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Research Article

Evaluation of Arterial Stiffness Markers in Childhood Obesity Using Different Anthropometric Indices

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Abstract

Background: Childhood obesity is an increasing public health concern associated with early cardiovascular changes. Anthropometric indices may help identify children at risk of increased arterial stiffness.

Objectives: This study aimed to investigate associations between conventional and novel anthropometric adiposity indices and echocardiographic markers of aortic stiffness in children.

Methods: This cross-sectional study included 130 children referred to Ali Asghar Hospital in Iran in 2022. Anthropometric indices, including body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), A Body Shape Index (ABSI), Body Roundness Index (BRI), and the conicity index (CI), were calculated. Blood pressure and echocardiographic aortic elasticity parameters, including aortic strain (AS), aortic stiffness beta index (ASβI), aortic distensibility (AD), and pressure strain elastic modulus (PSEM), were assessed. Participants were classified as overweight/obese or normal weight according to each index, and comparisons were performed ($P < 0.05$).

Results: Among the participants, 39% were girls, and 50% were overweight or obese. The prevalence of overweight/obesity varied by index: WHtR (31.5%), WC (52.2%), ABSI (61.5%), BRI (35.4%), and CI (59.2%). Obesity defined by BMI, WC, WHtR, and BRI was associated with lower AS and AD and higher ASβI and PSEM. CI showed significant associations only with AD ($P = 0.016$) and PSEM ($P = 0.031$), whereas ABSI showed no significant associations with aortic stiffness parameters.

Conclusions: Indices reflecting general and abdominal adiposity, particularly BMI, WC, WHtR, and BRI, were more consistently associated with aortic stiffness in children than CI and ABSI. ABSI may have limited sensitivity in pediatric populations because of growth-related changes in body proportions. Reduced aortic distensibility may serve as an early indicator of cardiovascular risk in children.

Keywords: Arterial Stiffness, Anthropometric Indices, Children, Obesity

1. Background

The global prevalence of overweight and obesity is steadily increasing, with projections suggesting that up to 57.8% of the world population may be affected (1). This trend is primarily driven by rapid urbanization, sedentary behaviors, and reduced physical activity, making childhood obesity a major global public health concern. Notably, the prevalence of obesity among children has increased by approximately 23% in developed countries and 14% in developing regions, highlighting the global scope of the problem (2). In Iran, obesity represents a substantial health burden and contributes to nearly 70% of deaths related to chronic diseases, particularly cardiovascular conditions.

Given the multifaceted nature of obesity, several anthropometric indices have been developed for its assessment. Body Mass Index (BMI) remains the most widely used measure in clinical and research settings; however, it does not adequately reflect body fat

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distribution or the extent of adipose tissue accumulation associated with vascular toxicity (3). Despite this limitation, elevated BMI has been linked to alterations in vascular function, suggesting a potential role in vascular adaptive or defensive responses rather than direct injury (3).

Waist circumference (WC) has gained importance as an indicator of central obesity and metabolic syndrome, although it does not consistently capture visceral fat accumulation with precision (4). To address these limitations, additional indices, such as the waist-to-height ratio (WHtR) and A Body Shape Index (ABSI), have been introduced to better characterize body fat distribution and have shown modest correlations with BMI (5). More recently, the Body Roundness Index (BRI) has been proposed as a novel anthropometric measure that estimates total and visceral adipose tissue by modeling body shape as an oval, potentially providing enhanced insight into obesity-related health risks (6).

Although the association between excess body weight and cardiovascular disease (CVD) is well established (7), the relationship between obesity and arterial stiffness (AS) remains controversial. Cardiovascular risk varies substantially by fat distribution, with visceral adiposity conferring a higher risk than subcutaneous fat (8). Arterial stiffness reflects progressive vascular aging and loss of arterial elasticity and is recognized as an early marker and strong predictor of CVD (5, 6). Vascular stiffening increases with advancing age and in the presence of metabolic abnormalities, such as dyslipidemia, ultimately becoming a hallmark of cardiovascular pathology (9). Importantly, AS has been shown to predict future cardiovascular events in both clinical and general populations, independent of traditional cardiovascular risk factors (10). Although magnetic resonance imaging provides accurate measurement of aortic stiffness through pulse wave velocity (PWV), its high cost and limited availability restrict routine clinical use (11). Consequently, echocardiographic assessment using systolic and diastolic blood pressure in combination with aortic diameter is commonly used to calculate aortic elasticity indices, including the aortic stiffness beta index, aortic distensibility, and the pressure strain elastic modulus.

2. Objectives

This study aimed to comprehensively examine the associations between conventional obesity indices (BMI, WC, and WHtR) and novel obesity indices (ABSI, BRI, and CI) and detailed aortic elasticity parameters in children. By adopting a multidimensional approach, this investigation sought to provide a more nuanced understanding of obesity-related vascular alterations in the pediatric population.

3. Methods

3.1. Study Design and Participants

This cross-sectional comparative study was conducted among children referred to Ali Asghar Pediatric Hospital, affiliated with Zahedan University of Medical Sciences, Zahedan, Iran, for routine check-ups in 2022. Children were enrolled based on BMI status, categorized according to the CDC Growth Charts for children and adolescents aged 2 - 19 years. BMI classifications included underweight (less than the 5th percentile), healthy weight (5th to less than the 85th percentile), overweight (85th to less than the 95th percentile), and obese (95th percentile or greater). Underweight children were excluded, and only overweight/obese children and normal-weight children were included in the two study groups. A total of 130 children aged 4 - 16 years were included, with equal numbers of overweight/obese and normal-weight children. Children with diabetes mellitus, hypertension, dyslipidemia, autoimmune diseases, infections, liver disease, renal disease, lung disease, smoking exposure, or metabolic syndrome were excluded. Children receiving antihypertensive or lipid-lowering medications and those with a family history of dyslipidemia were also excluded.

3.2. Measurements and Threshold Measures

Height, weight, and WC were measured. Weight was recorded using a calibrated medical electronic scale (Seca 770, Birmingham, UK) with a precision of 100 mg, and height was measured using a height rod (Seca 222, Birmingham, UK). WC was measured in the standing position above the hip bone during exhalation (12). All measurements were performed twice by an experienced nurse, and the mean was recorded. The anthropometric indices CI, WHtR, ABSI, and BRI were then calculated using the appropriate formulas. Cutoff values for WC, WHtR, ABSI, BRI, and CI were selected based on previously published pediatric and population-based studies to ensure consistency and comparability with the existing literature. WC cutoffs were based on a study by Mederico et al. (13), with mean values of 76.65 cm for girls and 77.95 cm for boys. WHtR was calculated as WC divided by height, with a cutoff value of 0.6, as reported by Shrestha et al. (14). ABSI was calculated using the appropriate formula, with a cutoff value of 0.08 based on Xu et al. (6). BRI was calculated using a formula developed by Chang et al. (15), with a cutoff of 5.00. CI was calculated using the appropriate formula, with a cutoff value of 1.18 based on Mangla et al. (16).

3.3. Echocardiographic and Blood Pressure Assessment

All children underwent medical history evaluation, physical examination, chest X-ray, and echocardiography using My Lab 60 transducers 3 and 8 (Italy). Echocardiography was performed without respiratory control, and measurements were repeated over three cycles, with the mean recorded. Conventional echocardiographic parameters included aortic systolic diameter (AOS) and aortic diastolic diameter (AOD), measured 3 cm above the aortic valve (17, 18).

Blood pressure was measured in the brachial artery after 5 minutes of rest, with three readings obtained at least 2 minutes apart. The mean was recorded, with systolic and diastolic blood pressure corresponding to Korotkoff phases I and V, respectively.

Aortic elasticity parameters were calculated as follows: aortic strain, aortic stiffness beta index, aortic distensibility, and pressure strain elastic modulus were calculated using the appropriate formulas (17, 18).

3.4. Ethical Approval

The study was approved by the Ethics Committee of Zahedan University of Medical Sciences (IR.ZAUMS.REC.1400.095).

3.5. Statistical Analysis

SPSS version 18 was used to analyze the data. Numerical data were summarized as means and standard deviations, and categorical data as frequencies and percentages. Non-parametric statistical tests were applied because several continuous variables were not normally distributed. Receiver operating characteristic (ROC) curve analysis was performed to assess the discriminatory ability of each anthropometric index to identify altered aortic elasticity parameters. The Mann-Whitney U test was used to compare the overweight/obese and normal-weight groups. Pearson and Spearman correlations were used for normally and non-normally distributed data, respectively. The AUC-ROC test was used to evaluate the diagnostic ability of obesity for each anthropometric measurement. AUC scores ranged from 0.5, indicating no discrimination, to more than 0.9, indicating outstanding discrimination. A P value of less than 0.05 was considered statistically significant.

4. Results

Based on BMI classification, participants were evenly distributed between the overweight/obese and normal-weight groups. Overall, 39% of the children were girls; among girls, 40% were classified as overweight/obese, compared with 56.3% of boys. The mean age of overweight/obese children was 10.79 ± 2.53 years, whereas normal-weight children had a mean age of 10.44 ± 1.28 years. The median ages were 10.76 and 10 years, respectively, with no statistically significant difference between groups (P = 0.320). ROC curve analysis was used to assess the ability of anthropometric indices to discriminate between overweight/obese and normal-weight children. The AUC reflects the degree of separation between the two groups rather than diagnostic performance. The ABSI (AUC = 0.419, P = 0.136) and CI (AUC = 0.540, P = 0.430) showed limited discrimination. In contrast, WC (AUC = 0.827, P < 0.001), WHtR (AUC = 0.773, P < 0.001), and BRI (AUC = 0.773, P < 0.001) demonstrated greater separation between overweight/obese and normal-weight children (Table 1).

Using the identified cutoff values (Figure 1), the proportion of children classified as overweight/obese varied across indices: 41% according to WHtR, 68% for WC, 80% for ABSI, 46% for BRI, and 77% for CI.

Associations between clinical variables and vascular stiffness parameters are summarized in Table 2. Systolic blood pressure (SBP) was inversely associated with AS and AD, with statistical significance observed for AD (P = 0.005). SBP was positively associated with ASβI (P = 0.035) and PSEM (P = 0.046). Diastolic blood pressure (DBP) showed weaker, non-significant associations with vascular stiffness indices. AOS and AOD exhibited patterns similar to those observed for SBP, with statistically significant relationships observed for most stiffness parameters, except PSEM.

Mean values of vascular stiffness parameters across overweight/obese and normal-weight groups, as defined by different anthropometric indices, are presented in Table 3, and cardiac parameters are shown in Table 4. When obesity status was defined by BMI, significant differences were observed between groups for SBP, AOS, AOD, AS, ASβI, AD, and PSEM (all P < 0.001). Using CI-based classification, overweight/obese children exhibited lower AD (P = 0.016) and higher PSEM (P = 0.031). No significant differences in cardiac or vascular parameters were observed when obesity was defined using ABSI.

5. Discussion

With improvements in living standards, excess body weight has emerged as a major global public health problem. Anthropometric indicators used to assess

Table 1. Area Under the ROC Curve Values for Anthropometric Parameters

Anthropometric Parameters	Area Under the ROC Curve (AUC)	Standard Deviation (SD)	P-Value	95% CI Lower Bound	95% CI Upper Bound
Waist circumference (WC)	0.83	0.035	< 0.001	0.76	0.90
Waist-to-height ratio (WHtR)	0.78	0.044	< 0.001	0.69	0.86
Body Roundness Index (BRI)	0.78	0.044	< 0.001	0.69	0.86
A Body Shape Index (ABSI)	0.42	0.054	0.136	0.31	0.52
Conicity Index (CI)	0.54	0.053	0.43	0.46	0.62

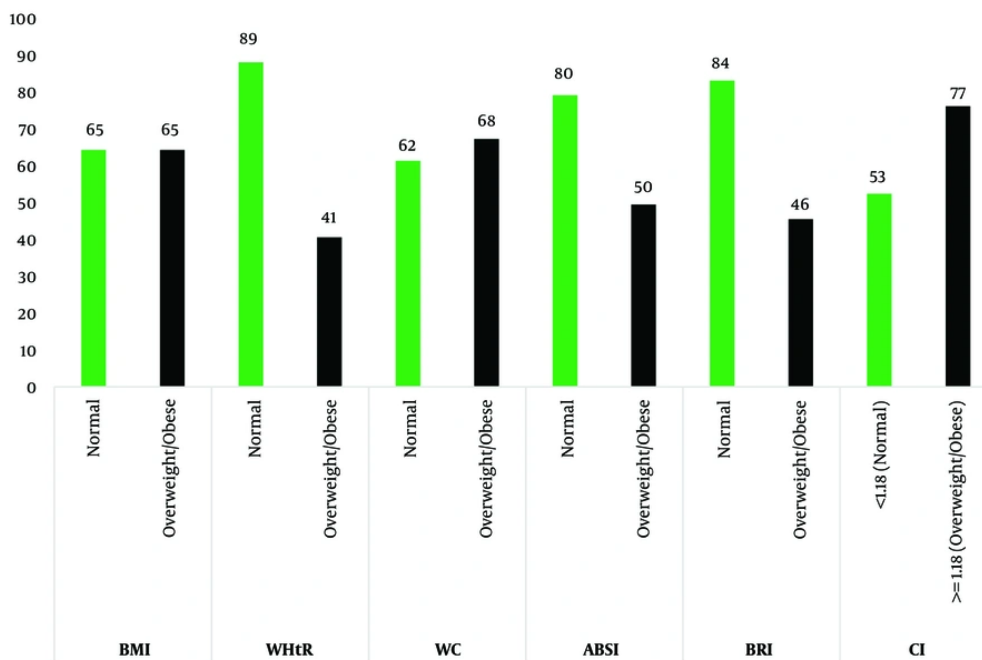

Figure 1. Frequency of Overweight/Obesity According to Different Indicators in the Study Population

obesity are commonly classified into traditional measures, including BMI, WC, and WHtR, and newer indices, such as ABSI, BRI, and CI (19). Visceral adiposity is closely linked to metabolic disturbances, including dyslipidemia, insulin resistance, diabetes, and hypertension, all of which substantially increase cardiovascular risk (20). Aortic stiffness is an established surrogate marker of cardiovascular risk and has been shown to be more strongly associated with abdominal obesity than with BMI alone (20).

In this study, we investigated the relationships between conventional and novel anthropometric indices and echocardiographic markers of aortic stiffness in children. Overall, indices reflecting general and central adiposity, particularly BMI, WC, WHtR, and BRI, showed more consistent associations with aortic elasticity parameters than CI and ABSI. Obesity defined by BMI, WC, WHtR, and BRI was associated with reduced aortic strain and aortic distensibility, along with increased aortic stiffness index and pressure strain elastic modulus. In contrast, ABSI-based obesity classification did not reveal significant differences in vascular or cardiac stiffness parameters.

The lack of significant associations for ABSI may be attributable to limitations inherent in its conceptual framework and target population. ABSI was originally developed and validated in adult populations, in whom body proportions are relatively stable. Childhood,

Table 2. Correlations Between Arterial Stiffness Parameters and Clinical Parameters [a]

Clinical Parameters and Statistics	AS	ASβI	AD	PSEM
SBP				
Pearson value	-0.071	0.185	-0.243	0.175
P value	0.422	0.035	0.005	0.046
DBP				
Pearson value	0.040	-0.171	0.116	-0.076
P value	0.648	0.051	0.189	0.387
AOD				
Pearson value	-0.277	0.348	-0.400	0.025
P value	0.001	< 0.001	< 0.001	0.779
AOS				
Pearson value	-0.21	0.262	-0.290	-0.088
P value	0.015	0.003	0.001	0.320
Total	130	130	130	130

[a] Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; AOS, aortic diameter in systole; AOD, aortic diameter in diastole; AS, aortic strain; ASβI, aortic stiffness beta index; AD, aortic distensibility; PSEM, pressure strain elastic modulus.

however, is characterized by rapid growth and age-dependent changes in height, weight, and fat distribution. These developmental dynamics may reduce the sensitivity of ABSI to detect obesity-related vascular alterations in pediatric populations, thereby limiting its applicability for identifying differences in aortic stiffness observed with other indices.

Although PWV is widely used to measure arterial stiffness in research settings, its routine use in pediatric clinical practice is limited by technical and logistical challenges. Previous studies, including those by Lentferink et al. (21) and Bittencourt et al. (22), have reported increased PWV in obese individuals compared with normal-weight controls. Associations between PWV and anthropometric indices, such as BMI, WC, and WHtR, have also been described, although results have varied across studies. Chao et al. (23) reported significant associations with BMI, WC, and WHtR, whereas Gómez-Sánchez et al. (24) found no association with BMI but identified correlations with WHtR and BRI.

Several pediatric studies have also demonstrated relationships between arterial stiffness and adiposity measures (25-31). Consistent with the present findings, Khadilkar et al. (25) reported a relationship between WHtR and arterial stiffness in children, although the direction of the association differed across studies. Tang et al. (8) and Kim et al. (9) observed positive correlations, and Kim et al. (9) noting that WC correlated more strongly with arterial stiffness than BMI, particularly in younger children, in whom obesity may be underestimated. Khadilkar et al. (25) also identified positive correlations between arterial stiffness and BMI, WC, and body fat, findings that are consistent with those reported by Dangardt et al. (26), Hu et al. (27), and Liu et al. (28). Zachariah et al. (29) further confirmed that obese children exhibit significantly greater arterial stiffness.

Some studies have suggested that replacing WC with ABSI may improve the prediction of cardiovascular risk and future renal function decline in the general population (32-34). However, other evidence indicates that ABSI contributes minimally to improving CVD risk assessment (35), which aligns with the results of the present study.

The primary aim of the present study was to apply arterial stiffness parameters comparable to PWV, including aortic stiffness, ASβI, AD, and PSEM. These measures have been used in studies assessing aortic elasticity in various conditions, including celiac disease (35), asthma (36), obesity (37), diabetes (38), end-stage renal disease, and thalassemia (39). Across these conditions, ASβI and PSEM consistently increased, whereas aortic strain and distensibility decreased in affected patients.

Dangardt et al. (40) demonstrated that obesity significantly alters arterial stiffness parameters in adolescents aged 14 - 19 years compared with non-obese controls. Both the degree and duration of obesity appear to influence cardiovascular changes, particularly arterial stiffness, which serves as an early biomarker of vascular dysfunction (28). Adiposity itself may contribute directly to vascular remodeling and hypertension, whereas traditional cardiovascular risk markers may fluctuate during adolescence (40). Hudson et al. (41) reported that arterial stiffness parameters vary primarily with age rather than pubertal stage, and Haraguchi et al. (42) also identified a significant association between obesity and arterial stiffness. Furthermore, increased arterial stiffness may contribute to the development of cardiac hypertrophy in obese individuals (43). Variability across studies likely reflects differences in the anthropometric indices used, as distinct patterns of adiposity may exert differential effects on various organs.

5.1. Limitations

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design precludes causal inference between adiposity indices and arterial stiffness parameters. Second, the relatively small sample size and single-center setting limit generalizability to broader pediatric populations. Third, arterial stiffness was assessed using echocardiography-derived surrogate markers rather than PWV, the gold-standard method. Fourth, obesity classification relied on cutoff values derived from heterogeneous populations, as pediatric- and ethnicity-specific reference values for newer indices, such as ABSI and CI, remain limited. In addition, important confounding factors, including physical activity, dietary patterns, pubertal stage, and family history of CVD, were not systematically assessed. Finally, anthropometric and echocardiographic measurements are operator-dependent, and potential measurement variability cannot be excluded.

5.2. Conclusions

This cross-sectional study demonstrates that anthropometric indices reflecting general and abdominal adiposity, particularly BMI, WC, WHtR, and BRI, are more consistently associated with echocardiographic markers of aortic stiffness in children than are CI and ABSI. Obesity defined by these indices was associated with reduced aortic strain and distensibility and increased stiffness indices, suggesting early vascular alterations. In contrast, ABSI did not show meaningful associations with arterial stiffness parameters, likely reflecting its limited applicability in pediatric populations undergoing rapid growth. Although these findings highlight the potential utility of simple anthropometric measures for early cardiovascular risk stratification, larger longitudinal studies incorporating multivariable adjustment and standardized pediatric cutoff values are needed to determine their predictive value for future cardiovascular outcomes.

Footnotes

AI Use Disclosure: For the purpose of Text Editing, the To Check Grammatical Errors was used Minor in the Discussion section.

Authors' Contribution: N. M. N. supervised the study and contributed to the main concept, literature review, and drafting of the manuscript. M.N.M. contributed to data collection and literature review. S. G. reviewed the literature and drafted the primary version of the manuscript. A. T. contributed to data collection and analysis, literature review, and drafting of the manuscript.

Conflict of Interests Statement: The Authors declare no conflict of interest.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication. The data are not publicly available due to privacy concerns.

Ethical Approval: The study was approved by the Ethics Committee of Zahedan University of Medical Sciences (IR.ZAUMS.REC.1400.095).

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Table 3. Mean and Standard Deviation of Heart Parameters in Obese and Non-Obese Children According to Different Body Indices [a]

Heart Parameters; Body Indices and Statistics	Values (Mean ± SD)
SBP	
BMI	
Normal	108.31 ± 10.48
Overweight/Obese	118.07 ± 14.61
CI	
Normal	108.68 ± 12.18
Overweight/Obese	113.51 ± 12.93
ABSI	
Normal	112 ± 12.73
Overweight/Obese	111.25 ± 12.92
BRI	
Normal	108.98 ± 11.52
Overweight/Obese	116.22 ± 13.8
WC	
Normal	105.1 ± 7.74
Overweight/Obese	117.41 ± 13.7
WHtR	
Normal	109.54 ± 11.59
Overweight/Obese	115.88 ± 14.32
DBP	
BMI	
Normal	69.48 ± 7.74
Overweight/Obese	70.49 ± 12.06
CI	
Normal	68.23 ± 7.33
Overweight/Obese	70.91 ± 10.43
ABSI	
Normal	70.84 ± 9.19
Overweight/Obese	69.18 ± 9.46
BRI	
Normal	69.31 ± 7.81
Overweight/Obese	70.74 ± 11.71
WC	
Normal	68.27 ± 6.37
Overweight/Obese	71.22 ± 11.29
WHtR	
Normal	69.27 ± 7.72
Overweight/Obese	71 ± 12.21
AOS	
BMI	
Normal	2.14 ± 0.3
Overweight/Obese	2.38 ± 0.37
CI	
Normal	2.23 ± 0.35
Overweight/Obese	2.21 ± 0.34
ABSI	
Normal	2.18 ± 0.35
Overweight/Obese	2.25 ± 0.33
BRI	
Normal	2.18 ± 0.35
Overweight/Obese	2.29 ± 0.32
WC	
Normal	2.09 ± 0.33
Overweight/Obese	2.34 ± 0.32
WHtR	
Normal	2.19 ± 0.34
Overweight/Obese	2.29 ± 0.33
AOD	
BMI	
Normal	1.99 ± PSEM
Overweight/Obese	2.26 ± 0.35
CI	
Normal	2.07 ± 0.33
Overweight/Obese	2.08 ± 0.33
ABSI	
Normal	2.03 ± 0.34
Overweight/Obese	2.11 ± 0.32
BRI	
Normal	2.03 ± 0.34
Overweight/Obese	2.16 ± 0.3
WC	
Normal	1.92 ± 0.3
Overweight/Obese	2.22 ± 0.29
WHtR	
Normal	2.04 ± 0.34
Obese	2.16 ± 0.31
AS	
BMI	7.87 ± 5.36
Normal	5.44 ± 5.15
Overweight/Obese	
CI	7.92 ± 5.1
Normal	6.48 ± 5.55
Overweight/Obese	

Heart Parameters; Body Indices and Statistics	Values (Mean ± SD)
ABSI	7.2 ± 6.16
Normal	6.99 ± 4.9
Overweight/Obese	
BRI	7.63 ± 4.73
Normal	6.04 ± 6.37
Overweight/Obese	
WC	8.96 ± 4.47
Normal	5.34 ± 5.62
Overweight/Obese	
WHtR	7.55 ± 4.68
Normal	6.02 ± 6.64
Overweight/Obese	
ASβI	
BMI	12.31 ± 22.69
Normal	18.33 ± 17.46
Overweight/Obese	
CI	11.45 ± 15.74
Normal	16.26 ± 24.2
Overweight/Obese	
ABSI	18.1 ± 28.89
Normal	11.92 ± 14.25
Overweight/Obese	
BRI	11.84 ± 21.54
Normal	18.8 ± 20.09
Overweight/Obese	
WC	6.67 ± 5.77
Normal	21.25 ± 27.09
Overweight/Obese	
WHtR	11.85 ± 20.98
Normal	19.63 ± 21.03
Overweight/Obese	
AD	
BMI	0.0044 ± 0.0031
Normal	0.0023 ± 0.0024
Overweight/Obese	
CI	0.0044 ± 0.0032
Normal	0.0032 ± 0.0028
Overweight/Obese	
ABSI	0.0037 ± 0.0032
Normal	0.0037 ± 0.0030
Overweight/Obese	
BRI	0.0042 ± 0.0029
Normal	0.0027 ± 0.0031
Overweight/Obese	
WC	0.0051 ± 0.0027
Normal	0.0024 ± 0.0027
Overweight/Obese	
WHtR	0.0041 ± 0.0029
Normal	0.0027 ± 0.0032
Overweight/Obese	
PSEM	
BMI	25.83 ± 43.16
Normal	35.24 ± 38.37
Overweight/Obese	
CI	22.42 ± 29.37
Normal	33.43 ± 48.12
Overweight/Obese	
ABSI	36.35 ± 54.51
Normal	36.35 ± 54.51
Overweight/Obese	
BRI	24.57 ± 42.75
Normal	36.92 ± 38.99
Overweight/Obese	
WC	16.46 ± 21.38
Normal	40.32 ± 51.58
Overweight/Obese	
WHtR	24.53 ± 41.66
Normal	38.52 ± 40.75
Obese	

[a] Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; AOS, aortic diameter in systole; AOD, aortic diameter in diastole; AS, aortic strain; ASβI, aortic stiffness beta index; AD, aortic distensibility; PSEM, pressure strain elastic modulus.

Table 4. Comparison of Cardiac Parameters Between Overweight/Obese and Normal-Weight Participants Based on Different Anthropometric Indices [a]

Obesity Indicator; Cardiac Parameters and Body Status	Median	Mann-Whitney U	P Value
BMI			
SBP		1221	< 0.001
Normal weight	110		
Overweight/Obese	120		
DBP		2051.5	0.768
Normal weight	70		
Overweight/Obese	70		
AOS		1240.5	< 0.001
Normal weight	2.06		
Overweight/Obese	2.35		
AOD		1060	< 0.001
Normal weight	1.91		
Overweight/Obese	2.18		
AS		1179	< 0.001
Normal weight	7.96		
Overweight/Obese	4.59		
ASβI		914	< 0.001
Normal weight	5.094		
Overweight/Obese	11.51		
AD		896.5	< 0.001
Normal weight	0.0064		
Overweight/Obese	0.0017		
PSEM		1185.5	< 0.001
Normal weight	12.32		
Overweight/Obese	23.39		
CI			
SBP		1560.5	0.019
Normal weight	100.00		
Overweight/Obese	110.00		
DBP		1792.5	0.223
Normal weight	70.00		
Overweight/Obese	70.00		
AOS		2035	0.979
Normal weight	2.18		
Overweight/Obese	2.18		
AOD		1913.5	0.547
Normal weight	2		
Overweight/Obese	2.05		
AS		1642.5	0.059
Normal weight	7.14		
Overweight/Obese	5.55		
ASβI		1661.5	0.073
Normal weight	6.14		
Overweight/Obese	9.80		
AD		1532.5	0.016
Normal weight	0.0038		
Overweight/Obese	0.0024		
PSEM		1586	0.031
Normal weight	13.90		
Overweight/Obese	18.35		
ABSI			
SBP		1883	0.565
Normal weight	109		
Overweight/Obese	110		
DBP		1808.5	0.341
Normal weight	70		
Overweight/Obese	70		
AOS		1721.5	0.182
Normal weight	2.14		
Overweight/Obese	2.25		
AOD		1743	0.219
Normal weight	2		
Overweight/Obese	2.11		
AS		1957.5	0.839
Normal weight	6.6		
Overweight/Obese	6.65		
ASβI		1925.5	0.721
Normal weight	7.48		
Overweight/Obese	7.31		
AD		1959	0.844
Normal weight	0.0028		
Overweight/Obese	0.00227		
PSEM		1763	0.257
Normal weight	16.42		
Overweight/Obese	15.61		
BRI			
SBP		1361	0.004
Normal weight	105		
Overweight/Obese	116.1		
DBP		1884.5	0.81
Normal weight	70		
Overweight/Obese	70		
AOS		1564	0.073

Obesity Indicator; Cardiac Parameters and Body Status	Median	Mann-Whitney U	P Value
Normal weight	2.14		
Overweight/Obese	2.25		
AOD		1466.5	0.023
Normal weight	2		
Overweight/Obese	2.11		
AS		1311	0.002
Normal weight	7.3		
Overweight/Obese	4.56		
ASβI		1154	< 0.001
Normal weight	6		
Overweight/Obese	11.51		
AD		1111.5	< 0.001
Normal weight	0.0038		
Overweight/Obese	0.0018		
PSEM		1202	< 0.001
Normal weight	13.89		
Overweight/Obese	24.41		
WC			
SBP		1031.5	< 0.001
Normal weight	100		
Overweight/Obese	120		
DBP		1834.5	0.186
Normal weight	70		
Overweight/Obese	70		
AOS		1214	< 0.001
Normal weight	2.055		
Overweight/Obese	2.31		
AOD		959.5	< 0.001
Normal weight	1.9		
Overweight/Obese	2.18		
AS		955.5	< 0.001
Normal weight	8.15		
Overweight/Obese	4.35		
ASβI		884	< 0.001
Normal weight	5		
Overweight/Obese	11.67		
AD		714	< 0.001
Normal weight	0.005		
Overweight/Obese	0.0017		
PSEM		1139.5	< 0.001
Normal weight	12.41		
Overweight/Obese	23.41		
WHtR			
SBP		1382	0.023
Normal weight	105		
Overweight/Obese	120		
DBP		1762.5	0.747
Normal weight	70.00		
Overweight/Obese	70.00		
AOS		1524	0.132
Normal weight	2.15		
Overweight/Obese	2.28		
AOD		1431	0.049
Normal weight	2.00		
Overweight/Obese	2.13		
AS		1225.5	0.003
Normal weight	7.27		
Overweight/Obese	4.17		
ASβI		1098	< 0.001
Normal weight	6.13		
Overweight/Obese	11.83		
AD		1064.5	< 0.001
Normal weight	0.0037		
Overweight/Obese	0.0018		
PSEM		1136	0.001
Normal weight	13.96		
Overweight/Obese	26.42		

[a] Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; AOS, aortic diameter in systole; AOD, aortic diameter in diastole; AS, aortic strain; ASβI, aortic stiffness beta index; AD, aortic distensibility; PSEM, pressure strain elastic modulus.