectively; both had p<0.001).

Table 5. Correlations between body weight and BMI with blood pressure in the young age group

Variable	n	Pearson correlation (r)	p-value
Correlation between body weight and SBP	1107	0.699	<0.001*
Correlation between body weight and DBP	1107	0.374	<0.001*
Correlation between BMI and SBP	1107	0.488	<0.001*
Correlation between BMI and DBP	1107	0.358	<0.001*

*Statistically significant at p=0.001

Simple linear regression was conducted and found that all equation values represent a positive sign, which means that there was a positive correlation between body weight and BMI with blood pressure (**Table 6**). This positive correlation suggested that an increase in body weight and BMI was also followed by an increase in SBP and DBP. The equation Y=74.079+0.725 (**Table 6**) indicated that an increase in body weight of 1 kg was followed by an increase in SBP of 0.725 mmHg. Likewise, DBP would increase by 0.318 mmHg with the equation (Y=58.874+0.318). Meanwhile, an increase in BMI of 1 kg/m^2 was followed by an increase in SBP and DBP of 1.6 mmHg and 0.834 mmHg (Y=78,630+1.618 and Y=58,170+0.834), respectively.

Table 6. Interpretation of the regression equation for the association between body weight and BMI on blood pressure in the young age group

Variable		Regression equation
Independent (X)	Dependent (Y)	
Body weight (n=1107)	Systolic blood pressure	Y=74.079+0.725
	Diastolic blood pressure	Y=58.874+0.318
Body mass index (n=1107)	Systolic blood pressure	Y=78.630+1.618
	Diastolic blood pressure	Y=58.170+0.834

Discussion

High BMI contributed to 4 million deaths and represented approximately 7.1% of all-cause deaths in 2015 [18]. Overweight and obesity, which were formerly thought to be issues exclusive to high-income countries, are now increasing in low- and middle-income countries [19-21]. Obesity is a global health issue in Indonesia, with an estimated prevalence of roughly 13%, while 39% of the population over the age of 18 is overweight [22,23]. The obesity prevalences in men and women were roughly 19.7% and 32.9%, respectively [24]. Meanwhile, the prevalences of overweight in men and women were 39% and 40% [24]. Increased adiposity raises the risk of obesity by around 65% in women and 78% in men [22].

Increasing body weight plays a major role in the occurrence of hypertension, and increasing BMI will lead to the risk of hypertension in all age groups [11,25,28,29]. Overweight and obesity account for 40% of new instances of hypertension [25]. Obesity also contributes to 65–78% of primary hypertension [26,27]. It is estimated that the risk of hypertension increases by around 20–30% for every 5% increase in body weight [4]. The prevalence of hypertension is significantly higher in obese people, with a prevalence reaching 60–77% compared to normo-weight people, which is around 34% [26,28]. A study in 2015 found that the global prevalence of hypertension in adulthood is more experienced by men than women (24.1% of men and 20.1% of women) [28].

Hypertension is characterized by a chronic, continual rise in blood pressure [24,30]. Hypertension is the leading cause of premature death worldwide, and an estimated 1.13 billion people live with hypertension [31]. Data from 2015 indicated that as many as 1 in 4 men and 1 in 5 women have hypertension [31]. The World Health Organization's most current data indicates that one in three adults worldwide suffers from hypertension [32]. Hypertension was the third

leading cause of mortality in Indonesia [33]. The prevalence of hypertension in adults over 18 years in the country was 25.8% in 2013 [24]. Hypertension is twice as common in persons aged 20 to 39 years who are overweight compared to those with normal weight [34]. Risk factors for hypertension are older age, genetics, lifestyle (diet and physical inactivity), and obesity [35,36].

In this study, we found that an increase in body weight is followed by an increase in SBP and DBP in both young men and women. Moreover, an increase in BMI of 1 kg/m^2 in people aged 18–22 years old results in an increase in SBP and DBP of 1.6 mmHg and 0.834 mmHg, respectively. A previous study stated that every increase in body weight of 4.5 kg will followed by an increase in SBP of 4 mmHg [34]. SBP and DBP are reduced by 4.4 and 3.6 mmHg, respectively, for every 5 kg loss in body weight [22]. Increasing body weight will result in an increase in SBP and DBP, making it a high-risk factor for hypertension [37-39]. The buildup of visceral fat causes a larger release of free fatty acids into the systemic circulation, leading to insulin resistance and a decrease in endothelial nitric oxide (NO) secretion [28]. NO is a potent vasodilator that plays a crucial role in blood pressure regulation. Angiotensin-converting enzyme (ACE) levels, aldosterone levels, and renin activity in obese people are higher than in normo-weight people [26,40]. Renin-angiotensin-aldosterone system (RAAS) activity causes systemic vasoconstriction due to increased angiotensin II production. Angiotensin II increases fluid retention and sodium reabsorption in the kidneys, resulting in intravascular volume expansion and hypertension [26,40]. RAAS raises blood pressure by increasing sympathetic nervous system activity and sympathetic tone [26].

The relationship between BMI and hypertension is a crucial issue that is currently attracting public attention in developing countries because the increased risk of morbidity and mortality due to cardiovascular disease in hypertensive people with overweight and obesity has been widely reported [12,22,41], which is around 10.4 million deaths annually [26]. Obesity is an independent risk factor for the development of hypertension [39,42]. The global population with high blood pressure rose from 594 million in 1975 to 1.13 billion in 2015, and the illness contributed to 9.4 million deaths worldwide [43]. Blood pressure generally has a positive linear relationship with BMI [44,45]. Since there is a strong correlation between blood pressure and body weight, lowering body weight will also lower blood pressure [22,46,47]. Reducing body weight by approximately 5 kg can lower DBP by 3.6 mmHg and SBP by 4.4 mmHg [22]. Obesity is multifactorial and generally occurs due to an imbalance between energy intake (diet) and energy expenditure (physical activity) [6,9,48]. A sedentary lifestyle is a trigger factor for the increasing incidence of overweight and obesity [49,50]. Physical inactivity is the cause of around 6%–10% of non-communicable diseases, including obesity, hypertension, type 2 diabetes, coronary heart disease, and also causes premature death in 9% of cases [51].

The pathogenesis of hypertension linked with obesity is extremely complicated [28,46]. Various factors that trigger hypertension associated with obesity are vascular endothelial dysfunction, which results in disruption of the production of vasoactive substances and disruption of molecular signaling, the leptin-melanocortin pathway, increased oxidative stress, insulin resistance, kidney injury, and sleep apnea syndrome [25,46]. Leptin and adiponectin are key hormones that modulate blood pressure and the arterial tone produced by adipose tissue [52]. Obesity lowers adiponectin levels while increasing leptin levels. High amounts of leptin enhance sympathetic tone, which raises blood pressure [52]. Adipose tissue produces pro-inflammatory cytokines (tumor necrosis factor-α and interleukin-6), which can induce endothelial dysfunction and insulin resistance [4,52]. Endothelial dysfunction results in impaired secretion of vasodilators and vasoconstrictors, resulting in hypertension. Endothelin is a potent vasoconstrictor secreted by the endothelium, so increased secretion will increase the vasoconstrictive effect of blood vessels, thereby triggering hypertension [52].

Conclusion

Blood pressure and nutritional status are tightly related. There is a substantial positive association between body weight with SBP and DBP, and between BMI and SBP and DBP in young men and women. Every 1 kg increase in weight is accompanied by a 0.725 mmHg increase in SBP and a 0.318 mmHg increase in DBP. Meanwhile, an increase in BMI of 1 kg/m^2 will result in a modest increase in SBP and DBP, approximately 1.6 mmHg and 0.834 mmHg.

Ethics approval

This study was approved by the Ethical Approval Committee of Faculty of Medicine, Universitas Syiah Kuala, Indonesia with the ethical approval letter 110/EA/FK/2023. Subjects agreed voluntarily by filling out written informed consent before participating in all research procedures.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

How to cite

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