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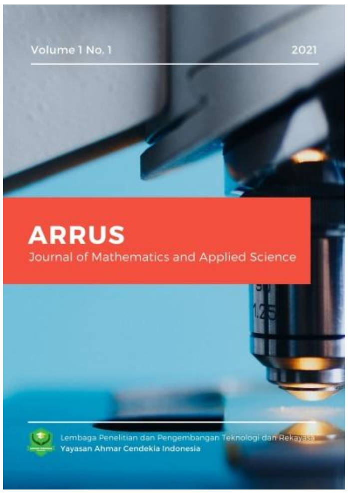

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RESEARCH ARTICLE

Body Composition Indicators and Cardiovascular Health Score among Young Adults: An Early Cardiovascular Aging Perspective

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Abstract: This study examined the association between body composition indicators and cardiovascular health score among young adults from an early cardiovascular aging perspective. A cross-sectional analytic study was conducted using de-identified data from 44 young adults, consisting of 35 females and 9 males. Body composition indicators included body mass index, waist circumference, body fat percentage, skeletal muscle percentage, and visceral fat index. Cardiovascular and metabolic markers included systolic blood pressure, diastolic blood pressure, total cholesterol, and random blood glucose. Cardiovascular health was assessed using a modified Life's Essential 8-based cardiovascular health score. Spearman correlation and age- and sex-adjusted linear regression analyses were performed. Higher adiposity indicators were significantly associated with lower cardiovascular health score, including body mass index, waist circumference, body fat percentage, and visceral fat index. Visceral fat index showed the strongest inverse association with cardiovascular health score. In contrast, skeletal muscle percentage was positively associated with cardiovascular health score. Adiposity indicators were also associated with less favorable blood pressure profiles, particularly systolic blood pressure. These findings suggest that body composition indicators, especially visceral fat index and skeletal muscle percentage, may provide practical insight into early cardiovascular health variation among young adults.

Keywords: Body Composition, Cardiovascular Health, Young Adults, Visceral Fat, Early Cardiovascular Aging

1. Introduction

Cardiovascular disease remains the leading cause of death worldwide and continues to represent a major challenge for health systems, particularly in low- and middle-income

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countries. The World Health Organization reported that an estimated 19.8 million people died from cardiovascular diseases in 2022, representing approximately 32% of all global deaths, with heart attack and stroke accounting for most of these deaths (World Health Organization, 2025). More than three quarters of cardiovascular deaths occur in low- and middle-income countries, indicating that prevention must be strengthened not only in high-income settings but also in countries undergoing rapid demographic, nutritional, and lifestyle transitions.

Indonesia faces a substantial cardiovascular burden. World Heart Federation data estimated 765,660 cardiovascular deaths in Indonesia in 2021 and placed Indonesia among the countries with relatively high age-standardized cardiovascular mortality (World Heart Federation, n.d.). A national burden analysis using Global Burden of Disease data also reported that cardiovascular mortality, morbidity, and prevalence increased in Indonesia from 1990 to 2019, with stroke and ischemic heart disease remaining dominant contributors to cardiovascular burden (Muharram et al., 2024). These findings suggest that cardiovascular disease is not only a global health issue but also an urgent national priority in Indonesia.

The urgency of prevention is increasingly relevant in young adults because cardiometabolic risk may begin long before clinical cardiovascular disease becomes apparent. Conventional short-term cardiovascular risk estimation may underestimate risk in younger populations, while exposure to elevated blood pressure, dyslipidemia, adiposity, impaired glucose regulation, smoking, physical inactivity, and poor diet can accumulate over time. The 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease recommends risk factor assessment and lifetime risk consideration in adults aged 20–39 years, supporting the importance of early prevention before overt disease develops (Arnett et al., 2019).

Body composition may provide practical insight into early cardiovascular health variation. Body mass index is widely used because it is simple and accessible, but it does not distinguish between fat mass, skeletal muscle mass, and fat distribution. The American Heart Association scientific statement on obesity and cardiovascular disease emphasizes that adiposity contributes to hypertension, dyslipidemia, diabetes, and other cardiovascular risk factors, while abdominal adiposity may provide additional risk information beyond BMI alone (Powell-Wiley et al., 2021). This is particularly relevant in Asian populations, where cardiometabolic risk may occur at lower BMI levels than in Western populations (WHO Expert Consultation, 2004).

Despite the growing emphasis on early prevention, evidence on the relationship between body composition indicators and cardiovascular health score among young adults remains limited, particularly in the Indonesian context. Therefore, this study aimed to examine the association between body composition indicators and cardiovascular health score among young adults from an early cardiovascular aging perspective. Specifically, the study assessed adiposity indicators, skeletal muscle percentage, cardiometabolic markers, and cardiovascular health score using a preventive framework a ligned with the American Heart Association's Life's Essential 8 construct (Lloyd-Jones et al., 2022).

2. Literature Review

2.1. Cardiovascular Health in Young Adults

Cardiovascular disease prevention increasingly emphasizes the preservation of cardiovascular health before clinical disease becomes apparent. This approach is particularly important in young adults, because conventional short-term cardiovascular risk estimation may underestimate lifetime risk in this age group. The 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease recommends that adults aged 20–39 years should be assessed for risk factors and encouraged to maintain healthy lifestyle behaviors across the life course (Arnett et al., 2019). From this perspective, young adulthood represents a critical

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period for identifying early cardiometabolic risk patterns before hypertension, dyslipidemia, diabetes, vascular stiffness, and clinical cardiovascular disease become established.

The American Heart Association's Life's Essential 8 provides a contemporary framework for assessing cardiovascular health. This framework includes eight components: diet, physical activity, nicotine exposure, sleep health, body mass index, blood lipids, blood glucose, and blood pressure. The score ranges from 0 to 100, with higher scores indicating better cardiovascular health (Lloyd-Jones et al., 2022). Life's Essential 8 is useful for young adult research because it shifts the focus from disease diagnosis to cardiovascular health preservation. Higher Life's Essential 8 scores have also been associated with lower all-cause and cardiovascular mortality, supporting its relevance as a preventive cardiovascular health framework (Sun et al., 2023).

2.2. *Body Composition Beyond Body Mass Index*

Body composition is an important component of cardiovascular health assessment. Body mass index remains widely used because it is simple, inexpensive, and practical, but BMI does not distinguish between fat mass, skeletal muscle mass, and fat distribution. This limitation is clinically relevant because individuals with similar BMI values may have different cardiometabolic profiles depending on visceral adiposity, body fat percentage, waist circumference, and skeletal muscle percentage. The American Heart Association scientific statement on obesity and cardiovascular disease emphasizes that obesity contributes directly to cardiovascular risk factors, including dyslipidemia, type 2 diabetes, hypertension, and sleep disorders (Powell-Wiley et al., 2021).

Adiposity distribution is particularly important. Visceral adipose tissue is metabolically active and contributes to insulin resistance, low-grade inflammation, dyslipidemia, endothelial dysfunction, and blood pressure elevation. Despréss (2012) emphasized that body fat distribution, especially visceral adiposity, is a major determinant of obesity-related cardiovascular risk. Therefore, waist circumference and visceral fat index may provide clinically meaningful information beyond BMI alone. This is also relevant in Asian populations, where cardiometabolic risk may occur at lower BMI values than in Western populations; therefore, Asian-specific BMI cutoffs are often recommended for cardiometabolic risk interpretation (WHO Expert Consultation, 2004).

Body fat percentage provides another useful perspective because it more directly reflects adiposity than BMI. However, body fat percentage should be interpreted with attention to sex because women physiologically have higher body fat percentages than men. Gallagher et al. (2000) proposed sex- and age-specific body fat percentage ranges, supporting the principle that body fat percentage should not be interpreted using one universal cutoff for all adults. In the present study, body fat percentage is therefore treated as a continuous analytical variable, while sex-specific body fat ranges are used descriptively to support clinical interpretation.

2.3. *Skeletal Muscle and Cardiometabolic Resilience*

Skeletal muscle is increasingly recognized as a metabolically active tissue relevant to cardiovascular health. Beyond its mechanical role, skeletal muscle contributes to glucose uptake, insulin sensitivity, lipid metabolism, inflammatory regulation, and functional reserve. Low skeletal muscle may therefore reflect reduced cardiometabolic resilience, particularly when accompanied by excess adiposity. Recent cardiovascular literature has emphasized that sarcopenia is associated with adverse cardiovascular outcomes, frailty, reduced functional capacity, and poorer prognosis in several cardiovascular conditions (Damluji et al., 2023).

From a longevity perspective, the balance between adiposity and skeletal muscle is more informative than body weight alone. Higher adiposity may reflect metabolic stress, whereas higher skeletal muscle percentage may indicate better metabolic reserve and physical

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resilience. This concept is relevant even in young adults because early cardiovascular health variation may appear before overt disease. Therefore, evaluating BMI, waist circumference, body fat percentage, visceral fat index, and skeletal muscle percentage together may provide a more complete view of early cardiovascular health than evaluating BMI alone.

2.4. *Early Cardiovascular Aging Perspective*

The early cardiovascular aging perspective provides the conceptual basis for this study. Cardiovascular aging is characterized by gradual changes in vascular and metabolic function, including arterial stiffening, endothelial dysfunction, blood pressure elevation, metabolic dysregulation, and reduced cardiovascular reserve. Early vascular aging refers to the presence of vascular or cardiometabolic changes earlier than expected for chronological age, often related to cumulative exposure to unfavorable risk factors (Nilsson, 2020). Although direct measures of vascular aging, such as pulse wave velocity or vascular age, were not included in this study, the framework remains useful for interpreting early variation in cardiovascular health among young adults.

In this article, early cardiovascular aging is used as an interpretive framework, not as a diagnostic claim. The study does not claim to diagnose accelerated cardiovascular aging. Instead, it examines whether body composition indicators are associated with cardiovascular health score and cardiometabolic markers. This approach is consistent with preventive cardiology, in which early identification of unfavorable risk patterns is important before clinical cardiovascular disease develops (Arnett et al., 2019; Lloyd-Jones et al., 2022).

2.5. *Conceptual Framework and Hypotheses*

The conceptual framework of this study links body composition indicators with cardiovascular health through cardiometabolic pathways. Higher adiposity indicators, including BMI, waist circumference, body fat percentage, and visceral fat index, are expected to represent an unfavorable body composition profile. These indicators may be associated with less favorable cardiometabolic markers, particularly higher blood pressure, less favorable cholesterol level, and altered glucose profile. Conversely, higher skeletal muscle percentage is expected to represent a favorable body composition marker because skeletal muscle contributes to glucose utilization, metabolic reserve, and cardiometabolic resilience (Damluji et al., 2023; Powell-Wiley et al., 2021).

Within this framework, lower cardiovascular health score is interpreted as an early signal of less favorable cardiovascular health. The conceptual pathway is: unfavorable body composition profile, cardiometabolic alteration, lower cardiovascular health score, and interpretation within an early cardiovascular aging perspective. Because the study uses a cross-sectional design, this framework does not imply causality. Rather, it provides a hypothesis-guiding model for examining associations between body composition and cardiovascular health among young adults.

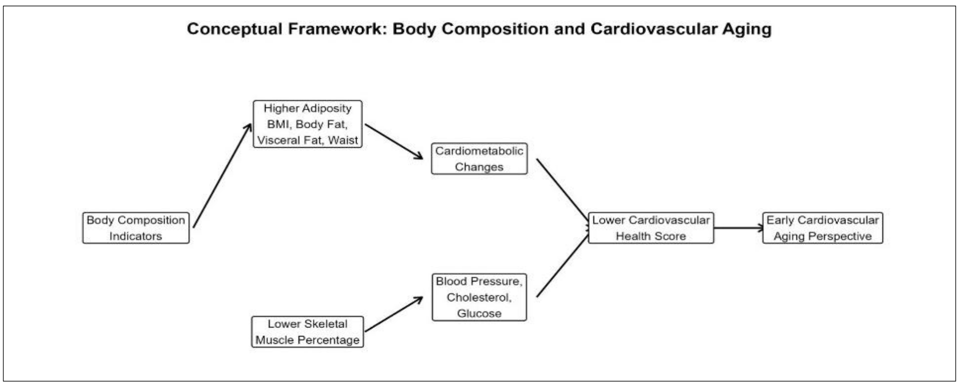

Figure 1. Conceptual framework linking body composition indicators, cardiometabolic markers, and cardiovascular health score from an early cardiovascular aging perspective.

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The framework proposes that higher adiposity indicators and lower skeletal muscle percentage may be associated with less favorable cardiometabolic profiles and lower cardiovascular health score. The framework is conceptual and does not imply causal inference.

Based on this conceptual framework, the following hypotheses were proposed:

H1: Higher adiposity indicators, including BMI, waist circumference, body fat percentage, and visceral fat index, are significantly associated with lower cardiovascular health score among young adults.
H2: Among body composition indicators, visceral fat index shows the strongest inverse relationship with cardiovascular health score.
H3: Higher skeletal muscle percentage is significantly associated with higher cardiovascular health score among young adults.
H4: Higher adiposity indicators are significantly associated with less favorable cardiometabolic markers, particularly higher systolic and diastolic blood pressure.

3. Research Method

3.1. *Study design and Participants*

This study employed a cross-sectional analytic design to examine the association between body composition indicators and cardiovascular health among young adults. The study was framed from an early cardiovascular aging perspective, with emphasis on identifying unfavorable cardiovascular health patterns before the development of clinically apparent cardiovascular disease. Because all variables were measured at a single point in time, the findings were interpreted as associations rather than causal relationships.

The study included young adult participants whose demographic, anthropometric, body composition, cardiovascular, and metabolic data were recorded and de-identified before analysis. The final analytic dataset consisted of 44 participants, comprising 9 males and 35 females. Participants were included when data were available for the core variables required for analysis, including age, sex, body mass index, waist circumference, body composition indicators, blood pressure, total cholesterol, random blood glucose, and cardiovascular health score.

3.2. *Anthropometric and Body Composition Measurements*

Anthropometric variables included body weight, height, body mass index, and waist circumference. Body mass index was calculated as body weight in kilograms divided by height in meters squared. Waist circumference was recorded in centimeters and used as an indicator of central adiposity. Body mass index was categorized using Asian-specific cutoffs, because Asian populations may experience cardiometabolic risk at lower BMI values than Western populations. Participants were classified as underweight if BMI was below 18.5 kg/m^2, normal weight if BMI was 18.5–22.9 kg/m^2, overweight if BMI was 23.0–24.9 kg/m^2, and obese if BMI was 25.0 kg/m^2 or above (WHO Expert Consultation, 2004).

Central obesity was defined using Asian waist circumference cutoffs, with central obesity classified as waist circumference of 90 cm or above in males and 80 cm or above in females (Alberti et al., 2006). Body composition indicators included body fat percentage, skeletal muscle percentage, and visceral fat index. These parameters were obtained using bioelectrical impedance analysis and treated as continuous exposure variables in the main analyses. Bioelectrical impedance analysis is widely used as a practical and non-invasive method for estimating body composition, although its accuracy may be influenced by hydration status, device type, and measurement conditions (Ward, 2019)

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3.3. *Cardiovascular and Metabolic Measurements*

Cardiovascular and metabolic variables included systolic blood pressure, diastolic blood pressure, total cholesterol, and random blood glucose. Blood pressure was recorded in millimeters of mercury, while total cholesterol and random blood glucose were recorded in milligrams per deciliter. Blood pressure was categorized according to the American College of Cardiology/American Heart Association classification, which defines normal blood pressure as systolic blood pressure below 120 mmHg and diastolic blood pressure below 80 mmHg, elevated blood pressure as systolic blood pressure 120–129 mmHg with diastolic blood pressure below 80 mmHg, stage 1 hypertension as systolic blood pressure 130–139 mmHg or diastolic blood pressure 80–89 mmHg, and stage 2 hypertension as systolic blood pressure 140 mmHg or above or diastolic blood pressure 90 mmHg or above (Whelton et al., 2018).

Total cholesterol was categorized as desirable below 200 mg/dL, borderline high at 200–239 mg/dL, and high at 240 mg/dL or above, consistent with the National Cholesterol Education Program Adult Treatment National Cholesterol Education Program Expert Panel III classification (National Cholesterol Education Program Expert Panel, 2002). Random blood glucose was analyzed as a continuous cardiometabolic marker.

3.4. *Cardiovascular Health Score*

The primary outcome was the cardiovascular health score, derived from the American Heart Association Life's Essential 8 framework. Life's Essential 8 conceptualizes cardiovascular health through behavioral and biological components, including diet, physical activity, nicotine exposure, sleep, body mass index, blood lipids, blood glucose, and blood pressure. The score ranges from 0 to 100, with higher scores indicating better cardiovascular health; scores below 50 indicate low cardiovascular health, scores of 50–79 indicate moderate cardiovascular health, and scores of 80 or above indicate high cardiovascular health (Lloyd-Jones et al., 2022).

In this study, the cardiovascular health score was interpreted as a modified Life's Essential 8-based cardiovascular health score because the available dataset focused on clinical components, including body mass index, total cholesterol, random blood glucose, and blood pressure. For descriptive purposes, the score was also divided into tertiles representing lower, middle, and higher cardiovascular health score groups. These tertile categories were used only for distributional analysis and descriptive comparison, while correlation and regression analyses used the continuous cardiovascular health score.

3.5. *Statistical Analysis*

All statistical analyses were conducted using R software (Team, 2024). Continuous variables were summarized using mean and standard deviation or median and interquartile range, depending on distribution, while categorical variables were summarized as frequency and percentage. Normality was assessed using the Shapiro-Wilk test. Sex-based comparisons were conducted as exploratory analyses; continuous variables were compared using the Wilcoxon rank-sum test, while categorical variables were compared using Fisher's exact test.

Spearman's rank correlation was used to evaluate associations between body composition indicators and cardiovascular health markers because of the modest sample size and non-normal distribution of several variables. The main exposure variables were BMI, waist circumference, body fat percentage, skeletal muscle percentage, and visceral fat index. The primary outcome was the cardiovascular health score, while secondary outcomes included systolic blood pressure, diastolic blood pressure, total cholesterol, and random blood glucose. Age- and sex-adjusted linear regression models were then used to examine the association between each body composition indicator and cardiovascular health score. Each body composition indicator was entered into a separate adjusted model with age and sex as

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covariates to reduce overfitting and multicollinearity. A p-value below 0.05 was considered statistically significant.

4. Results and Discussion

4.1. Participant Characteristics

A total of 44 young adults were included in the analysis, consisting of 35 females and 9 males. The mean age was 27.25 ± 3.63 years. Overall, the mean body mass index was 23.92 ± 6.03 kg/m², and the mean waist circumference was 81.45 ± 13.77 cm. The mean systolic and diastolic blood pressures were 117.50 ± 14.00 mmHg and 79.77 ± 8.76 mmHg, respectively. The mean cardiovascular health score was 74.00 ± 8.57 among participants with available score data, corresponding to a moderate cardiovascular health category according to the Life's Essential 8 scoring interpretation (Lloyd-Jones et al., 2022). One participant had missing cardiovascular health score data.

Variable	Overall N=44	Male N=9	Female N=35	p-value
Age (years)	**27.25 (3.63)**	**27.11 (4.08)**	**27.29 (3.57)**	**0.725**
Weight (kg)	**58.71 (15.70)**	**77.33 (14.97)**	**53.92 (11.99)**	**<0.001**
Height (cm)	**157.39 (7.06)**	**166.56 (7.06)**	**155.03 (4.83)**	**<0.001**
BMI (kg/m²)	**23.92 (6.03)**	**27.94 (5.25)**	**22.89 (5.84)**	**0.007**
Waist circumference (cm)	**81.45 (13.77)**	**98.33 (12.10)**	**77.11 (10.52)**	**<0.001**
Skeletal muscle (%)	**35.85 (5.54)**	**39.00 (4.67)**	**35.04 (5.51)**	**0.067**
Body fat (%)	**33.51 (10.07)**	**30.50 (8.42)**	**34.29 (10.41)**	**0.337**
Visceral fat index	**7.73 (4.53)**	**9.22 (5.02)**	**7.34 (4.39)**	**0.273**
Systolic BP (mmHg)	**117.50 (14.00)**	**134.44 (15.90)**	**113.14 (9.63)**	**<0.001**
Diastolic BP (mmHg)	**79.77 (8.76)**	**87.78 (10.93)**	**77.71 (6.90)**	**0.009**
Total cholesterol (mg/dL)	**190.02 (30.47)**	**160.22 (27.67)**	**197.69 (26.43)**	**0.001**
Random blood glucose / GDS (mg/dL)	**103.02 (16.65)**	**101.33 (9.07)**	**103.46 (18.17)**	**0.838**
Cardiovascular health score	**74.00 (8.57)**	**72.56 (10.47)**	**74.38 (8.14)**	**0.601**
Age group				**0.845**
≤25 years	16 (36.4%)	3 (33.3%)	13 (37.1%)	
26–30 years	21 (47.7%)	5 (55.6%)	16 (45.7%)	
>30 years	7 (15.9%)	1 (11.1%)	6 (17.1%)	
BMI category, Asian cutoff				**0.181**
Underweight (<18.5 kg/m²)	8 (18.2%)	0 (0.0%)	8 (22.9%)	
Normal (18.5–22.9 kg/m²)	15 (34.1%)	2 (22.2%)	13 (37.1%)	
Overweight (23.0–24.9 kg/m²)	4 (9.1%)	1 (11.1%)	3 (8.6%)	
Obese (≥25.0 kg/m²)	17 (38.6%)	6 (66.7%)	11 (31.4%)	
Central obesity, Asian cutoff				**0.128**
No (male <90 cm; female <80 cm)	26 (59.1%)	3 (33.3%)	23 (65.7%)	
Yes (male ≥90 cm; female ≥80 cm)	18 (40.9%)	6 (66.7%)	12 (34.3%)	
Body fat category, sex-specific reference range				**0.464**
Low body fat (male <10%; female <18%)	1 (2.3%)	0 (0.0%)	1 (2.9%)	
Normal body fat (male 10–20%; female 18–28%)	11 (25.0%)	1 (11.1%)	10 (28.6%)	
High body fat (male >20%; female >28%)	32 (72.7%)	8 (88.9%)	24 (68.6%)	
Blood pressure category				**0.006**
Normal (SBP <120 and DBP <80 mmHg)	11 (25.0%)	1 (11.1%)	10 (28.6%)	
Elevated (SBP 120–129 and DBP <80 mmHg)	1 (2.3%)	0 (0.0%)	1 (2.9%)	
Stage 1 HT (SBP 130–139 or DBP 80–89 mmHg)	22 (50.0%)	2 (22.2%)	20 (57.1%)	
Stage 2 HT (SBP ≥140 or DBP ≥90 mmHg)	10 (22.7%)	6 (66.7%)	4 (11.4%)	
Cholesterol category				**0.123**
Desirable (<200 mg/dL)	26 (59.1%)	8 (88.9%)	18 (51.4%)	
Borderline high (200–239 mg/dL)	16 (36.4%)	1 (11.1%)	15 (42.9%)	
High (≥240 mg/dL)	2 (4.5%)	0 (0.0%)	2 (5.7%)	
Cardiovascular health score tertile				**0.760**
Lower score tertile (58–69)	15 (34.9%)	4 (44.4%)	11 (32.4%)	
Middle score tertile (70–79)	15 (34.9%)	3 (33.3%)	12 (35.3%)	
Higher score tertile (80–88)	13 (30.2%)	2 (22.2%)	11 (32.4%)	

Figure 2. Table of Baseline characteristics by sex

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Using Asian-specific BMI cutoffs, 17 participants (38.6%) were categorized as obese, 4 (9.1%) as overweight, 15 (34.1%) as normal weight, and 8 (18.2%) as underweight (WHO Expert Consultation, 2004). Central obesity was present in 18 participants (40.9%) using Asian waist circumference cutoffs of ≥90 cm in males and ≥80 cm in females (Alberti et al., 2006). When body fat percentage was interpreted using sex-specific descriptive reference ranges, 32 participants (72.7%) had high body fat percentage, 11 (25.0%) were within the normal range, and 1 (2.3%) had low body fat percentage (Gallagher et al., 2000). Blood pressure classification showed that 22 participants (50.0%) were in stage 1 hypertension and 10 (22.7%) were in stage 2 hypertension according to ACC/AHA categories (Whelton et al., 2018). Total cholesterol was desirable in 26 participants (59.1%), borderline high in 16 (36.4%), and high in 2 (4.5%) based on the National Cholesterol Education Program Adult Treatment Panel III classification (National Cholesterol Education Program Expert Panel, 2002).

These baseline findings indicate that unfavorable body composition and blood pressure profiles were already present in a substantial proportion of the young adult sample. This is important because young adults may appear low-risk when assessed using short-term cardiovascular event prediction, even though adiposity, elevated blood pressure, and dyslipidemia may already be accumulating. The 2019 ACC/AHA prevention guideline emphasizes risk factor assessment and lifetime risk consideration in adults aged 20–39 years, supporting the relevance of early cardiovascular screening in this age group (Arnett et al., 2019).

4.2. *Body Composition Indicators and Cardiovascular Health Score*

Spearman correlation analysis showed that several body composition indicators were significantly associated with cardiovascular health score. BMI was negatively correlated with cardiovascular health score (r = -0.457, p = 0.002), as were waist circumference (r = -0.436, p = 0.003), body fat percentage (r = -0.489, p < 0.001), and visceral fat index (r = -0.559, p < 0.001). Visceral fat index showed the strongest negative correlation. In contrast, skeletal muscle percentage was positively correlated with cardiovascular health score (r = 0.447, p = 0.003).

Values are Spearman r (p-value). Higher CV health score indicates better cardiovascular health.

Body composition indicator	CV health score	Systolic BP	Diastolic BP	Total cholesterol	Random blood glucose / GDS
BMI	-0.457 (0.002)	0.510 (<0.001)	0.338 (0.025)	-0.230 (0.133)	-0.151 (0.328)
Waist circumference	-0.436 (0.003)	0.637 (<0.001)	0.496 (<0.001)	-0.334 (0.027)	0.104 (0.502)
Body fat percentage	-0.489 (<0.001)	0.262 (0.086)	0.196 (0.203)	-0.057 (0.711)	-0.157 (0.309)
Skeletal muscle percentage	0.447 (0.003)	-0.186 (0.226)	-0.155 (0.317)	0.014 (0.929)	0.157 (0.310)
Visceral fat index	-0.559 (<0.001)	0.387 (0.009)	0.268 (0.078)	-0.125 (0.420)	-0.148 (0.338)

Figure 3. Table of Spearman correlation analysis between body composition indicators and cardiovascular markers

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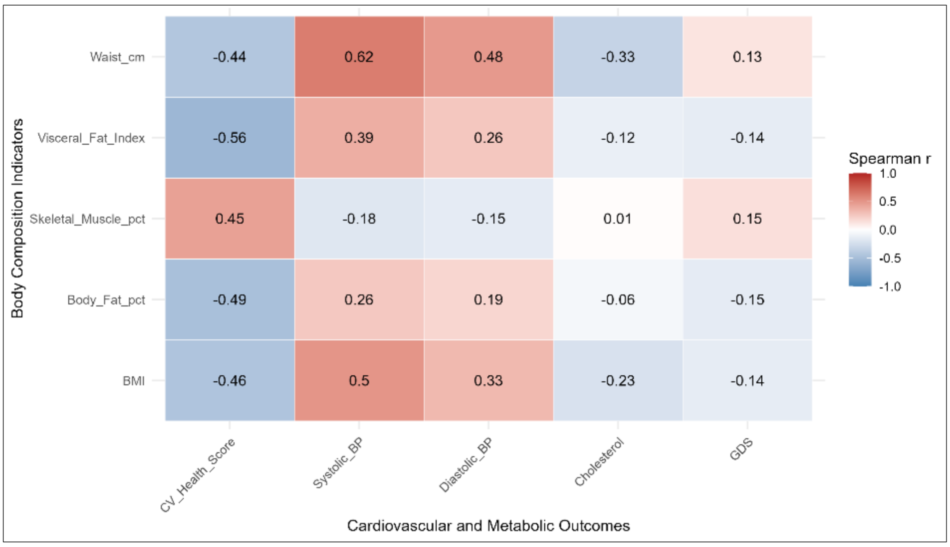

Figure 3. Spearman correlation heatmap between body composition indicators and cardiovascular markers

These findings support the first hypothesis that higher adiposity indicators are associated with lower cardiovascular health score among young adults. The inverse associations between adiposity indicators and cardiovascular health score suggest that less favorable body composition profiles may already be reflected in cardiovascular health variation before clinically apparent cardiovascular disease develops. This interpretation is consistent with the American Heart Association scientific statement, which highlights the role of obesity and adiposity in hypertension, dyslipidemia, diabetes, and cardiovascular remodeling (Powell-Wiley et al., 2021).

The correlation heatmap in Figure 2 provides an integrated visual summary of these relationships. Higher BMI, waist circumference, body fat percentage, and visceral fat index generally showed inverse correlations with cardiovascular health score, while skeletal muscle percentage showed a favorable positive correlation. This pattern supports the broader interpretation that body composition is closely related to early cardiovascular health variation.

4.3. *Visceral Fat Index as the Strongest Indicator*

Age- and sex-adjusted regression models were fitted separately for each body composition indicator, with cardiovascular health score as the outcome. BMI was negatively associated with cardiovascular health score (β = -0.706, 95% CI: -1.128 to -0.283, p = 0.002). Waist circumference (β = -0.436, 95% CI: -0.651 to -0.222, p < 0.001), body fat percentage (β = -0.447, 95% CI: -0.680 to -0.214, p < 0.001), and visceral fat index (β = -1.129, 95% CI: -1.618 to -0.640, p < 0.001) also showed significant negative associations. Skeletal muscle percentage showed a positive association with cardiovascular health score (β = 0.813, 95% CI: 0.371 to 1.255, p < 0.001).

Body composition indicator	n	β	95% CI	p-value	R^2	Adjusted R^2
BMI	43	-0.706	-1.128 to -0.283	0.002	0.242	0.184
Waist circumference	43	-0.436	-0.651 to -0.222	<0.001	0.318	0.265
Body fat percentage	43	-0.447	-0.680 to -0.214	<0.001	0.294	0.24
Skeletal muscle percentage	43	0.813	0.371 to 1.255	<0.001	0.278	0.222
Visceral fat index	43	-1.129	-1.618 to -0.640	<0.001	0.372	0.324

Figure 4. Table of Age- and sex-adjusted regression models for cardiovascular health score

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Visceral fat index showed the strongest inverse association with cardiovascular health score, as indicated by the largest absolute Spearman correlation coefficient and the highest adjusted R^2 among the adjusted models. This is clinically plausible because visceral adipose tissue is metabolically active and contributes to insulin resistance, low-grade inflammation, dyslipidemia, endothelial dysfunction, and blood pressure elevation. Despréss (2012) emphasized that body fat distribution, particularly visceral adiposity, is a major determinant of obesity-related cardiovascular risk and may explain why individuals with similar BMI values can have different cardiometabolic profiles.

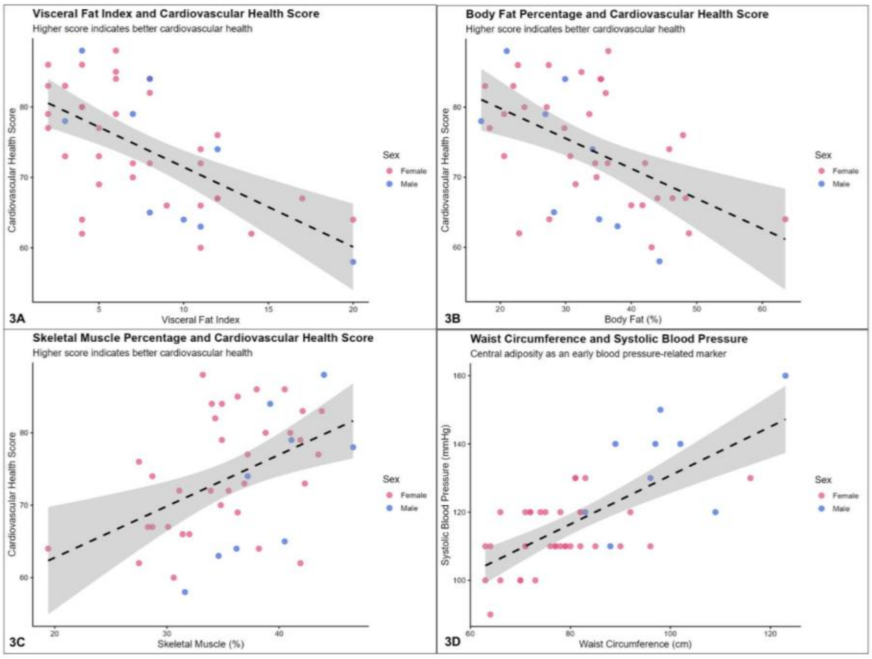

Figure 2. Key visual patterns between body composition and cardiovascular health markers

Figure 3A illustrates the inverse association between visceral fat index and cardiovascular health score. This visual pattern reinforces the value of assessing visceral or central adiposity rather than relying only on BMI. In young adults, identifying higher visceral adiposity may be useful for early preventive intervention before persistent hypertension, dyslipidemia, glucose dysregulation, or vascular dysfunction becomes established.

4.4. *Skeletal Muscle Percentage as a Favorable Indicator*

Skeletal muscle percentage showed a significant positive association with cardiovascular health score in both correlation and adjusted regression analyses. This supports the third hypothesis that higher skeletal muscle percentage is associated with better cardiovascular health. Figure 3C also shows a favorable visual association between skeletal muscle percentage and cardiovascular health score.

This finding is relevant because skeletal muscle is increasingly recognized as a metabolically active tissue. It contributes to glucose uptake, insulin sensitivity, lipid metabolism, inflammatory regulation, and functional reserve. In cardiovascular research, low skeletal muscle and sarcopenia have been associated with frailty, reduced functional capacity, adverse cardiometabolic outcomes, and poorer prognosis in several cardiovascular conditions (Damluji et al., 2023). Although this study did not diagnose sarcopenia, the positive association between skeletal muscle percentage and cardiovascular health score supports the concept that muscle preservation may be favorable for cardiovascular health.

These findings suggest that body composition assessment should not focus only on excess fat. A preventive and longevity-oriented approach should consider both unfavorable

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adiposity and favorable muscle-related indicators. Cardiovascular prevention in young adults may therefore benefit from strategies that reduce excess adiposity while preserving or improving skeletal muscle, including regular physical activity, resistance training, adequate nutrition, and broader healthy lifestyle behaviors.

4.5. *Adiposity Indicators and Blood Pressure Profile*

For secondary cardiometabolic markers, BMI was positively correlated with systolic blood pressure ($r = 0.510$, $p < 0.001$) and diastolic blood pressure ($r = 0.338$, $p = 0.025$). Waist circumference showed positive correlations with systolic blood pressure ($r = 0.637$, $p < 0.001$) and diastolic blood pressure ($r = 0.496$, $p < 0.001$). Visceral fat index was also positively correlated with systolic blood pressure ($r = 0.387$, $p = 0.009$). These findings support the fourth hypothesis, particularly for blood pressure.

The associations of adiposity indicators with cholesterol and random blood glucose were less consistent, suggesting that blood pressure may be the most sensitive cardiometabolic marker in this young adult sample. The relationship between adiposity and blood pressure is biologically plausible because excess adiposity may contribute to sympathetic nervous system activation, renin–angiotensin–aldosterone system activation, sodium retention, endothelial dysfunction, inflammation, and vascular remodeling. The ACC/AHA guideline emphasizes early identification of elevated blood pressure because even modest increases in blood pressure are associated with higher cardiovascular risk over time (Whelton et al., 2018).

Figure 3D presents the relationship between waist circumference and systolic blood pressure using sex-stratified panels. The vertical dashed lines indicate Asian central obesity cutoffs of 90 cm in males and 80 cm in females. Waist circumference showed a positive relationship with systolic blood pressure, particularly among female participants. Among males, the correlation was also positive but did not reach statistical significance, likely because of the limited male subgroup size.

4.6. *Integrated Visual and Early Cardiovascular Aging Interpretation*

The combined visual patterns in Figure 3 summarize the main findings. Figure 3A shows the inverse relationship between visceral fat index and cardiovascular health score. Figure 3B shows the association between body fat percentage and cardiovascular health score in sex-stratified panels, with shaded bands indicating descriptive normal ranges of 10–20% in males and 18–28% in females (Gallagher et al., 2000). Figure 3C shows the positive association between skeletal muscle percentage and cardiovascular health score, while Figure 3D shows the positive relationship between waist circumference and systolic blood pressure. Together, these patterns support the interpretation that higher adiposity and lower skeletal muscle percentage are associated with less favorable cardiovascular health patterns.

Overall, the findings can be interpreted within an early cardiovascular aging perspective. Higher adiposity indicators and lower skeletal muscle percentage may represent unfavorable body composition patterns associated with early cardiometabolic changes, particularly blood pressure elevation. These changes may then be reflected in lower cardiovascular health score. Although this study did not directly measure vascular age, pulse wave velocity, endothelial function, or subclinical atherosclerosis, the observed associations suggest that body composition may provide an accessible window into early cardiovascular health variation.

This interpretation is consistent with the concept of early vascular aging, which describes vascular or cardiometabolic changes occurring earlier than expected for chronological age, often due to cumulative exposure to unfavorable risk factors such as elevated blood pressure, obesity, metabolic abnormalities, and unhealthy lifestyle patterns (Nilsson, 2020). However, the cardiovascular health score should not be interpreted as a direct measure of vascular age or biological age. Rather, it provides a practical cardiovascular health profile that may help identify young adults who could benefit from earlier preventive intervention.

4.7. *Strengths and Limitations*

This study has several strengths. First, it focused on young adults, a population in which cardiovascular prevention is important but often underemphasized. Second, it evaluated multiple body composition indicators, including BMI, waist circumference, body fat percentage, skeletal muscle percentage, and visceral fat index, allowing a broader assessment than BMI alone. Third, the study used a cardiovascular health score aligned with the Life's Essential 8 framework, which is increasingly recognized as a contemporary construct for cardiovascular health assessment (Lloyd-Jones et al., 2022).

Several limitations should be acknowledged. The cross-sectional design does not allow causal inference. The sample size was modest, and the male subgroup was small, limiting the interpretation of sex-stratified patterns. Body composition was assessed using bioelectrical impedance analysis, which is practical and non-invasive but may be influenced by hydration status, device characteristics, and measurement conditions (Ward, 2019). In addition, the cardiovascular health score was based on available clinical components; therefore, it should be interpreted as a modified Life's Essential 8-based cardiovascular health score if behavioral components such as HDL, HbA1c, and fasting blood glucose were not fully available.

Despite these limitations, the findings provide preliminary evidence that body composition indicators are associated with cardiovascular health variation among young adults. The results support the value of integrating adiposity and skeletal muscle indicators into early cardiovascular health screening, particularly within preventive and longevity-oriented approaches.

5. Conclusion

This study found that body composition indicators were associated with cardiovascular health among young adults. Higher adiposity indicators, including BMI, waist circumference, body fat percentage, and visceral fat index, were associated with lower cardiovascular health score. Among these indicators, visceral fat index showed the strongest inverse relationship with cardiovascular health score. In contrast, skeletal muscle percentage showed a favorable positive association, suggesting that muscle-related indicators may provide additional insight into early cardiovascular health beyond adiposity alone.

Adiposity indicators were also associated with less favorable blood pressure profiles, particularly systolic blood pressure, supporting the relevance of body composition assessment in early cardiovascular risk identification. Although this study was cross-sectional and cannot establish causality, the findings support the use of body composition indicators as practical markers for identifying early variation in cardiovascular health among young adults. From an early cardiovascular aging perspective, integrating adiposity and skeletal muscle assessment into preventive screening may help identify individuals who could benefit from earlier lifestyle and cardiometabolic intervention.

Future studies should include larger and more balanced samples, longitudinal follow-up, complete Life's Essential 8 components, and direct vascular aging markers such as pulse wave velocity, endothelial function, or subclinical atherosclerosis measures. These additions would strengthen the understanding of how body composition patterns contribute to cardiovascular health trajectories across early adulthood

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7. Submission Declaration Statements

The authors hereby confirm that the manuscript has no any actual or potential conflict of interest with any parties, including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence or be perceived to influence. The authors confirm that the paper has not been published previously, it is not under consideration for publication elsewhere, and the manuscript is not being simultaneously submitted elsewhere

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