Nutrition, Metabolism and Cardiovascular Diseases 36 (2026) 104518

Contents lists available at ScienceDirect

Nutrition, Metabolism and Cardiovascular Diseases

journal homepage: www.elsevier.com/locate/nmcd

Research Paper

Novel adiposity indices and their role in identifying left ventricular hypertrophy among hypertensive individuals undergoing echocardiography

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ARTICLE INFO

Handling Editor: Prof. F. Galletti

Keywords:
A body shape index
Body roundness index
Cardiovascular risk
Echocardiography
Hypertension
Left ventricular hypertrophy
Obesity

ABSTRACT

Background and aims: While body mass index (BMI) is the most used measure of adiposity, it does not account for fat distribution. Novel indices, such as A Body Shape Index (ABSI) and Body Roundness Index (BRI), may better reflect cardiometabolic risk. However, their association with subclinical cardiac damage, particularly left ventricular hypertrophy (LVH), remains unclear. The aim of this study was to evaluate the association between novel adiposity indices (ABSI and BRI) and left ventricular mass (LVM) assessed by echocardiography in a large cohort of patients with hypertensive.

Methods and results: We conducted a cross-sectional study including 724 hypertensive adults who underwent standardized anthropometric and echocardiographic assessments. Adiposity indices (BMI, waist circumference, ABSI, and BRI) were calculated, and left ventricular mass was indexed to body surface area and height$^{2.7}$. Correlations and multivariate analyses were performed, and receiver operating characteristic (ROC) curves were used to assess diagnostic performance. All adiposity indices were significantly higher in individuals with LVH. BRI showed the strongest correlation with LVMH$^{2.7}$ ($r = 0.423$), particularly in women. In multivariate analysis, BRI remained significantly associated with LVMH$^{2.7}$ in both sexes, while ABSI was not independently associated in men. ROC curve analysis demonstrated that BRI had the highest diagnostic accuracy for identifying LVH, outperforming BMI and ABSI, especially when LVH was defined using LVMH$^{2.7}$.

Conclusions: BRI outperformed traditional and novel adiposity indices in identifying LVH in hypertensive patients, particularly when LVM was indexed to height$^{2.7}$. Given its superior diagnostic performance, BRI may represent a valuable tool in cardiovascular risk stratification, though further studies are warranted.

1. Introduction

Over recent decades, the global increase in excess body weight has reached alarming levels, with more than 2.5 billion adults living with overweight and over 890 million with obesity as of 2022, establishing obesity as one of the most widespread and complex health challenges

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https://doi.org/10.1016/j.numecd.2025.104518
Received 20 September 2025; Received in revised form 15 November 2025; Accepted 5 December 2025
Available online 10 December 2025

worldwide. It affects individuals across all age groups and poses a mounting burden on healthcare systems, largely due to its strong and well-established association with a range of chronic diseases, most notably cardiovascular (CV) disease [1,2].

The body mass index (BMI) has been the standard anthropometric measure for assessing obesity, due to its simplicity and ease of use in clinical and epidemiological practice. However, it does not provide information on fat distribution—especially visceral fat—and may underestimate CV risk in normal-weight individuals with central obesity or overestimate it in muscular individuals. It is now widely accepted that comprehensive assessments beyond BMI-based definitions are essential to better understand and address the health consequences and systemic impacts of obesity [3–5].

Various alternative measures of obesity have been proposed to provide more actionable and nuanced assessments of adiposity. Among them, Krakauer et al. introduced the A Body Shape Index (ABSI) in 2012—a metric that adjusts waist circumference (WC) for BMI and height—and identified it as a strong and independent predictor of premature mortality [4]. The following year, Thomas et al. developed the Body Roundness Index (BRI), a geometric measure combining height and WC to more accurately capture total and visceral fat distribution [5]. These indices complement BMI by offering improved associations with CV mortality and subclinical organ damage [6–8]. Despite growing evidence supporting their utility in predicting CV outcomes, the extent to which these indices relate to overt CV risk is not fully established [8]. In particular, their potential correlation with echocardiographic markers of left ventricular hypertrophy (LVH) could provide valuable insights into CV risk stratification [9]. LVH is a key indicator of cardiac target organ damage and a recognized marker of subclinical myocardial remodeling. Defined as an increase in left ventricular mass, it reflects the myocardium's adaptive response to sustained pressure overload and is highly prevalent in patients with arterial hypertension [8,10,11]. Extensive evidence has shown that left ventricular mass exceeding physiological thresholds is associated with increased risk of CV events, including stroke, myocardial infarction, and sudden cardiac death [11, 12].

Accordingly, we sought to determine whether the novel adiposity indices ABSI and BRI are associated with echocardiographically measured left ventricular mass in hypertensive patients, thereby clarifying their potential role in CV risk assessment.

2. Methods

2.1. Study design and population

The cross-sectional study was conducted on a cohort of 724 consecutives individuals with arterial hypertensive selected from patients referred to the Regional Reference Center for Arterial Hypertension and European Center of Excellence of the European Society of Hypertension (ESH) at the University of Palermo (Palermo, Italy), between September 2022 and September 2024. Hypertension was defined according to the 2024 ESH Guidelines [13], based on a previous clinical diagnosis (office SBP $\geq$140 mmHg and/or DBP $\geq$90 mmHg on repeated measurements) and/or current use of antihypertensive therapy. Patients aged between 20 and 80 years and having either newly diagnosed or long-standing, treated hypertension requiring specialist evaluation were included. The following exclusion criteria were applied:

- Secondary forms of hypertension (renovascular, endocrine, or malignant);
- Obstructive sleep apnea syndrome (OSAS);
- Left ventricular ejection fraction <50%;
- Heart failure classified as NYHA functional class III or IV;
- Severe chronic kidney disease (CKD, define as estimated glomerular filtration rate [eGFR] < 30 mL/min/1.73 m^2);
- Major non-CV comorbidities with significant impact on health status (e.g., active malignancy, severe pulmonary disease, severe gastrointestinal disease).

All exclusion criteria were assessed through review of clinical documentation and confirmed during the outpatient evaluation. Secondary forms of hypertension were excluded by Duplex-Doppler ultrasound examination of the renal arteries, as well as laboratory assessment of serum electrolytes, plasma renin activity, and plasma aldosterone concentration. When clinically indicated, plasma catecholamine levels were determined and renoscintigraphy was performed. All patients underwent a comprehensive medical history evaluation and a detailed physical examination. Those who reported having quit smoking within the previous year (n = 39) were classified as smokers. Each participant underwent a standardized assessment including blood pressure measurement, anthropometric evaluation of adiposity, venous blood sampling for key biochemical markers, and a complete transthoracic echocardiographic examination. OSAS was ruled out using the Berlin questionnaire and the Epworth Sleepiness Scale, with polysomnography performed in selected cases. The following laboratory parameters were measured using standard techniques using on an analyzer: serum creatinine, fasting blood glucose, total cholesterol, high-density lipoprotein cholesterol (HDL-C), and triglycerides. Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedwald formula [14]. The eGFR was determined using the CKD-EPI Collaboration equation [15].

All participants provided written informed consent before inclusion in the study, which was approved by the Ethics Committee of Palermo, under protocol no. 928/2025. All data were analyzed anonymously.

2.2. Blood pressure measurement

Office blood pressure was measured by a physician using a validated electronic oscillometric device (Microlife WatchBP Office, Widnau, Switzerland). In addition, 24-h ambulatory blood pressure monitoring (ABPM) was performed in all participants using a portable, noninvasive recorder (SpaceLabs 90207, Redmond, WA). Blood pressure measurements were automatically obtained at 15-min intervals during daytime and at 20-min intervals during the nighttime resting period. Each ABPM dataset was automatically screened to remove artefactual readings according to predefined editing criteria: systolic values > 260 mmHg or <70 mmHg, diastolic values > 150 mmHg or <40 mmHg, and pulse pressure values > 150 mmHg or <20 mmHg were automatically discarded. Only recordings with >80% of valid readings were accepted. ABPMs with nonconsecutive hours without valid data or with >3h of missing readings were excluded. When feasible and with the patient's consent, low-quality recordings were repeated within one week of the first evaluation.

2.3. Assessment of anthropometric indices of adiposity

Body weight and height were measured with participants barefoot and wearing light clothing and recorded to the nearest 0.1 kg and 0.1 cm, respectively. WC was measured using a non-elastic tape, to the nearest 0.1 cm, at a midpoint between the lower margin of the rib cage and the superior border of the iliac crest, following a normal exhalation as previously described [16]. BMI was calculated as weight in kg divided by height in meters square (kg/m^2). Body surface area (BSA)—expressed in m^2—was calculated using the DuBois formula [17].

$$BSA = 0.007184 \times weight_{(kg)}^{0.425} \times height_{(cm)}^{0.725}$$

As described by Krakauer et al., ABSI—expressed in $m^{11/6}kg^{-2/3}$—was calculated using height (m), BMI (kg/m^2), and WC (m), according to the following formula: [4].

$$ABSI = WC / (BMI^{2/3} \times height^{1/2})$$

BRI was obtained from the height (cm) and WC (cm). The first step involved calculating the eccentricity (ε), defined as the degree of circularity of an ellipse, with values ranging from 0 (perfect circle) to 1 (vertical line):

$$\varepsilon = \sqrt{1 - \left(\frac{\left[\frac{WC}{2\pi}\right]^2}{[0.5 \times height]^2} \right)}$$

Subsequently, the BRI (dimensionless) was calculated using the formula:

$$BRI = 364.2 - 365.5 \times \varepsilon.$$

As described by Thomas et al. [5], ε values approaching 1 are typical of leaner individuals, while lower values—reflecting greater circularity—indicate increased abdominal adiposity and a rounder body shape.

2.4. Echocardiography

Echocardiographic examinations were performed using an Acuson Sequoia 512 system (Siemens, Mountain View, CA, USA). M-mode echocardiography was conducted in accordance with the recommendations of the American Society of Echocardiography (ASE) [18]. All images were acquired with the patient in partial left lateral decubitus position to evaluate the left ventricle (LV) end-diastolic and end-systolic diameters, posterior wall thickness, and interventricular septum thickness. Only frames providing optimal visualization of the interfaces and simultaneous measurement of the septum, posterior wall, and LV diameters were considered for the analysis. Left ventricular mass (LVM) was calculated using the Devereux formula and was indexed for the body surface area (LVMI) and for height raised to 2.7 ($LVMH^{2.7}$). LVH was defined as LVMI $\geq$125 g/m^2 in men and >110 g/m^2 in women, or $LVMH^{2.7} \geq 51$ g/m$^{2.7}$ in both sexes. A relative wall thickness (RWT) threshold of 0.42, applied to height-indexed LV mass, was used to classify LV geometric patterns. Accordingly, patients were categorized into four groups: (i) normal mass with RWT <0.42 (normal geometry); (ii) normal mass with RWT $\geq$0.42 (concentric remodeling); (iii) increased mass with RWT <0.42 (eccentric hypertrophy); and (iv) increased mass with RWT $\geq$0.42 (concentric hypertrophy). Echocardiographic values were calculated as the mean of five complete cardiac cycles. All measurements were performed by a single cardiologist who was blinded to the clinical characteristics of the study participants.

2.5. Statistical analysis

Analyses were performed on the entire study population and stratified by sex and by the presence of LVH, defined as $LVMH^{2.7} \geq 51$ g/m$^{2.7}$). The distribution of variables was assessed using the Kolmogorov-Smirnov test and confirmed through visual inspection of histograms and Q–Q plots. Continuous variables were expressed as mean $\pm$ standard deviation (SD) or as median and interquartile range (IQR), as appropriate. To be included in the analyses, triglyceride levels were log-transformed due to non-Gaussian distribution. Categorical variables were reported as counts and percentages. Between-group comparisons were conducted using the independent-samples Student's *t*-test for continuous variables and the Chi-square (χ^2) test with Yates' correction or Fisher's exact test, as appropriate, for categorical variables. Associations between adiposity indices and echocardiographic parameters were assessed using Pearson's correlation coefficient and linear regression analysis. Correlation coefficients were compared between sexes using the Fisher r-to-z transformation. To control for potential confounding, partial correlation coefficients were calculated adjusting for age, sex, duration of hypertension, antihypertensive treatment, and 24-h systolic and diastolic blood pressure. Covariates were selected a priori according to biological plausibility and established determinants of LVM in hypertension, rather than through automated stepwise procedures, to ensure model stability and reduce the risk of data-driven overfitting. Partial correlation analysis was used to assess the direct association between adiposity indices and echocardiographic parameters while controlling for key confounders, without assuming a directional or predictive relationship. This approach allowed for uniform adjustment across multiple variable pairs and enabled formal comparison between subgroups using Fisher's r-to-z transformation. The diagnostic ability of adiposity indices to detect LVH was evaluated using receiver operating characteristic (ROC) curves, with areas under the curve (AUCs) calculated for each index. Optimal cut-off points were defined by maximizing the Youden index (sensitivity + specificity – 1). The diagnostic performance of ABSI and BRI was compared to that of BMI by testing differences between AUCs according to Hanley and McNeil's method.

All statistical analyses were performed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA), while ROC analyses were conducted with MedCalc version 12.0 (MedCalc Software, Ostend, Belgium). A two-tailed p-value <0.05 was considered statistically significant. A formal a priori power calculation was not conducted because the study included all consecutive eligible patients during the recruitment period. However, a post hoc analysis based on the observed correlation between BRI and $LVMH^{2.7}$ (r = 0.423) indicated a power >99% (α = 0.05), confirming adequate sample size for the main analyses. Because missing data accounted for <10% of the dataset, no imputation was performed.

3. Results

The study population comprised 724 hypertensive individuals (456 men and 268 women). Women were significantly older than men (47.2 $\pm$ 10.7 vs. 44.2 $\pm$ 12.2 years) and less frequently current smokers (15.6% vs. 49.2%). Men had greater weight, height, and WC, and significantly higher values of ABSI and BRI, whereas BMI did not differ between sexes. Women were more often receiving antihypertensive treatment and had a longer duration of diagnosed hypertension. Office systolic blood pressure (SBP) was higher in women, while daytime SBP and nighttime diastolic blood pressure (DBP) were generally lower in women. Notably, men had a lower 24-h heart rate than women. Echocardiographic assessment revealed that men had significantly greater left ventricular end-diastolic diameter, septal and posterior wall thicknesses, and overall left ventricular mass. However, $LVMH^{2.7}$ was slightly but not significantly lower in men. All demographic, anthropometric, metabolic, and echocardiographic characteristics are presented in Table 1. When dividing the overall population into individuals with and without LVH, all adiposity indices were found to be significantly higher in those with increased LVM (Fig. 1).

Table 2 reports metrics of the correlations of LVMI and $LVMH^{2.7}$ with adiposity indices. In univariate correlation analysis, $LVMH^{2.7}$ showed significant associations with all anthropometric adiposity indices in both men and women. In contrast, LVMI demonstrated a sex-specific pattern of correlation: in men, it was significantly associated only with ABSI and BRI, whereas in women, significant correlations were observed exclusively with BMI and WC. Stronger associations were observed when LVM was indexed to height raised to the power of 2.7 ($LVMH^{2.7}$). Among the adiposity indices, BRI showed the strongest correlation with $LVMH^{2.7}$ (r = 0.423), with consistently higher correlation values in women compared to men. However, the difference in correlation strength between the sexes was not statistically significant (Fig. 2).

In multivariate partial correlation analyses, adjusted for potential confounders, only BMI and WC remained independently associated with LVMI in the overall population. Regarding $LVMH^{2.7}$, all adiposity indices remained significantly associated in the overall population, with BRI showing the strongest independent association (r = 0.339). These associations were confirmed in both sexes, although ABSI did not reach statistical significance in men and BMI in women.

Analysis of the area under the ROC curves (Figs. 3 and 4) demonstrated that BRI was the most accurate adiposity index for identifying

Table 1
Demographic, anthropometric, and metabolic characteristics of the study population, overall and stratified by sex.

Characteristics	Overall population (n = 724)	Men (n = 456)	Women (n = 268)	Comparison (*P*-value)
Age (years)	45.29 ± 11.74	44.21 ± 12.15	47.15 ± 10.70	0.001
Current smokers (%)	37.4	49.2	15.6	0.003
Weight (kg)	78.31 ± 13.94	83.68 ± 12.32	69.34 ± 11.70	<0.001
Height (m)	1.67 ± 0.10	1.72 ± 0.07	1.58 ± 0.07	<0.001
BMI (kg/m^2)	28.09 ± 4.01	28.24 ± 3.62	27.83 ± 4.61	0.221
Waist circumference (cm)	95.99 ± 11.49	98.75 ± 9.36	91.28 ± 13.16	<0.001
ABSI ($m^{11/6}kg^{-2/3}$)	0.081 ± 0.006	0.082 ± 0.006	0.080 ± 0.006	<0.001
BRI	4.97 ± 1.60	4.91 ± 1.26	5.06 ± 2.05	<0.001
Total cholesterol (mg/dL)	205.70 ± 39.79	201.99 ± 38.37	212.04 ± 41.42	0.001
HDL-c (mg/dL)	45.42 ± 10.23	44.07 ± 9.51	47.74 ± 11.01	<0.001
LDL-c (mg/dL)	133.98 ± 31.69	130.50 ± 31.69	140.04 ± 40.86	0.001
Triglycerides (mg/dL)	114 (81–165)	125 (85.5–170.5)	105 (76–147)	<0.001
Blood glucose (mg/dL)	94.96 ± 16.43	95.62 ± 16.77	93.84 ± 15.80	0.161
Creatinine (mg/dL)	0.87 ± 0.19	0.95 ± 0.17	0.75 ± 0.16	<0.001
eGFR ($mL/min/1.73m^2$)	95.86 ± 17.61	96.70 ± 17.56	94.40 ± 17.65	0.091
Antihypertensive treatment (%)	60.6	57.8	71.2	<0.001
Duration of hypertension (months)	24 (6–60)	18.5 (5–54)	36 (12–84)	<0.001
Office SBP (mmHg)	153 ± 20.06	151 ± 18.82	156 ± 21.66	0.001
Office DBP (mmHg)	93 ± 13.19	93 ± 12.40	93 ± 12.32	0.777
24-h SBP (mmHg)	134 ± 12.39	135 ± 12.40	133 ± 12.23	0.092
24-h DBP (mmHg)	85 ± 9.80	86 ± 9.75	83 ± 9.68	<0.001
24-h heart rate (bpm)	75 ± 9.00	74 ± 8.64	77 ± 9.16	<0.001
Daytime SBP (mmHg)	139 ± 12.56	140 ± 12.53	137 ± 12.40	0.007
Daytime DBP (mmHg)	89 ± 10.06	90 ± 9.85	87 ± 10.01	<0.001
Nighttime SBP (mmHg)	125 ± 13.77	125 ± 13.05	124 ± 14.93	0.636
Nighttime DBP (mmHg)	77 ± 11.26	78 ± 11.58	75 ± 10.47	0.002
LV end-diastolic diameter (mm)	49.82 ± 5.55	51.27 ± 5.04	47.41 ± 5.52	<0.001
Interventricular septum (diastole) (mm)	10.39 ± 1.77	10.56 ± 1.73	10.10 ± 1.80	<0.001
Posterior wall (diastole) (mm)	9.78 ± 1.62	9.93 ± 1.53	9.53 ± 1.74	0.002
Left ventricular mass (g)	186.2 ± 55.3	197.5 ± 52.9	167 ± 54.2	<0.001
LVMI (g/m^2)	99.47 ± 27.8	101.2 ± 26.8	96.54 ± 29.1	0.030
$LVMH^{2.7}$ ($g/m^{2.7}$)	46.92 ± 14.5	46.08 ± 13.0	48.37 ± 16.7	0.054
Relative wall thickness	0.39 ± 0.08	0.39 ± 0.07	0.40 ± 0.09	0.021
Left atrial diameter (mm)	35.29 ± 4.49	36.14 ± 4.38	33.60 ± 4.20	<0.001

Abbreviations: ABSI = A Body Shape Index; BMI = Body Mass Index; BRI = Body Roundness Index; DBP = Diastolic Blood Pressure; eGFR = Estimated Glomerular Filtration Rate calculated using the CKD-EPI equation; HDL = High-Density Lipoprotein Cholesterol; LDL = Low-Density Lipoprotein Cholesterol; LV = Left Ventricular; LVMI = Left Ventricular Mass index; $LVMH^{2.7}$ = Left Ventricular Mass indexed to height raised to 2.7; SBP = Systolic Blood Pressure.

LVH, defined as $LVMH^{2.7} \geq 51\ g/m^{2.7}$, both in the overall population and when stratified by sex. The diagnostic performance of all adiposity indices, including BRI, was consistently lower in men compared to women. The distribution of left ventricular geometric patterns based on $LVMH^{2.7}$ criteria is illustrated in Fig. 5. Comparable results were obtained when assessing the ability of each adiposity index to identify concentric and eccentric LVH separately in the total population as well as in both sexes (data not shown).

4. Discussion

This study investigated the relationship between traditional and novel adiposity indices and echocardiographically assessed LVH in a large cohort of hypertensive individuals. Among all the indices evaluated, the BRI demonstrated the strongest and most consistent association with $LVMH^{2.7}$, both in univariate and multivariate analyses. The diagnostic performance of BRI in identifying LVH, as assessed by the AUC, was superior to that of other indices in the overall population as well as in sex-stratified analyses. While BRI maintained its diagnostic accuracy in both men and women, other indices such as BMI and WC showed sex-specific performance, and the ABSI was consistently the least informative, particularly in men. Although BRI demonstrated the highest diagnostic accuracy among the evaluated indices, the AUC values (~0.72) indicate only moderate discriminative ability, reflecting the multifactorial pathophysiology of LVH, in which adiposity represents only one of several contributing mechanisms. The slightly better diagnostic performance observed in women may relate to sex-specific patterns of fat distribution and hormonal influences on cardiac remodeling, as previously suggested in population-based studies [19,20].

The stronger associations observed when LVM was indexed to $height^{2.7}$ rather than body surface area (LVMI) support previous research highlighting the advantages of using height-based indexing, particularly in individuals with increased adiposity. $LVMH^{2.7}$ has been shown to better identify true hypertrophy in people with obesity by minimizing the masking effect of excess fat mass on body surface area measurements [21,22]. This has both diagnostic and prognostic implications: using $LVMH^{2.7}$ rather than LVMI results in a higher detection rate of hypertrophy among people with obesity and increases the attributable risk in the population, potentially identifying a larger number of patients at elevated CV risk who could benefit from preventive strategies.

Our findings align with a large multicenter study that demonstrated how indexing LVM by body surface area fails to capture deviations from normality in people with obesity [23]. By contrast, indexing to $height^{2.7}$ linearizes the relationship between cardiac mass and body size, providing a more accurate and actionable parameter for identifying subclinical target organ damage.

Among the anthropometric indices evaluated, BRI consistently showed the strongest correlation with $LVMH^{2.7}$ and the highest diagnostic accuracy for identifying LVH. This was true not only in the overall cohort but also in sex-specific subgroups. In men, BRI was the only index that retained significant accuracy in detecting LVH. These results confirm and expand on previous observations from studies conducted in Asian populations. For instance, a 2016 study by Chang et al. in a rural Chinese population reported that BRI had the highest area under the curve for predicting LVH, particularly of the eccentric type [24]. Similarly, Cai et al. found that BRI was a strong predictor of LVH in hypertensive patients in central China, especially among women, with ABSI again showing the weakest performance [25]. Another study conducted

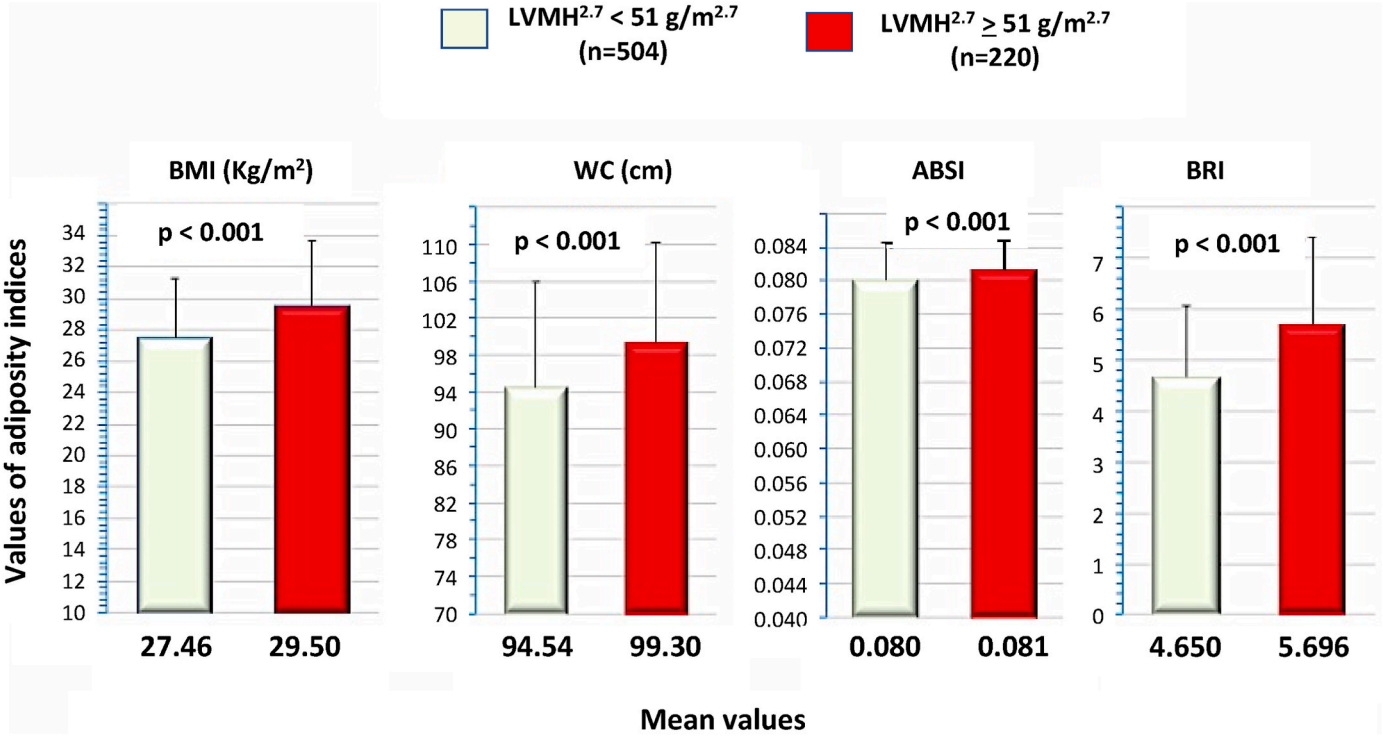


Fig. 1. Comparison of adiposity indices (BMI, WC, ABSI, and BRI) between patients with and without left ventricular hypertrophy defined by $LVMH^{2.7} \geq 51$ g/$m^{2.7}$
Abbreviations: ABSI = A Body Shape Index; BMI = Body Mass Index; BRI = Body Roundness Index; $LVMH^{2.7}$ = Left Ventricular Mass indexed to height raised to 2.7; WC = Waist Circumference.

Table 2
Bivariate and multivariate correlations between adiposity indices and left ventricular mass indices (LVMI and $LVMH^{2.7}$) in the overall population and stratified by sex.

	Bivariate			
	LVMI			
	BMI	**WC**	**ABSI**	**BRI**
Overall population	0.129*	0.147*	0.127*	0.155*
Men	0.052	0.072	0.109*	0.160*
Women	0.217*	0.194*	0.119	0.213
	$LVMH^{2.7}$			
	BMI	**WC**	**ABSI**	**BRI**
Overall population	0.316*	0.257*	0.164*	0.423*
Men	0.235*	0.220*	0.136*	0.373*
Women	0.411*	0.370*	0.272*	0.455*
	Multivariate			
	LVMI			
	BMI	**WC**	**ABSI**	**BRI**
Overall population	0.083*	0.097*	0.047	0.056
Men	0.017	0.072	0.023	0.050
Women	0.137*	0.018	0.007	0.108
	$LVMH^{2.7}$			
	BMI	**WC**	**ABSI**	**BRI**
Overall population	0.280*	0.234*	0.083*	0.339*
Men	0.209*	0.170*	0.036	0.279*
Women	0.335	0.281*	0.155*	0.359*

*P-value <0.05.
Abbreviations: ABSI = A Body Shape Index; BMI = Body Mass Index; BRI = Body Roundness Index; LVMI = Left Ventricular Mass Index (indexed to body surface area); $LVMH^{2.7}$ = Left Ventricular Mass indexed to height raised to 2.7; WC = Waist Circumference.

in an older Chinese population demonstrated the association of BRI with hypertension-mediated organ damage, particularly in women [26]. Zhao et al. demonstrated that BRI served as an alternative index for assessing diabetes in Han Chinese individuals in northeastern China [27]. Additional studies further corroborate the value of BRI,

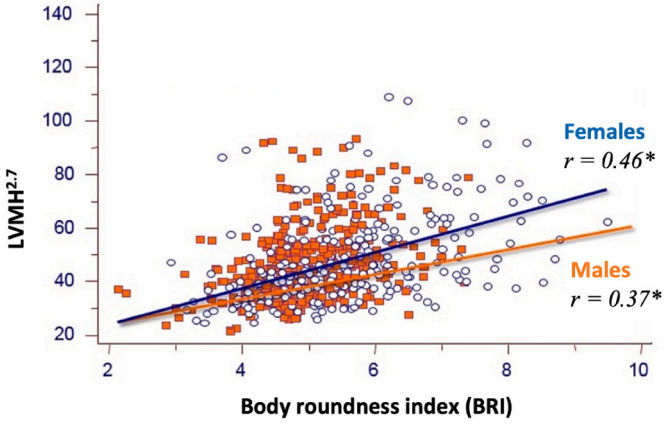
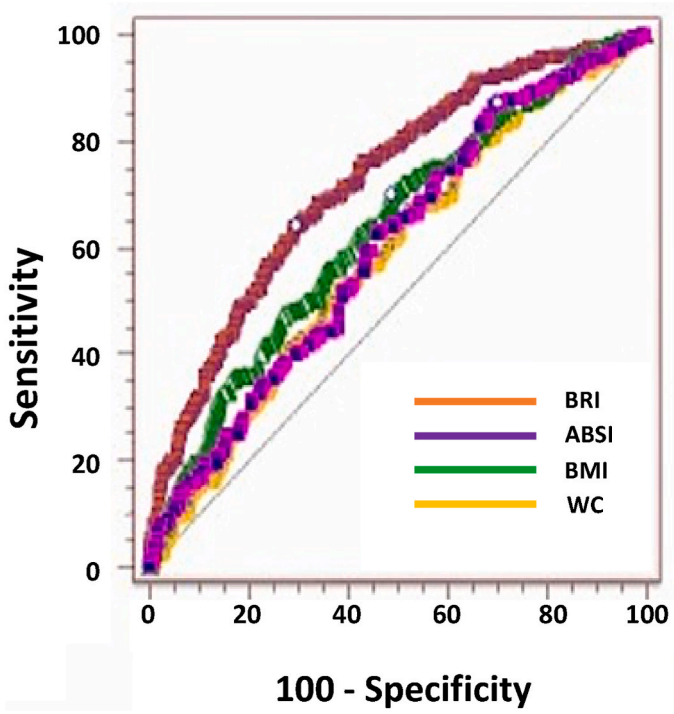


Fig. 2. Correlation between Body Roundness Index (BRI) and left ventricular mass indexed to $height^{2.7}$ ($LVMH^{2.7}$) in men and women.

demonstrating its associations with organ damage mediated by hypertension, non-alcoholic fatty liver disease (NAFLD), hyperuricemia, and metabolic syndrome components [28–30].

The reproducibility of these findings across diverse ethnic groups, including our European cohort, is noteworthy. It is well established that Asians tend to have a higher percentage of body fat and visceral adipose tissue for the same BMI compared to Caucasians [31], which could influence the performance of adiposity indices. Nonetheless, BRI maintained its superiority in both settings. This supports the growing recognition of BRI as a robust marker of cardiometabolic risk that may outperform traditional indices and ABSI, particularly in hypertensive populations [32,33].

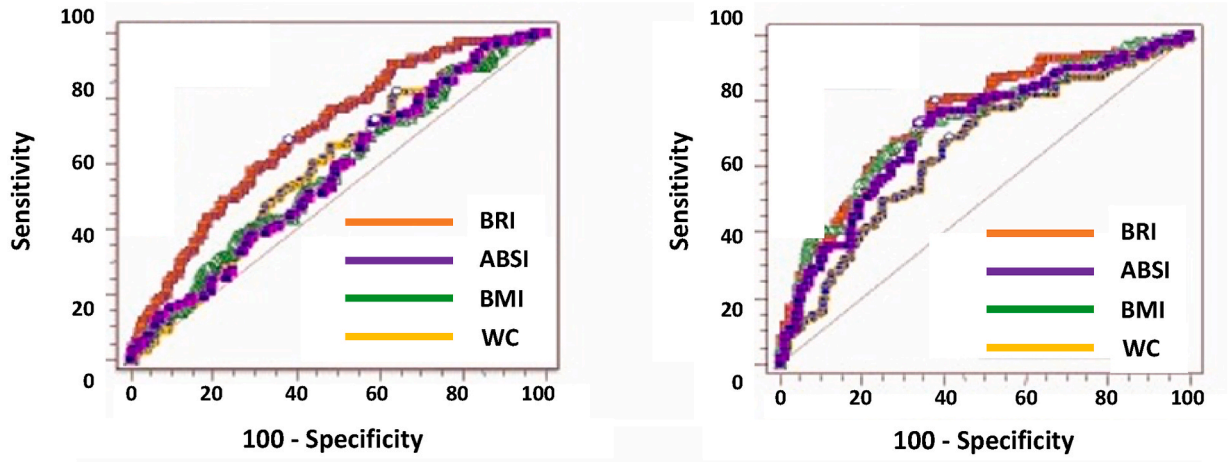
Although ABSI was originally proposed as a health-risk index less influenced by body size, our results and those of others raise questions about its clinical utility. Studies such as the DECODE project have not



	AUC	95% CI
BRI	0.724*	0.689 to 0.758
ABSI	0.585$	0.546 to 0.622
BMI	0.638^	0.601 to 0.675
WC	0.599	0.561 to 0.637

*BRI vs ABSI; vs BMI; vs WC: p < 0.001
$BMI vs WC: p = 0.0014
^ABSI vs BMI: p = 0.060

Fig. 3. Receiver operating characteristic (ROC) curves and area under the curve (AUC) values for adiposity indices in identifying left ventricular hypertrophy ($LVMH^{2.7} \geq 51$ g/$m^{2.7}$)
Abbreviations: AUC = Area Under the Curve; 95%CI = 95% Confidence Interval; ABSI = A Body Shape Index; BMI = Body Mass Index; BRI = Body Roundness Index; WC = Waist Circumference.



	AUC	95% CI
BRI	0.692*$	0.645 to 0.736
ABSI	0.587	0.538 to 0.634
BMI	0.574	0.525 to 0.622
WC	0.566	0.517 to 0.614

*BRI vs ABSI: p = 0.005
$BRI vs BMI; vs WC: p < 0.001

	AUC	95% CI
BRI	0.747*$	0.689 to 0.800
ABSI	0.652§	0.590 to 0.711
BMI	0.732^	0.673 to 0.786
WC	0.711	0.651 to 0.767

*BRI vs ABSI: p < 0.001; $BRI vs WC: p= 0.080
§ABSI vs BMI; vs WC: p=0.010; ^BMI vs WC: p=0.070

Fig. 4. Receiver operating characteristic (ROC) curves and area under the curve (AUC) values for adiposity indices in identifying left ventricular hypertrophy ($LVMH^{2.7} \geq 51$ g/$m^{2.7}$), stratified by sex (male on the left)
Abbreviations: AUC = Area Under the Curve; 95%CI = 95% Confidence Interval; ABSI = A Body Shape Index; BMI = Body Mass Index; BRI = Body Roundness Index; WC = Waist Circumference.

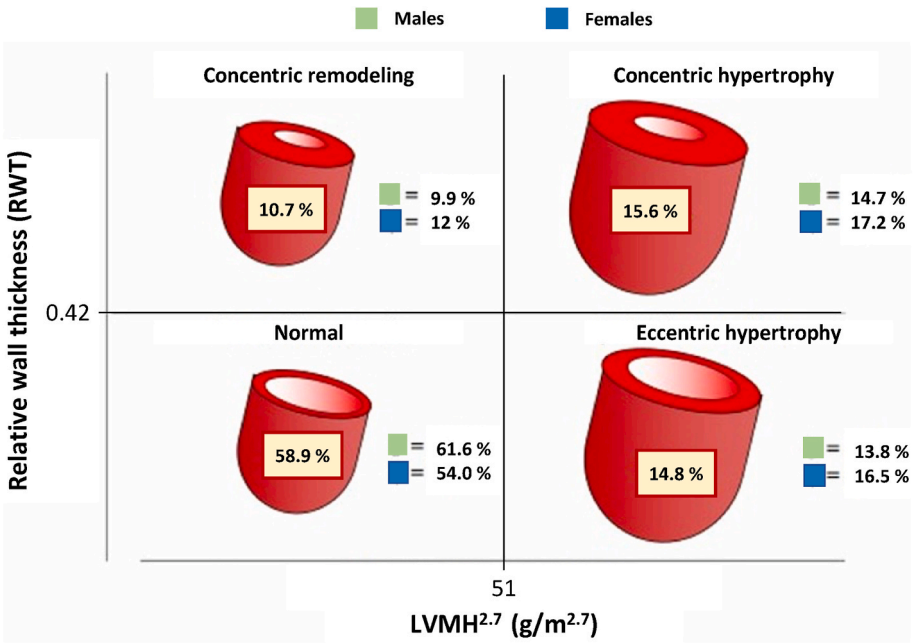


Fig. 5. Distribution of left ventricular geometric patterns based on relative wall thickness (RWT) and Left Ventricular Mass indexed to height raised to 2.7 ($LVMH^{2.7}$), stratified by sex.

confirmed any prognostic advantage of ABSI over traditional indices such as BMI or WC in predicting CV or all-cause mortality [34]. These findings suggest that while ABSI may offer theoretical appeal, its practical relevance—especially in CV risk stratification—remains limited.

This study has several limitations that should be acknowledged. First, the single-center design and inclusion of patients referred for specialist evaluation may introduce a degree of selection bias, potentially limiting the generalizability of our findings. Moreover, the cross-sectional nature of the study precludes causal inference and reduces external validity, underscoring the need for multicentric, prospective studies to confirm these associations and explore their temporal direction. Second, although missing data represented less than 10% and were not imputed, this may introduce a slight bias in the analyses. Furthermore, this study relied on indirect anthropometric indices rather than direct measures of body fat distribution (e.g., dual-energy X-ray absorptiometry or magnetic resonance imaging), which may have reduced precision in estimating adiposity. It should be also noted that the diagnostic performance of adiposity indices may vary in specific clinical subgroups. For example, people with CKD often present altered fluid balance, sarcopenia, or cachexia, which can affect both anthropometric measures and cardiac remodeling, potentially biasing the interpretation of results [35–37]. Similar caution may apply to other high-risk groups, including people with diabetes [38]. The potential for dilution bias due to heterogeneous antihypertensive treatment regimens and interindividual variation in adiposity and metabolic status should also be considered. Future studies specifically designed for these populations are warranted to validate the applicability of ABSI and BRI in such settings. Although all echocardiographic assessments were conducted according to the existing guidelines and by a single experienced operator, reproducibility testing was not performed and may represent an additional limitation. Finally, despite adjustment for several covariates, residual confounding from antihypertensive therapy or unmeasured metabolic factors cannot be excluded.

Nevertheless, despite these limitations, the study offers valuable insight into the relationship between novel adiposity indices—particularly BRI—and echocardiographically measured left ventricular mass in hypertensive individuals. Future research should confirm these findings in longitudinal, multicentric, and multiethnic cohorts, employ direct adiposity assessment techniques, and incorporate a more comprehensive set of confounders to strengthen internal and external validity.

In conclusion, among hypertensive patients, BRI showed the strongest association with $LVMH^{2.7}$, outperforming both traditional anthropometric measures and ABSI in the identification of left ventricular hypertrophy. Since $LVMH^{2.7}$ is a robust and independent predictor of CV events, these findings support the potential value of BRI as a tool for improved CV risk stratification in clinical practice. This relevance is further underscored by the global obesity epidemic and the rising prevalence of central obesity among patients with hypertension, conditions in which accurate assessment of adiposity is particularly critical. Further prospective and multicentric studies are needed to confirm these results and to clarify whether BRI may also contribute to guiding therapeutic strategies and risk reduction interventions in hypertension.

Author contributions

GG and CC conceived and designed the study. GG, TP, RLM, VP, VC, GC, FP, MB, EN, and CC curated the data. All authors contributed to the interpretation of results. GG and PF drafted the first version of the manuscript, with critical revisions from all authors. PF also provided statistical feedback. GM and RP supervised the study. All authors reviewed and approved the final version of the manuscript.

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Palermo, under protocol no. 928/2025. All data were analyzed anonymously.

Funding

This research received no external funding.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] GBD 2021 Adult BMI Collaborators. Global, regional, and national prevalence of adult overweight and obesity, 1990-2021, with forecasts to 2050: a forecasting study for the global burden of disease study 2021. Lancet 2025;405(10481):813–38. https://doi.org/10.1016/S0140-6736(25)00355-1.

[2] Okunogbe A, Nugent R, Spencer G, Powis J, Ralston J, Wilding J. Economic impacts of overweight and obesity: current and future estimates for 161 countries. BMJ Glob Health 2022;7(9):e009773. https://doi.org/10.1136/bmjgh-2022-009773.

[3] Rubino F, Cummings DE, Eckel RH, et al. Definition and diagnostic criteria of clinical obesity. Lancet Diabetes Endocrinol 2025;13(3):221–62. https://doi.org/10.1016/S2213-8587(24)00316-4.

[4] Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PLoS One 2012;7(7):e39504. https://doi.org/10.1371/journal.pone.0039504. Li S, ed.

[5] Thomas DM, Bredlau C, Bosy-Westphal A, et al. Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity 2013;21(11):2264–71. https://doi.org/10.1002/oby.20408.

[6] Maessen MFH, Eijsvogels TMH, Verheggen RJHM, Hopman MTE, Verbeek ALM, de Vegt F. Entering a new era of body indices: the feasibility of a body shape index and body roundness index to identify cardiovascular health status. PLoS One 2014;9(9):e107212. https://doi.org/10.1371/journal.pone.0107212. 35 Gong Y, ed.

[7] Malara M, Kęska A, Tkaczyk J, Lutosławska G. Body shape index versus body mass index as correlates of health risk in young healthy sedentary men. J Transl Med 2015;13(1):75. https://doi.org/10.1186/s12967-015-0426-z.

[8] Geraci G, Ferrara P, Pallotti F, Le Moli R, Calabrese V, Paternò V, et al. Correlations between novel adiposity indices and electrocardiographic evidence of left ventricular hypertrophy in individuals with arterial hypertension. J Personalized Med 2025;15(6):229. https://doi.org/10.3390/jpm15060229.

[9] Hu T, Yao L, Gustat J, Chen W, Webber L, Bazzano L. Which measures of adiposity predict subsequent left ventricular geometry? Evidence from the bogalusa heart study. Nutr Metabol Cardiovasc Dis 2015;25(3):319–26. https://doi.org/10.1016/j.numecd.2014.11.001.

[10] Bornstein AB, Rao SS, Marwaha K. Left ventricular hypertrophy. In: StatPearls [internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan [Updated 2023 Aug 8], https://www.ncbi.nlm.nih.gov/books/NBK557534/.

[11] Nemtsova V, Burkard T, Vischer AS. Hypertensive heart disease: a narrative review series-part 2: macrostructural and functional abnormalities. J Clin Med 2023;12(17):5723. https://doi.org/10.3390/jcm12175723.

[12] Wang CC, Liang LK, Luo SM, Wang HC, Wang XL, Cheng YH, Pan GM, Peng JY, Han SJ, Wang X. Nomogram-based risk assessment model for left ventricular hypertrophy in patients with essential hypertension: incorporating clinical characteristics and biomarkers. J Clin Hypertens (Greenwich) 2024;26(4):363–73. https://doi.org/10.1111/jch.14786.

[13] McEvoy JW, McCarthy CP, Bruno RM, et al. ESC scientific document group. 2024 ESC guidelines for the management of elevated blood pressure and hypertension. Eur Heart J 2024;45(38):3912–4018. https://doi.org/10.1093/eurheartj/ehae178.

[14] Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 1972;18:499–502.

[15] Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro 3rd AF, Feldman HI, Kusek JW, Eggers P, Van Lente F, Greene T, Coresh J. CKD-EPI (chronic kidney disease epidemiology collaboration). A new equation to estimate glomerular filtration rate. Ann Intern Med 2009;150(9):604–12. https://doi.org/10.7326/0003-4819-150-9-200905050-00006.

[16] Geraci G, Zammuto M, Gaetani R, et al. Relationship of a body shape index and body roundness index with carotid atherosclerosis in arterial hypertension. Nutr Metabol Cardiovasc Dis 2019;29(8):822–9. https://doi.org/10.1016/j.numecd.2019.04.013.

[17] DuBois D, DuBois EF. A formula to estimate the approximate surface area if height and weight be known. Nutrition 1989;5:303–11.

[18] Marwick TH, Gillebert TC, Aurigemma G, et al. Recommendations on the use of echocardiography in adult hypertension: a report from the european association of cardiovascular imaging (EACVI) and the American society of echocardiography (ASE). J Am Soc Echocardiogr 2015;28(7):727–54. https://doi.org/10.1016/j.echo.2015.05.002.

[19] Losev V, Lu C, Tahasildar S, Senevirathne DS, Inglese P, Bai W, King AP, Shah M, de Marvao A, O'Regan DP. Sex-specific body fat distribution predicts cardiovascular ageing. Eur Heart J 2025. https://doi.org/10.1093/eurheartj/ehaf553. ehaf553.

[20] Li H, Yin G, Zhang Y, Wang Z, Lv F, Li R, Qin J, Ye X. Effect of fat distribution on left ventricular structure and function in different sexes: a Mendelian randomization study. Front Endocrinol 2025;16:1355968. https://doi.org/10.3389/fendo.2025.1355968.

[21] Taylor HCM, Chaturvedi N, Davey Smith G, Ferreira DLS, Fraser A, Howe LD, Hughes AD, Lawlor DA, Timpson NJ, Park CM. Is Height2.7 appropriate for indexation of left ventricular mass in healthy adolescents? The importance of sex differences. Hypertension 2023;80(10):2033–42. https://doi.org/10.1161/HYPERTENSIONAHA.121.17109.

[22] Cuspidi C, Meani S, Negri F, Giudici V, Valerio C, Sala C, Zanchetti A, Mancia G. Indexation of left ventricular mass to body surface area and height to allometric power of 2.7: is the difference limited to obese hypertensives? J Hum Hypertens 2009;23(11):728–34. https://doi.org/10.1038/jhh.2009.16.

[23] de Simone G, Daniels SR, Devereux RB, et al. Left ventricular mass and body size in normotensive children and adults: assessment of allometric relations and impact of overweight. J Am Coll Cardiol 1992;20(5):1251–60. https://doi.org/10.1016/0735-1097(92)90385-Z.

[24] Chang Y, Guo X, Li T, Li S, Guo J, Sun Y. A body shape index and body roundness index: two new body indices to identify left ventricular hypertrophy among rural populations in northeast China. Heart Lung Circ 2016;25(4):358–64. https://doi.org/10.1016/j.hlc.2015.08.009.

[25] Cai S, Dong J, Cheng B, Zhang A, Sun J, Li M, Su Y, Bao Q, Zhu P, Wang S. Relationship of a new anthropometric index with left ventricular hypertrophy in hypertensive patients among the Han Chinese. BMC Cardiovasc Disord 2022;22(1):16. https://doi.org/10.1186/s12872-022-02463-6.

[26] Tang J, Zhao S, Yu S, Chi C, Ji H, Xiong J, Teliewubai J, Fan X, Maimaitiaili R, Xu Y, Zhang Y. Association between hypertension-mediated organ damage and obesity defined by novel anthropometric indices in community-dwelling elderly individuals. Clin Nutr 2021;40(6):4473–80. https://doi.org/10.1016/j.clnu.2020.12.035.

[27] Zhao Q, Zhang K, Li Y, Zhen Q, Shi J, Yu Y, Tao Y, Cheng Y, Liu Y. Capacity of a body shape index and body roundness index to identify diabetes mellitus in Han Chinese people in Northeast China: a cross-sectional study. Diabet Med 2018;35(11):1580–7. https://doi.org/10.1111/dme.13787.

[28] Motamed N, Rabiee B, Hemasi GR, et al. Body roundness index and waist-to-height ratio are strongly associated with non-alcoholic fatty liver disease: a population-based study. Hepat Mon 2016;16(9):e39575. https://doi.org/10.5812/hepatmon.39575.

[29] Zhang N, Chang Y, Guo X, Chen Y, Ye N, Sun Y. A body shape index and body roundness index: two new body indices for detecting association between obesity and hyperuricemia in rural area of China. Eur J Intern Med 2016;29:32–6. https://doi.org/10.1016/j.ejim.2016.01.019.

[30] Zaid M, Ameer F, Munir R, et al. Anthropometric and metabolic indices in assessment of type and severity of dyslipidemia. J Physiol Anthropol 2017;36:19. https://doi.org/10.1186/s40101-017-0134x.

[31] Wulan SN, Westerterp KR, Plasqui G. Ethnic differences in body composition and the associated metabolic profile: a comparative study between Asians and Caucasians. Maturitas 2010;65(4):315–9. https://doi.org/10.1016/j.maturitas.2009.12.012.

[32] Qin X, Chen C, Wang J, Cai A, Feng X, Jiang X, Feng Y. Association of adiposity indices with cardiometabolic multimorbidity among 101,973 chinese adults: a cross-sectional study. BMC Cardiovasc Disord 2023 Oct 21;23(1):514. https://doi.org/10.1186/s12872-023-03543-x.

[33] Zhan Q, An Q, Zhang F, Zhang T, Liu T, Wang Y. Body roundness index and the risk of hypertension: a prospective cohort study in Southwest China. BMC Public Health 2024;24(1):2539. https://doi.org/10.1186/s12889-024-20049-z.

[34] Song X, Jousilahti P, Stehouwer CD, Söderberg S, Onat A, Laatikainen T, Yudkin JS, Dankner R, Morris R, Tuomilehto J, Qiao Q, DECODE Study Group. Cardiovascular and all-cause mortality in relation to various anthropometric measures of obesity in Europeans. Nutr Metabol Cardiovasc Dis 2015;25(3):295–304. https://doi.org/10.1016/j.numecd.2014.09.004.

[35] Nardi E, Mulè G, Giammanco A, Mattina A, Geraci G, Nardi C, Averna M. Left ventricular hypertrophy in chronic kidney disease: a diagnostic criteria comparison. Nutr Metabol Cardiovasc Dis 2021;31(1):137–44. https://doi.org/10.1016/j.numecd.2020.08.028.

[36] Mulè G, Nardi E, Guarino L, Cacciatore V, Geraci G, Calcaterra I, et al. Plasma aldosterone and its relationship with left ventricular mass in hypertensive patients with early-stage chronic kidney disease. Hypertens Res 2015;38(4):276–83. https://doi.org/10.1038/hr.2014.171.

[37] Nardi E, Mulè G, Nardi C, Geraci G, Giammanco A, Bentivegna R, Averna M. Is echocardiography mandatory for patients with chronic kidney disease? Intern Emerg Med 2019;14(6):923–9. https://doi.org/10.1007/s11739-019-02028-0.

[38] Liu S, Ke J, Feng X, Xu Y, Zhu L, Yang L, Zhao D. Diabetic microvascular complications are associated with left ventricular hypertrophy in patients with type 2 diabetes mellitus. J Diabet Complicat 2025;39(2):108947. https://doi.org/10.1016/j.jdiacomp.2024.108947.