Original Article

Association between adiposity indices and arterial stiffness measures in women

Associação entre índices de adiposidade e medidas de rigidez arterial em mulheres

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ABSTRACT

Introduction: The development of cardiovascular diseases is influenced by increased adiposity and premature aging, resulting in arterial stiffness. This study aimed to assess the association between adiposity indices and arterial stiffness in adult women. **Methods:** Cross-sectional study, including women aged 19 to 59 years, without abnormalities in the spine, lower limbs and hydrocephalus. Arterial stiffness outcomes (pulse wave velocity and augmentation index) were analyzed by oscillometry, while exposure variables included body mass index, body shape index, and circumference of the waist, waist-to-height ratio, conicity index, body roudness index, relative fat mass and estimated total body fat. Multiple linear regressions were performed. **Results:** 190 women were included and after adjusting for age, race/color, risk factors, and menopause the conicity index (β=3.264; 95%CI=2.429-4.100), body shape index (β=0.050; 95%CI=0.008-0.093) and estimated total body fat (β=0.041; 95%CI=0.030-0.052) were associated with pulse wave velocity. Regarding augmentation index, both central adiposity indices, waist-to-height ratio (β=20.162; 95%CI=0.224-40.099), conicity index (β=18.541; 95%CI=7.125-29.957), body roudness index (β=0.442; 95%CI=0.019-0.865), as well as relative fat mass (β=0.354; 95%CI=0.025-0.682) and estimated total body fat (β=0.254; 95%CI=0.101-0.407), and body fat estimates were positively associated. **Conclusion:** Central adiposity and body fat are associated with arterial stiffness, suggesting that adiposity indices may serve as simple and cost-effective tools for cardiovascular prognosis.

RESUMO

Introdução: O desenvolvimento de doenças cardiovasculares é influenciado pelo aumento da adiposidade e envelhecimento precoce, resultando em rigidez arterial. Este estudo teve como objetivo avaliar a associação entre índices de adiposidade e rigidez arterial em mulheres adultas. **Método:** Estudo transversal, incluindo mulheres de 19 a 59 anos, sem anormalidades na coluna vertebral, membros inferiores e hidrocefalia. Os resultados de rigidez arterial (velocidade da onda de pulso e índice de aumento) foram analisados por oscilometria, enquanto as variáveis de exposição incluíram índice de massa corporal, índice de forma corporal, circunferência da cintura, razão cintura-altura, índice de conicidade, índice de redondeza corporal, massa gorda relativa e gordura corporal total estimada. Regressões lineares múltiplas foram realizadas. **Resultados:** Foram incluídas 190 mulheres e, após ajuste para idade, raça/cor, fatores de risco e menopausa, o índice de conicidade (β=3,264; IC 95%=2,429-4,100), índice de forma corporal (β=0,050; IC95%=0,008-0,093) e gordura corporal total estimada (β=0,041; IC95%=0,030-0,052) foram associados à velocidade de onda de pulso. Em relação ao índice de aumento, ambos os índices de adiposidade central, razão cintura-estatura (β=20,162; IC95%=0,224-40,099), índice de conicidade (β=18,541; IC95%=7,125-29,957), BRI (β=0,442; IC95%=0,019-0,865), bem como massa gorda relativa (β=0,354; IC95%=0,025-0,682) gordura corporal total estimada (β=0,254; IC95%=0,101-0,407), e estimativas de gordura corporal foram positivamente associados. **Conclusão:** A adiposidade central e a gordura corporal estão associadas à rigidez arterial, sugerindo que índices de adiposidade podem ser ferramentas simples e econômicos para prognóstico cardiovascular.

Keywords:
Cardiovascular diseases. Vascular stiffnes. Obesity.

Unitermos:
Doenças cardiovasculares. Rigidez vascular. Obesidade.

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INTRODUCTION

Cardiovascular diseases (CVD) are considered the leading cause of death in developing countries. The projection is that by 2030, with the aging of the population, CVDs will correspond to 23.4 million deaths worldwide[1]. In Brazil, this condition contributes to the highest mortality rates since the late 1960s with the epidemiological transition[2], corresponding to 27.7% of deaths in the country[3].

The development of CVD is multifactorial. However, worldwide, obesity is one of the main exposures that implies its emergence, driven by the high level of cardio-metabolic risk factors strongly influenced by the increase in adiposity[4,5]. Women, when compared to men, have a higher percentage of body fat, with a greater deposition of adipose tissue on the hips and thighs[6]. This situation draws attention because a greater increase in mortality from CVD is perceived as the body mass index (BMI) or waist circumference (WC) increase[7].

In this context, to predict cardiovascular risk through anthropometric measurements related to general and central adiposity, some authors have investigated the association between these measurements, such as BMI, WC, waist-to-height ratio (WHtR)[8,9], and other alternative indices such as the body shape index (ABSI), body roundness index (BRI) and conicity index with cardiovascular outcomes and blood pressure parameters[10-12]. However, no adiposity index has been continuously better than others in discriminating CVD, especially when related to arterial stiffness measures.

From the central parameters of blood pressure, arterial stiffness appears as an emerging and promising measure as a prognostic marker for heart disease, being characterized as a pathological disorder caused by the premature aging of the vessels. This measure can be determined by central parameters, where it is possible to determine the pulse wave velocity (PWV), the gold standard to identify arterial stiffness, and the augmentation index, an indicator of vessel functionality[13].

Although previous studies have addressed adiposity parameters as risk factors for arterial stiffness, this finding is still controversial and the measurement of central parameters are more common in research settings or are not available at no cost by specialized cardiology services. In this sense, given the possibility of predicting the risk of CVD through premature vascular aging and at a low cost, the objective of this study is to evaluate the association between adiposity and arterial stiffness indices in adult women.

METHODS

Design and Study Population

The study was cross-sectional, carried out at the cardiological examination clinic of the Dr. Marco Mota Clinical Research Center (Maceió, AL, Brazil). Recruitment took place through an invitation to participants accompanied in these clinics and advertisements through posters at the collection points. Adult women (19-59 years old) were included in this study, while pregnant women, lactating women, or those with physical disabilities were excluded.

Data collection

The central parameters of arterial pressure and arterial stiffness were obtained through a non-invasive method, which determines the pressure based on brachial pulse waves, recorded through a cuff connected to the ARTERIS AOP® oscillometric device (Cardio Sistemas Comercial e Industrial Ltda., São Paulo, Brazil) which checks blood pressure and analyzes pulse wave. The preparation for measuring blood pressure followed the recommendations proposed in the Brazilian guidelines on arterial hypertension of 2020[14]. Blood pressure is determined using the validated oscillometric method[15], which consists of inflating the cuff to a pressure sufficient to reduce blood flow in the individual's arm, and then reducing it in a controlled manner, allowing blood flow to gradually return to normal. In this way, the system measures the amplitude of oscillations in blood pressure, known as oscillometric pulses. Through an algorithm, these pulses are computed to determine systolic and diastolic pressures. The device is programmed to perform monitoring for around 3 minutes, where it performs shots that assess brachial pressure and central parameters every minute, and the three measurements are recorded according to the AOBP protocol (PWA or triple PWA). In addition to pressure, this method also allows the determination of heart rate from measurements of the time intervals between oscillometric pulses.

The Arteries AOP® device together with the MAPs application make up an integrated system for pulse wave analysis (PWA). Pulse wave velocity analysis is based on the concept that the blood pressure curve includes hemodynamic information that goes beyond the measured blood pressure value. This is used to analyze all information regarding the central aortic pulse wave velocity. This method specifically allows for the analysis of the following parameters: systolic and diastolic central arterial pressure, pulse wave velocity (PWV), and augmentation index (AIx). The reference values adopted were based on a nationwide study conducted in Brazil, which take into account the different age groups and gender and also classify them according to the presence of risk factors, using the oscillometric method[16]. Considering that AIx is inversely related to heart rate, the adjusted variable standardized for a heart rate of 75 beats per minute (AIx@75) was used, as it is the frequency that neutralizes the effect of HR on this variable[17].

As exposure variables, the following adiposity indices were used: BMI (as general adiposity index), ABSI, and WC (as abdominal adiposity indices). In addition, alternative adiposity indices based on WC were used for comparison, such as: waist-to-height ratio, conicity index, body roundness index (BRI), relative fat mass (RFM), and estimated total body fat (eTBF). The calculation of anthropometric indices is described below:

- BMI = weight (kg)/height (m)^2
- ABSI = WC (mm)*weight (kg)$^{-2/3}$*height (m)$^{2/3}$
- BRI = 364.2–365.5*(1−((0.5*WC/π)^2/(0.5*height (m))^2))$^{0.5}$. BRI scores range from 1 (thinner body shape) to 16 (roundest body shape)[18].
- Conicity index = WC/(0.109*(weight (kg)/height (m))0.5)[19]. Points of ≥ 1.18 for men and women, based on the study by Pitanga & Lessa[20].
- WHtR = WC/height (m)
- eTBF = 100*(–Z+A−B)/C, where A=(4.15*WC*39.3701); B=(0.082*weight (kg)*2.20462); C = (weight (kg)*2.20462); Z = 76.76 (women)[21]
- RFM = 64−(20*height (m)/HC) + (12*S), where S = 1 (women)[22]

Complementary data included sociodemographic data, health status, and lifestyle. Sociodemographic data were collected through a questionnaire, including: gender, age, education, and color/race (participants were asked about the skin color or race they identified, where the options were yellow, white, brown, indigenous, or black). To determine economic class, the Critério de Classificação Econômica Brasil (CCEB) questionnaire was used, an instrument consisting of questions about the purchasing power of urban people and families, classifying individuals into classes ranging from "A" to "D-E"[23].

Data on health status and lifestyle were collected through a structured questionnaire, in which questions about lifestyle habits included physical exercise, alcohol consumption (frequency and type of drink consumed), and smoking (current smoker, for how long, and ex-smoker). The physical activity indicator was estimated from the questions addressed by the Ministry of Health survey carried out by the Surveillance of Risk and Protection Factors for Chronic Diseases by Telephone Survey[24], which includes at least frequency, duration, and type of exercise in the last three months. Health conditions were evaluated by the variables: use of medication (antihypertensive) and personal history (dyslipidemia, diabetes mellitus, and systemic arterial hypertension, CVD, diabetes mellitus, and systemic arterial hypertension).

Statistical analysis

Data were presented as mean and 95% confidence interval (95%CI) for continuous variables and relative and absolute frequencies for categorical variables. The association between anthropometric indices for cardiovascular risk (BMI, WC, WHtR, ABSI, conicity index, BRI, RFM, and eTBF) and arterial stiffness measures (PWV and AIx) were evaluated using linear regressions, where the indicators anthropometric variables were the independent variables and the central blood pressure parameters were the dependent variables, in models based on the causal diagram shown in Figure 1. The adjusted model

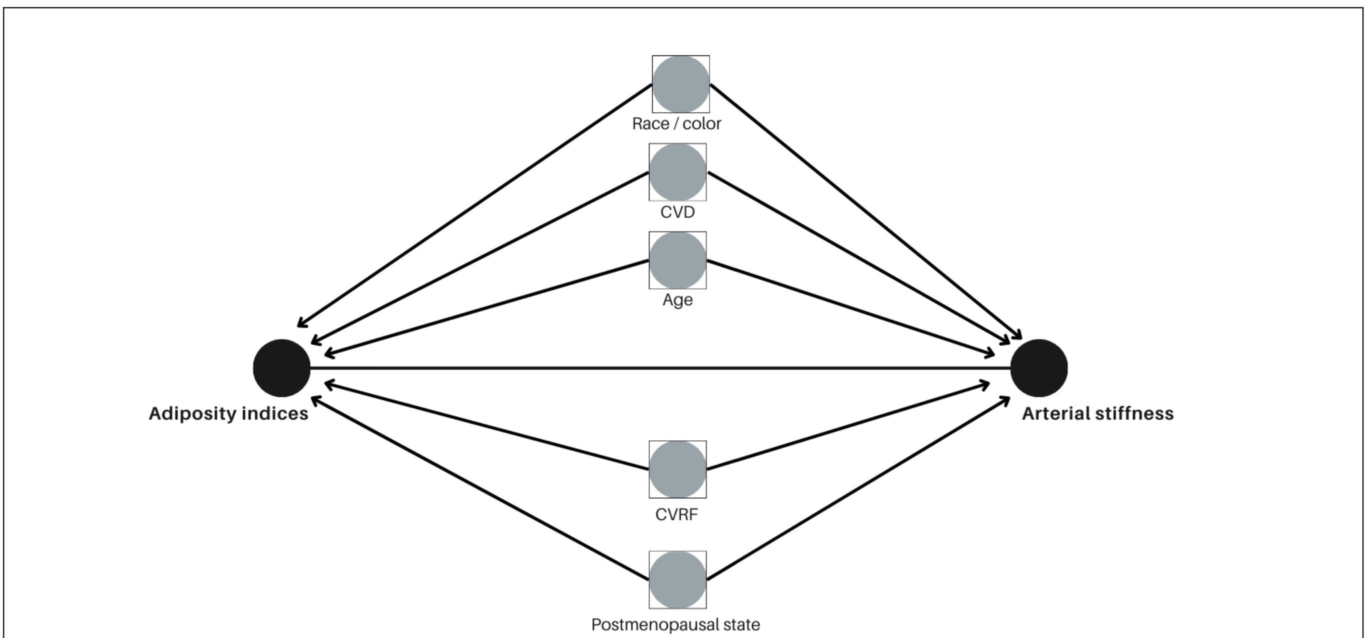

Figure 1 - Directed acyclic graph (DAG). Sphere with triangle = exposure variable; sphere with bar = outcome variable; gray line = causal pathway; light gray spheres = confounding variables to be fitted in the statistical model. CVRF = Cardiovascular risk factors; CVD = cardiovascular disease.

included the variables age, race, cardiovascular risk factors (hypertension, obesity, smoking, diabetes and dyslipidemia) according to the Framingham Heart Study[25], presence of CVD, and menopause. All analyzes were conducted with the support of the Jamovi computer Software (Version 1.6, The jamovi project, 2021, Sydney, Australia), and an alpha value equal to 5% was adopted for all analyzes.

Ethical aspects

This study was approved by the Research Ethics Committee of the Federal University of Alagoas, under protocol number 3.749.129 and, therefore, it was carried out following the ethical standards provided for in the Declaration of Helsinki of 1964 and subsequent amendments. All participants signed the Informed Consent Form to participate in the research.

RESULTS

One hundred and ninety participants were evaluated, with a mean age of 41.35 (CI95%= 39.854-42.862) years, predominantly brown (73.60%), without complete higher education (51.10%), and of the economic class C, D-E (68.20%). The other biological and sociodemographic characteristics can be seen in Table 1. As for lifestyle habits, also present in Table 1, 125 women (65.80%) declared not to exercise and 134 (70.50%) had some risk factor for CVD. Most of the participants did not have dyslipidemia, diabetes mellitus, SAH, and CVD.

In Table 2, the peripheral and central parameters of blood pressure and anthropometric data of the participants can be seen, in which it is highlighted that, on average, women are overweight (29,502 kg/m²; 95%CI=28,638-30,367 kg/m²), high values of WC, WHtR, conicity index, and body fat estimation by RFM and eTBF. The distribution of participants according to the BRI and ABSI classification was not performed, as the literature does not provide a consensus on cutoff points for diagnosis based on these new indices.

The association of anthropometric indices of adiposity and measures of arterial stiffness can be seen in Table 3. All anthropometric indices were associated with PWV, however, after adjusting for age, race/color, risk factor for CVD, use of medication for SAH and menopause, only the conicity index (β: 3.264; 95% CI=2.429-4.100), ABSI (β=0.050;

Table 1 – Biological, sociodemographic characteristics, lifestyle habits and health conditions of the participants' participants (n = 190).

Variables	n	%
Color/Race		
White	37	19.6
Brown/black	139	73.6
Others	13	6.9
Scholarity		
Non-higher	97	51.1
Higher education	93	48.9
Economic class		
A+B	29	15.6
C+D-E	159	84.4
Life habits		
Physical exercise	65	34.2
Alcoholism	80	42.1
Smoking	9	4.8
Cardiovascular risk factors	134	70.5
Personal		
Dyslipidemia	74	38.9
Diabetes Mellitus	36	18.9
SAH	30	16.0
CVD	45	23.8
Menopause	71	37.4

n =sample size; SAH = systemic arterial hypertension; CVD = cardiovascular disease.

Table 2 – Peripheral and central blood pressure parameters, and anthropometric data of the participants (n = 190).

Variables	Mean	IC95%
Peripheral parameters		
pSBP (mmHg)	116.22	112.73-119.71
pDBP (mmHg)	80.41	77.89-82.94
MBP (mmHg)	94.48	91.63-97.34
pPP (mmHg)	36.55	34.71-38.38
HR (bpm)	75.98	73.60-78.36
Central parameters		
cSBP (mmHg)	107.77	104.51-111.04
cDBP (mmHg)	81.90	79.36-84.45
cPP (mmHg)	26.27	24.94-27.59
AIx@75 (%)	22.65	21.22-24.07
PWV (m/s)	6.12	5.90-6.35
Anthropometric indices		
Weight (kg)	74.88	72.519-77.255
Height (cm)	1.592	1.582-1.601
BMI (kg/m²)	29.502	28.638-30.367
WC (cm)	93.46	91.496-95.429
WHtR	0.587	0.575-0.600
Conicity index	1.254	1.241-1.267
ABSI	10.197	9.777-10.616
FRM	41.165	40.374-41.956
ETBF	37.384	36.251-38.518
BRI	3.816	3.333-4.299

n = sample size; PWV = pulse wave velocity; AIx@75 = augmentation index adjusted to 75 bpm heart rate; CSBP = central systolic blood pressure; cDBP = central diastolic blood pressure; cPP = central pulse pressure; BMI = body mass index; WC = waist circumference; WHtR = waist-to-height ratio; ABSI = the body Shape Index; RFM = relative fat mass; ETBF = total body fat estimate; BRI = body roundness index.

Table 3 – Multiple regression with measures of peripheral, hemodynamic, and arterial stiffness as a dependent variable in all participants (N = 190)

	Univariable			Adjusted model		
	β	Adjusted R²	CI95%	β	Adjusted R²	CI 95%
PWV (m/s)						
BMI (kg/m²)	0.066	0.075	0.034-0.099	0.001	0.718	-0.022-0.023
WC (cm)	0.045	0.209	0.033-0.058	0.007	0.788	-0.002-0.015
WHtR	7.949	0.266	6.062-9.836	1.021	0.787	-0.369-2.410
Conicity index	0.766	0.375	5.519 8.013	3.264	0.788	2.429-4.100
ABSI	-0.084	0.027	-0.151--0.017	0.050	0.727	0.008-0.093
RFM	0.134	0.295	0.104-0.163	0.017	0.787	-0.005-0.040
ETBF	0.091	0.427	0.076-0.106	0.041	0.780	0.030-0.052
BRI	0.100	0.051	0.041-0.158	0.019	0.720	-0.016-0.054
AIx@75 (%)						
BMI (kg/m²)	0.094	-0.002	-0.135-0.322	0.103	0.083	-0.170-0.376
WC (cm)	0.104	0.017	0.005-0.203	0.101	0.099	-0.022-0.224
WHtR	20.536	0.031	5.244-35.828	20.162	0.105	0.224-40.099
Conicity index	22.039	0.083	11.792-32.286	18.541	0.131	7.125-29.957
ABSI	-0.114	-0.004	-0.573-0.345	-0.084	0.081	-0.609-0.441
RFM	0.352	0.037	0.108-0.595	0.354	0.108	0.025-0.682
ETBF	0.295	0.094	0.166-0.424	0,254	0.133	0.101-0.407
BRI	0.529	0.029	0.125-0.933	0.442	0.102	0.019-0.865

n = sample size; PWV = pulse wave velocity; AIx@75 = augmentation index adjusted to 75 bpm heart rate; BMI = body mass index; WC = waist circumference; WHtR = waist-to-height ratio; ABSI = the body Shape Index; RFM = relative fat mass; ETBF = total body fat estimate; BRI = body roundness index. Adjusted model: age, race, risk factor for cardiovascular disease, presence of cardiovascular disease and menopause.

95%CI=0.008-0.093) and ETBF (β=0.041; 95%CI=0.030-0.052) were positively associated with PWV, with the conicity index being an independent predictor of arterial stiffness. Meanwhile, WHtR (β=20.162; 95%CI=0.224-40.099), conicity index (β=18,541; 95%CI=7.125-29,957), BRI (β=0.442; 95%CI=0.019-0.865), and the estimates of body fat, RFM (β=0.354; 95%CI=0.025-0.682) and eTBF (β=0.254; 95%CI=0.101-0.407), were positively associated with AIx@75, being eTBF is an independent predictor of vessel functionality. Among the eight anthropometric indices analyzed, BMI and WC were not associated with PWV and AIx@75.

DISCUSSION

In this study, it was observed that only the conicity index, ABSI, and eTBF were positively associated with arterial stiffness measures by PWV, and the conicity index, WHtR, BRI, and body fat estimates (RFM and eTBF) were associated with the measure of blood vessel functionality estimated by the AIx@75. The conicity index is an independent predictor of arterial stiffness and the eTBF is an independent predictor of vessel functionality. Meanwhile, BMI and WC were not associated with either parameter.

Among studies that analyzed the risk of coronary artery disease as an outcome, a study conducted with individuals over 35 years of age and living in rural areas of China[26] observed that among eight analyzed adiposity indices, only the ABSI did not remain an independent indicator of risk of coronary artery disease in females, after adjusting for all possible factors of confusion. On the other hand, when studies adopt arterial stiffness as an outcome, the result is similar to our findings. In studies carried out with adult men and women from Asian countries, it is noticed that among the new adiposity indices, ABSI is associated with arterial stiffness determined by PWV[27,28].

Although it is a consensus that BMI is positively associated with systolic and diastolic blood pressure[38], the association of BMI with PWV was analyzed, especially in oriental populations, showing that individuals with obesity are at increased risk of arterial stiffness, regardless of their metabolic conditions[30,31]. In Western populations, gender-related differences in adipose tissue distribution influence the association between adiposity indices and vascular stiffness measured by PWV. When compared with adiposity indices between men and women, BMI was better associated with a higher PWV[32], however, we did not observe an association between these variables in our results.

When considering central adiposity indices, these are better predictors of CVD risk compared to general adiposity indices in women, as seen in other cross-sectional and cohort studies[11,33,34]. Abdominal adiposity, usually defined by WC, is considered a cardiovascular risk factor and is strongly associated with PWV measurements. In this sense, there is evidence in other populations that alternative anthropometric indices based on WC, such as the BRI, should be used among women to more accurately assess body composition and can be used as predictors of vascular remodeling or organic vascular dysfunction[28]. Furthermore, the BRI revealed superior predictive capacity and a significant association with accumulated cardiometabolic risk factors when compared to other anthropometric indices such as BMI, WC, and WHtR[35].

As observed in a study conducted with middle-aged Spanish adults, WHtR was associated with PWV but did not maintain an association in the multivariate model that included age, sex, BMI, neck circumference, waist circumference, and hip circumference[36], differently from our findings. In contrast, Wohlfahrt et al.[33] and Vallée et al.[34] found that central obesity parameters are more associated with aortic stiffness than BMI, suggesting that WHtR may be the best anthropometric measure of excess adiposity in the population in general. A similar index and, to our knowledge, little explored as a prognosis of CVD through markers such as PWV is the conicity index. Among rural young adults in South Africa, the conicity index was positively associated with cardiovascular risk factors such as insulin resistance, hypertension, and dyslipidemia[38], which encourages exploring its association in different populations as yet another index of adiposity to be adopted as a prognostic marker of CVD.

The measurement of body fat is at the heart of the assessment of body composition in association with CVD and PWV. Despite that, the instruments are based on robust and costly methods[39,40], which prevents it from being considered in practice. Body fat estimation formulas were constructed for this purpose and were accurate when compared to gold standard methods[21,40]. In the validation dataset, compared to BMI, the RFM better predicted body fat percentage, as measured by dual-energy X-ray absorptiometry (DEXA), both between women and men. RFM showed better accuracy than BMI and had fewer false-negative cases of obesity defined by body fat among women and men[40]. Associations were made between non-traditional and traditional indices of adiposity and cardiovascular mortality in an observational study of one million person-years of follow-up. eTBF, considered a sex-specific total body fat index, was more strongly associated with death from CVD than other adiposity indices, and may be an adequate clinical tool for assessing the cardiovascular risk associated with obesity[41].

This study has some limitations. First, body composition methods considered the gold standard were not adopted, which compromises the accuracy of body adiposity. However, the purpose of this study was to adopt validated adiposity indices that are easy to apply in clinical practice, due to their low cost and high accessibility. Second, cardiovascular risk factors were based on participants' reports of medical diagnosis or use of specific medications for each condition, which may underestimate the risk factors. Third, the delimited inclusion criteria are flexible in allowing the inclusion of women with and without cardiovascular risk factors. However, the decision to maintain this type of heterogeneity in the sample was considered because it guarantees the assumption of interchangeability to identify a causal effect when conditioning risk factors as conditional variables in the statistical model[53], as demonstrated in the DAG. Furthermore, the inclusion of women was determined by considering the reference values of central parameters and arterial stiffness for the Brazilian population, which stratifies by risk factors[24].

CONCLUSIONS

In conclusion, an association was observed between WC-based adiposity indices, such as WHtR, conicity index and BRI, and alternative adiposity indices and measures of arterial stiffness and blood vessel functionality in adult women. The conicity index is an independent predictor of arterial stiffness and the eTBF is an independent predictor of vessel functionality. These results suggest that adiposity indices can be convenient, highly cost-effective, and simple assessment tools as prognostic anthropometric markers of CVD in clinical practice.

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