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RESEARCH **Open Access**

The Association between Waist-to-Height Ratio and Vascular Characteristics in Normal Body Mass Index

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Abstract
Cardiovascular disease (CVD) is the leading cause of death globally. Male medical students are highly susceptible to CVD risk due to high academic stress and hormonal profiles. Although body mass index (BMI) is commonly used to assess nutritional status, this parameter cannot detect body fat distribution, especially visceral fat, which is more likely to cause CVD than subcutaneous fat. This study aims to investigate the relationship between Waist-to-Height Ratio (WHtR) and vascular characteristics in male medical students with normal BMI. This study used a cross-sectional design and a total sampling technique. Sample characteristics were collected using a questionnaire, while WHtR was measured using a waist circumference tape and a microtoise. Vascular characteristics were measured using an accelerated photoplethysmograph (APG) analyzer, SA-3000P. The participants were 49 male medical students aged 18-22 years, with normal BMI, light or moderate physical activity, and good sleep quality. The results of this study showed that the proportions of suboptimal aging index, arterial elasticity, peripheral elasticity, and wave type level 2 were higher in the high-risk WHtR group than in the normal WHtR group. However, statistical analysis using the Chi-square test indicated that these differences were not statistically significant ($p = 0.291$; $p = 0.742$; $p = 0.062$; $p = 0.648$, respectively). These findings emphasize the importance of individuals with high-risk WHtR adopting a healthy lifestyle, including regular exercise and a healthy diet, to maintain vascular health.

Keywords: Aging Index, Arterial Elasticity, Peripheral Elasticity, Wave Type, Waist-to-Height Ratio.

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1. INTRODUCTION

Cardiovascular disease (CVD) remains a global health problem. In 2023, CVD morbidity affected an estimated 626 million cases and caused 19.2 million deaths, representing an increase of 1.9 million deaths since 2019; more than 75% of these deaths occurred in low- and middle-income countries. A total of 347 million (79.6%) of CVD morbidity and mortality cases in 2023 were caused by modifiable risk factors (Estebsari et al., 2024; Global et al., 2025).

University students, including both non-medical and medical students, constitute a substantial proportion of the young adult population and are increasingly recognized as a group vulnerable to early development of CVD (Estebsari et al., 2024). Lifestyle-related risk factors are common among university students from different fields of study. Recent cross-sectional studies show that modifiable risk factors for non-communicable diseases are highly prevalent in this population. Many students present multiple risk factors, including physical inactivity, prolonged sedentary behavior, and unhealthy dietary patterns. These findings suggest that lifestyle-related cardiovascular risk factors are broadly prevalent among young adults in higher education (Cicekli & Gokce Eskin, 2025). The transition to university life is often a critical period characterized by behavioral and lifestyle changes. University students generally have more freedom to make choices about their lives than those who are usually under parental supervision. It could make them more likely to engage in risky behaviors. Among medical students, the combination of intensive academic workloads and psychological stress may make them more likely to live unhealthy lifestyles, which raises their risk of CVD (Mukhopadhay et al., 2021). Therefore, university students, particularly medical students, represent a relevant population for early identification of cardiovascular risk and for developing preventive measures in young adults.

Sex-related differences in body fat distribution may also contribute to variations in cardiovascular risk during young adulthood. A study on gender differences in visceral fat area showed that males had higher visceral fat than premenopausal females. This condition is caused by androgen hormones, such as testosterone, which are more active in males than in females, promoting the formation of fat cells in the abdominal area while inhibiting their formation in the hips and thighs (Cao et al., 2024). Consequently, young adult males may be more susceptible to central obesity.

In addition, extensive societal transformations have exacerbated the increasing burden of cardiometabolic risk. Economic growth and industrialization have triggered changes in diet and lifestyle, which have led to a high prevalence of overweight and obesity (Bakhtiyari et al., 2022). Previous studies have shown that overweight and obesity, especially central obesity, characterized by high visceral fat accumulation, are strong predictors of cardiometabolic risk (Xue, Yang, & Liu, 2024). The accumulation of visceral fat can alter vascular characteristics by increasing proinflammatory cytokine activity (Hennigs, Matuszcak, Trepel, & Körbelin, 2021). Changes in vascular characteristics are also important indicators in assessing CVD risk. Pulse wave velocity (PWV), stiffness index, vascular resistance, and vascular aging are the main structural and functional biomarkers in assessing changes in vascular characteristics (Pilz et al., 2024).

Although BMI is currently the most widely used parameter for determining obesity status, it cannot provide an overview of body fat distribution, especially visceral fat, which is more likely to cause CVD than subcutaneous fat (Erdoğan et al., 2025). Individuals with central obesity, even if they have a normal BMI, have a 27.9% higher risk of CVD compared to individuals who have a normal waist circumference and BMI (Xue et al., 2024).

Therefore, other anthropometric parameters are needed that have been proven to be more effective and efficient in detecting the risk of central obesity. Waist-to-height ratio (WHtR) is the ratio of waist circumference to height and can reflect visceral fat, and is a better cardiometabolic predictor than other anthropometric parameters, such as waist circumference

(WC) and waist-to-hip ratio (WHR) (Zhang et al., 2022). Although previous studies have extensively discussed the relationship between WHtR and CVD risk, most of these studies were conducted on obese populations with high WHtR. Research on WHtR and its relationship with vascular characteristics, which are also indicators of CVD risk in populations with normal BMI and high WHtR, particularly in younger populations, is still limited.

Investigating this relationship in young adults is important because early vascular changes may develop silently during this life stage, even in individuals who appear metabolically healthy based solely on BMI. University students, particularly male medical students, represent a relevant population for such investigation because academic demands and lifestyle patterns during university years may increase exposure to cardiovascular risk factors. Additionally, this study presents novelty by examining the association between WHtR and vascular characteristics in individuals with normal BMI using an accelerated photoplethysmography (APG) analyzer. By focusing on central adiposity in individuals who are generally considered to have normal nutritional status, this study aims to provide additional evidence on the potential role of WHtR in detecting early vascular changes in young adults. Therefore, this study aims to investigate the relationship between Waist-to-Height Ratio (WHtR) and vascular characteristics in male medical students with normal BMI.

2. RESEARCH METHOD

This study used a cross-sectional design with a total sampling technique. The research population consisted of all active students of the Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta (FM UPNVJ). The sample size was calculated using the formula for a hypothesis test of a proportion difference with $\alpha = 5\%$, $\beta = 80\%$, P1 = 0.603, and P2 = 0.211. Based on these calculations, the required sample size was 48 male students from the Faculty of Medicine at UPN "Veteran" Jakarta.

Participants were selected based on the following inclusion criteria: male medical students aged 18-22 years with light or moderate physical activity levels and good sleep quality. Participants who smoked, consumed alcohol, were taking medications that affect the cardiovascular system, had high blood pressure, or had a history of heart disease or metabolic disease were excluded.

Participant characteristics were collected using a questionnaire that included demographic information, the Global Physical Activity Questionnaire (GPAQ), and the Pittsburgh Sleep Quality Index (PSQI). The GPAQ is an instrument developed by the World Health Organization to assess adults' physical activity over the past week. The GPAQ has moderate-to-high reliability (kappa = 0.67-0.73) and moderate validity (r = 0.48) (Panthoja & Wibowo, 2022). The PSQI is an instrument designed to assess an individual's sleep quality over the past month. The PSQI has reliability (Cronbach's Alpha = 0.79) and validity (r = 0.89) (Alim, 2015). Blood pressure was measured using an Omron digital sphygmomanometer. WHtR was measured using a waist circumference tape (OneMed Waist Ruler OD 235) and a microtoise. Vascular characteristics were examined using a calibrated Accelerated Photoplethysmography (APG) Analyzer SA-3000P.

Waist circumference is measured at the midpoint between the rib cage and the iliac crest when the participant is in an anatomical position. At the same time, height is measured with the participant standing upright, facing the researcher, with their back against the microtoise. Next, the microtoise is pulled down until it touches the participant's head, while vascular characteristics are measured using an accelerated photoplethysmograph (APG) analyzer, SA-3000P. The vascular characteristic examination procedure is performed in a well-lit, quiet environment at normal room temperature. Participants must not consume caffeine or drugs that can stimulate the nervous system at least 3 hours before the examination, must not engage in physical activity at least 2 hours before the examination, and must not wear accessories during the examination. During the procedure, the participant is seated quietly, with both legs straightened, not moving or talking, ensuring that both eyes remain open and breathing remains regular. Then, turn on the device, enter the participant's data, and attach the finger probe to the left index finger for 3 minutes.

Data analysis was performed using SPSS software. This study used the Chi-square test to analyze the relationship between WHtR and vascular characteristics. If the Chi-square test is not applicable, Fisher's exact test or cell merging is used. A p-value < 0.05 will be considered statistically significant, indicating a relationship between WHtR and vascular characteristics among male medical students at the Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jakarta.

This study was conducted at the Medical Education and Research Center (MERCE) UPNVJ in November-December 2025. This study obtained ethical approval from the UPNVJ Research Ethics Committee (Number: 321/XII/2025/KEP).

3. RESULTS AND DISCUSSION

A total of 49 medical students participated in this study, aged 18 to 22 years. The largest age groups were 20 and 21 years, each comprising 13 participants (26.5%). Participants aged 19 years accounted for 10 individuals (20.4%), followed by those aged 18 years with 8 participants (16.3%). The smallest proportion was observed among 22-year-old participants, with 5 individuals (10.2%). Although participants were young, physiologically aging still contributed to changes in vascular characteristics. Endothelin production increases, while nitric oxide (NO) decreases with age, making the endothelium more sensitive to vasoconstrictors but less responsive to vasodilators such as acetylcholine (Li et al., 2023). Vascular changes can occur earlier in young people with cardiometabolic risk factors. Studies involving participants aged 16 years and with cardiometabolic risk factors showed a thickening of the vascular tunica intima and media of approximately 2.78 µm per year (Staudt et al., 2020). This thickening is exacerbated by increased oxidative stress and the activation of inflammatory responses, which drive local totipotent cells to differentiate into vascular smooth muscle cells (VSMCs). VSMCs subsequently increase extracellular matrix (ECM) synthesis, thereby increasing arterial stiffness (Li et al., 2023).

Body mass index (BMI) and WHtR are commonly used anthropometric indicators to assess nutritional status and central obesity risk. According to the classification of the World Health Organization, the normal BMI range for adults is 18.5-24.9 kg/m2. In contrast, WHtR values < 0.50 are considered normal, while values ≥ 0.50 indicate an increased central obesity or high-risk WHtR (Ashwell & Gibson, 2016). Based on WHtR, most participants were categorized as having a normal WHtR, accounting for 29 students (59.2%). Meanwhile, 20 participants (40.8%) were categorized as having high WHtR risk. In contrast, a study at FKIK UAJ found that nearly 60% of males had a high WHtR. This difference is thought to be due to differences in participants' characteristics. The participants in this study were males with normal BMI, whereas 40.5% of participants at FKIK UAJ had overweight or obese BMI. Overweight and obese individuals have higher abdominal fat than individuals with a normal BMI (Kie, Vetinly, Astiarani, & Santi, 2024).

Regarding physical activity levels, the majority of participants reported engaging in moderate physical activity, accounting for 42 individuals (85.7%). In contrast, only 7 participants (14.3%) were classified as having low levels of physical activity. These findings are consistent with research conducted at Universitas Negeri Makassar, which found that 64% of 200 students had low to moderate levels of physical activity (Anwar, Hasmyati, & Zulfikar, 2024). Research results in Pakistan also show that 78.9% of medical students have low to moderate levels of physical activity (Khan et al., 2022). This pattern is also reflected in the broader adult population. A study involving adults (>18 years) from 31 provinces in China reported a prevalence of insufficient physical activity of 23.3%, indicating that more than one in five adults had low physical activity levels. Male individuals, young adults, and highly educated individuals were identified as groups requiring greater attention in physical activity promotion (Gao et al., 2023). Therefore, strategies to promote physical activity should target young adult populations to improve physical activity-related health outcomes.

The APG is a non-invasive method that uses a light source, typically a light-emitting diode (LED), and a photodetector to measure changes in blood volume in microvascular tissue, especially in the skin. When light is incident on the skin, some of it is absorbed, scattered, or reflected, depending on the blood volume in the tissue. These changes in blood volume are detected by the photodetector and converted into a waveform. Several vascular characteristics can be derived from the APG waveform. These include wave type, arterial elasticity, peripheral elasticity, and the aging index—normal vascular conditions characterized by good arterial elasticity and efficient peripheral circulation. In contrast, suboptimal vascular conditions indicate reduced arterial elasticity, impaired peripheral circulation, and increased vascular stiffness associated with vascular aging (Park et al., 2022).

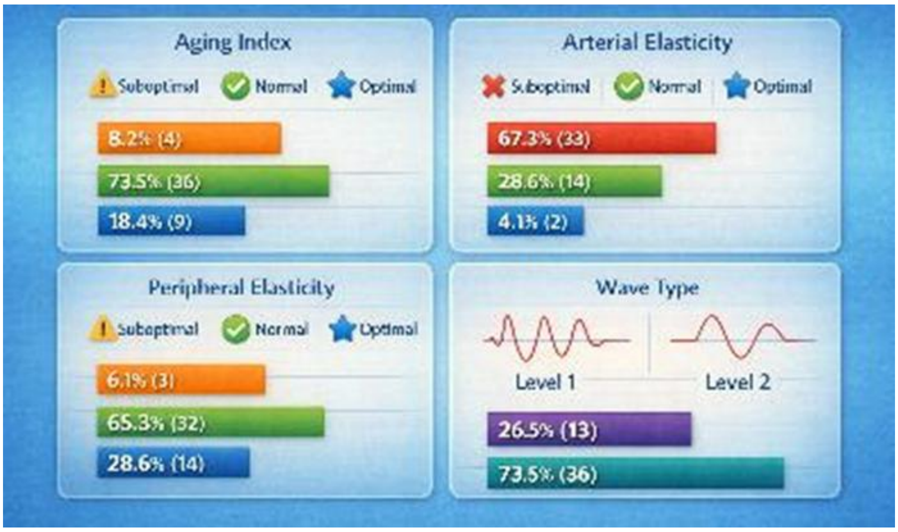

Figure 1 Vascular Characteristics of Participants

Table 1 shows that there is no significant relationship between WHtR and aging index (p = 0.291). These findings are consistent with research in Brazil on healthy adult populations, which showed that the relationship between WHtR and vascular aging was inconsistent, depending on the vascular biomarkers used. WHtR showed a significant association with subclinical atherosclerosis measured by Coronary Artery Calcium (CAC), but not with Carotid Intima-Media Thickness (CIMT), which better reflects changes in Early Vascular Aging (EVA) (Raele et al., 2020).

Table 1. Association between WHtR and Vascular Characteristics (n = 49)

Vascular Characteristic	WHtR Category	Suboptimal n (%)	Normal+Optimal n (%)	Total n (%)	p-value
Aging Index	High Risk	3 (15.0)	17 (85.0)	20 (100)	0.291
	Normal	1 (3.4)	28 (96.6)	29 (100)	
Arterial Elasticity	High Risk	14 (70.0)	6 (30.0)	20 (100)	0.742
	Normal	19 (65.5)	10 (34.5)	29 (100)	
Peripheral Elasticity	High Risk	3 (15.0)	17 (85.0)	20 (100)	0.062
	Normal	0 (0.0)	29 (100.0)	29 (100)	
Wave Type	High Risk	6 (30.0)	14 (70.0)	20 (100)	0.648
	Normal	7 (24.1)	22 (75.9)	29 (100)	

Vascular aging is a multifactorial process (Vatner et al., 2021). According to EVA theory, vascular aging is a progressive process that requires chronic exposure to risk factors to cause significant structural and biomechanical changes in the arterial wall (González, Romero-Orjuela, Rabeya, del Castillo, & Echeverri, 2023). In young healthy adults, early vascular changes are generally functional and reversible. The damage begins with endothelial dysfunction, which disrupts vasoregulation and endothelial homeostasis, leading to decreased vasodilation, proinflammatory conditions, and prothrombotic tendencies. However, these changes are not yet accompanied by permanent structural remodeling (Micieta, Cehakova, & Tonhajzerova, 2025).

This study found a higher proportion of suboptimal aging index in the high-risk WHtR group than in the normal WHtR group, although the difference was not significant (15% vs. 3.4%; $p = 0.291$). These findings indicate that high-risk WHtR can cause early vascular disorders, even in young participants.

One of the most effective strategies for reducing central obesity and preventing early vascular disorders is lifestyle modification. Regular exercise, particularly moderate aerobic exercise, has been shown to improve endothelial function, reduce arterial stiffness, and modulate cardiometabolic risk factors associated with vascular dysfunction. In addition, adopting a balanced diet rich in fruits, vegetables, whole grains, and healthy fats may help reduce abdominal fat accumulation and improve vascular health by lowering inflammation and oxidative stress (Herzog et al., 2025). Early identification and management of cardiovascular risk factors are also essential, as exposure to these factors during young adulthood can accelerate the development of subclinical atherosclerosis and increase long-term cardiovascular risk (Devesa et al., 2023). Therefore, detecting elevated WHtR may provide an opportunity to implement preventive intervention early, including lifestyle modifications.

The research shows that there is no significant relationship between WHtR and arterial elasticity ($p = 0.742$) or peripheral elasticity ($p = 0.062$). Physiologically, vascular elasticity is determined by the balance between elastin and collagen in the arterial wall. In young people, elastin content remains dominant, so vascular adaptation remains good (Vatner et al., 2021). A progressive decrease in elasticity and remodeling of the vascular wall especially occurs after chronic exposure to cardiovascular risk factors, such as obesity, type 2 diabetes, and chronic hypertension. Chronic hypertension can trigger excess collagen production, leading to stiffer arteries (Kim, 2023).

Therefore, a decrease in vascular elasticity generally only becomes significant in old age due to an imbalance between collagen and elastin, or in young individuals with chronic exposure to cardiovascular risk factors (Li et al., 2023). In contrast, the participants in this study were young adults aged 18-22 years old and without exposure to cardiovascular risk factors. The high-risk WHtR, reflecting central obesity, in the participants of this study is thought not to have persisted long enough for visceral fat accumulation to reach the duration and degree necessary to trigger vascular structural changes.

In line with the findings on the aging index, although no significant relationship was observed between WHtR and arterial or peripheral elasticity, there was a tendency toward a higher proportion of suboptimal arterial elasticity in the high-risk WHtR group compared with the normal WHtR group (70% vs. 65.5%). The proportion of suboptimal peripheral elasticity was also greater in the high-risk WHtR group compared to the normal WHtR group (15% vs. 0%). However, these differences in proportion were not statistically significant ($p = 0.742$ and $p = 0.062$).

Visceral fat is metabolically active and has a high potential to trigger inflammatory processes (Alser, Naja, & Elrayess, 2024). Visceral fat tissue has a richer blood supply, larger adipocytes, and richer immune cell infiltration than subcutaneous fat. Immune cell infiltration, such as interleukin-6 (IL-6), interleukin-1β, tumor necrosis factor-α (TNF-α), leptin, and stimulation of monocyte chemoattractant protein-1 (MCP-1), causes a decrease in adiponectin production and creates a proinflammatory environment that plays a role in autocrine and paracrine interactions with endothelial cells, fibroblasts, and immune cells. This process can trigger mild inflammation and early vascular dysfunction (Hennigs et al., 2021; Stranahan, 2022).

The Chi-square test result shows that there is no significant relationship between WHtR and wave type (p=0.648). Wave type is formed from the interaction between the forward pulse wave generated by heart contraction and the reflected wave originating from branching and changes in peripheral blood vessel impedance. Thus, the wave type produced is influenced by the interaction among hemodynamic factors, including ventricular stroke volume, vascular compliance, systemic vascular resistance, and other cardiovascular system characteristics (Jin, Geng, Zhang, Zhang, & Ye, 2023).

The classification of APG wave patterns reflects peripheral vascular condition and circulatory function. The waveforms are categorized into several levels representing different stages of vascular health. Wave type level 1 indicates normal vascular function with optimal blood circulation. Wave type level 2 is still considered good, but it indicates early vascular disorders that can develop into thrombosis later on. Higher wave types (level 3-7) indicate progressively impaired circulation, vascular aging, and possible vascular dysfunction or obstruction (Medicore, 2017).

This study found a higher proportion of wave type level 2 in the high-risk WHtR group than in the normal WHtR group, although the difference was not statistically significant (30% vs. 24.1%; p=0.648). WHtR plays a role in decreasing compliance and increasing systemic resistance through increased proinflammatory cytokines, but does not directly affect the wave type produced (Hennigs et al., 2021). Most of the participants had wave type level 2, namely 48 participants (72.73%).

Physiologically, thrombus formation can be prevented by the antithrombotic function of the vascular endothelium. Normal endothelium inhibits platelet adhesion and activation of the coagulation cascade through the expression of anticoagulant factors such as thrombomodulin, tissue factor pathway inhibitor (TFPI), and heparan sulfate, as well as through the production of NO and prostaglandin I2 (PGI2), which act as vasodilators and anti-aggregants (Donadini et al., 2025).

According to Virchow's classical triad theory, damage to the endothelium can induce the production of proinflammatory cytokines, causing endothelial cells to express procoagulant factors such as tissue factor (TF), von Willebrand factor (vWF), plasminogen activator inhibitor-1 (PAI-1), and adhesion molecules that can mediate interactions between the endothelium and platelets and immune cells (Schulman, Makatsariya, Khizroeva, Bitsadze, & Kapanadze, 2024). This early, subclinical endothelial dysfunction can occur even in the absence of permanent structural changes, leading to hemodynamic changes reflected in wave type (Lamprou et al., 2023).

4. CONCLUSION

This study shows that there is no significant relationship between WHtR and vascular characteristics. However, participants with high-risk WHtR tend to have suboptimal vascular characteristics (aging index, arterial elasticity, and peripheral elasticity) compared with those with normal WHtR. This study also found a higher proportion of participants with wave type level 2 in the high-risk WHtR group than in the normal WHtR group, although this difference was not significant. Therefore, young adults with high WHtR are advised to adopt a healthy lifestyle, including regular exercise and a healthy diet, to achieve a normal WHtR and maintain vascular health.

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