Acta Scientiarum

http://periodicos.uem.br/ojs
ISSN on-line: 1807-8648
Doi: 10.4025/actascihealthsci.v42i1.50918

Anthropometric indicators associated with blood pressure elevation in adults with obesity

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ABSTRACT. The aim of the study was to investigate the association between different anthropometric indicators and high blood pressure in adults with obesity.This is a cross-sectional study with a non-probabilistic sample of adults with obesity. Systolic and diastolic blood pressure were measured using automated equipment (OMRON, model 742 HEM). The anthropometric indicators used were body mass index (BMI), relative fat mass (RFM), waist circumference (WC), waist-to-stature ratio (WSR) and waist-hip ratio (WHR). The data were analyzed by crude and adjusted (sex and age) linear regression, adopting a level of significance p <0.05. Among the 63 adults with obesity evaluated (38 woman; 35.27±7.02 years; BMI: 33.46±2.89 kg m^{-2}; RFM: 39.98±6.70; WC: 109.38±10.15 cm; WSR: 0.64±0.05; WHR: 0.93±0.01), it was observed that the increase in systolic blood pressure was directly associated with the indicators RFM (p=0.011; Cohen's F^2= 0.42), WC (p=0.003; Cohen's F^2= 0.49), WSR (p=0.010; Cohen's F^2= 0.42) e WHR (p=0.001; Cohen's F^2= 0.52), but not to BMI (p=0.100). The elevation of diastolic blood pressure was directly associated with all the anthropometric indicators analyzed: BMI (p=0.040; Cohen's F^2= 0.14), RFM (p= 0.006; Cohen's F^2= 0.21), WC (p=0.002; Cohen's F^2= 0.26),WSR (p=0.004 Cohen's F^2=0.23) and WHR (p=0.012; Cohen's F^2=0.19). It was concluded blood pressure elevation was directly associated with the anthropometric indicators investigated and, among them, the WHR and the WC presented the best predictive capacity for systolic blood pressure and diastolic blood pressure elevations, respectively.

Keywords: body composition; arterial hypertension; body fat distribution.

Received on November 21, 2019.
Accepted on April 11, 2020.

Introduction

Hypertension is a chronic and multifactorial disease, characterized by elevated and sustained blood pressure levels, which is directly associated with an increased risk of fatal and non-fatal cardiovascular events (Sociedade Brasileira de Cardiologia, 2016; Khosravi et al., 2017). It is considered one of the main public health problems now a days due to high prevalence, impact on mortality and public costs (Kotchen, 2010).

Among the main risk factors associated to the development of arterial hypertension, obesity is highlighted (Daraki et al., 2015). A prospective cohort study observed a progressive increase in the incidence of hypertension with greater accumulation of body fat. Where obese men were almost 5 times more at risk for hypertension (Shihab et al., 2012).

Thus, during the last decades, some researchers have been focused on the development of low-cost techniques that, in addition to determining the corporal adiposity of simple way, are associated with the elevation of the blood pressure, the development of cardiovascular diseases and, consequently, are able to predict greater health risk in this population (Tuan, Adair, Stevens, & Popkin, 2010; Lee, Lim, Baek, Park, & Park, 2015; Zhang et al., 2017).

In this sense, the anthropometric indicators are the most used mainly due to the easy applicability in population studies (Tuan et al., 2010). Among the most widely used indicators are body mass index (BMI) (Nyamdorj et al., 2008; Lam, Koh, Chen, Wong, & Fallows, 2015), waist circumference (WC) (Lam et al., 2015), waist-to-stature ratio (WSR) (Nyamdorj et al., 2008) and waist-hip ratio (WHR) (Nyamdorj et al., 2008). Although these indicators are related to cardiovascular disease in the general population, in adults with obesity such association is still not well established. In this way, the search for and creation of new techniques and simple equations that are even more precise for different populations becomes necessary.

In this scenario, the relative fat mass (RFM), a simple indicator for estimating body fat percentage, based on the split stature ratio by WC, was recently proposed by (Woolcott & Bergman, 2018). This indicator seems to be more accurate and less biased when compared to BMI, maintaining the same clinical and epidemiological function (Woolcott & Bergman, 2018). This fact, evidenced in an observational study with adults and middle-aged individuals, where the RFM provided better predictability in dyslipidemia and metabolic syndrome compared to other anthropometric indicators (Kobo, Leiba, Avizohar, & Karban, 2019b). However, it is not known yet if RFM is related to risk factors for cardiovascular diseases, such as high blood pressure, especially among individuals who are already obese. Thus, the present study aimed to investigate the association between different anthropometric indicators and the elevation of systolic and diastolic blood pressure in adults with obesity. Given this, the hypothesis of this study would be that RFM will present a greater relationship with arterial hypertension in adults with obesity compared with other anthropometrics markers.

Material and methods

This is a cross-sectional study developed from the baseline data from a project entitled "Effects of different concurrent training protocols on health indicators in obese adults". The study was approved by the Human Research Ethics Committee of the Federal University of Santa Catarina under the opinion (n. 2,448,674).

The study population were consisted of adults of both sexes with obesity, selected in a non-probabilistic way. As inclusion criteria, participants should be between 20 and 50 years old, present grade I obesity (BMI between 30 and 39.9 kg/m²), no-smokers, were not drink alcohol in excess (<4 doses at the same time for women and <5 doses for men), were not using some medication for the control and / or treatment of obesity and had not performed any surgical procedure aiming at reducing weight, as well as not having a diagnosis of another chronic disease. All selected participants, after being clarified about the procedures to which they would be submitted, signed an informed consent form.

The dependent variables of this study were mean systolic and diastolic blood pressure. For their assessment, the participants were previously instructed to do not practice any kind of vigorous physical activity in the 24 hours preceding the measurement. On evaluation day, participants were advised to avoid any consumption of stimulant or alcoholic beverages. In addition, it was advised that the measurement be performed with the bladder emptied (Pickering et al., 2005). In the laboratory, five minutes of rest were adopted before the measurements, in the dorsal decubitus position, with illumination and controlled air conditioning. An automated oscillometric device (Omron HEM 742-E, Bannockburn, USA), for the accomplishment of three measures, with interval of one minute between them. For analyzes, the arithmetic mean of the three measures was considered. Data were expressed in millimeters of mercury (mmHg).

The independent variables of this study were the anthropometric indicators. Body mass and height were measured using a Wel my brand electronic scale, model W300A, with coupled stadiometer. In addition, the waist and hip circumference were measured using a tape at the umbilical scar point and the largest gluteal portion, respectively. All anthropometric measures followed the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). From these data, were calculated BMI, WHR, WSR.

$$BMI = \frac{Body\ mass\ (kg)}{height^2 (m^2)}$$

$$WHR = \frac{\text{waist circumference (cm)}}{\text{hip circumference (cm)}}$$

$$WSH = \frac{\text{waist circumference (cm)}}{\text{height (cm)}}$$

The RFM, which takes into account height and WP, was calculated according to the equation (Woolcott & Bergman, 2018):

$$RFM = 64 - \left(20 \times \frac{height\ (m)}{waist\ circunference\ (m)}\right) + (12 \times sex)$$

Being attributed, for the sex variable, zero for men and one for women. All measurements were made by the same evaluator, whose had training and certification for such, having a technical error of 2%.

In the data analysis, descriptive statistics were initially applied, with variables being expressed as mean, standard deviation and absolute and relative frequencies. Inferential analysis, on the other hand, was performed using crude and adjusted linear regression models (sex and age), in order to observe if the five anthropometric indicators (BMI, WSR, WC, WHR e RFM) are able to explain possible increases in systolic and diastolic blood pressure. For the comparison of the models, the value of $p \leqslant 0.05$ was used as statistical significance, beta value, standard deviation, standardized beta, coefficient of determination (R^2) for percentage of explanation, effect size through Cohen F^2, Variance Inflation Factor (VIF) as an indicator of multicollinearity, besides Bayesian Information Criterion (BIC) and Akaike Information Criteria (AIC) values. All analyzes were performed on STATA software (Stata Corporation, College Station, USA), version 15.0.

Results

The Table 1 shows the general sample characteristics, which was composed by 63 adults, mostly female (60.3%), with an average age of 35.3 years (±7.0). The participants had a mean BMI of 33.46 kg m^{-2} (± 2.89).

Tab1e 1. General characteristics of the sample (n=63).

Variables	μ ±sd
Sociodemographic	
Age (years)	35.27± 7.02
Stature (cm)	170.07± 9.98
Body Mass (kg)	97.19± 14.93
Anthropometric indicators	
BMI (kg m^{-2})	33.46± 2.89
RFM (%)	39.98± 6.70
SBP (mmHg)	117.19± 11.20
DBP (mmHg)	72.40 ± 7.53
WC (cm)	109.38± 10.15
WSR	0.64 ± 0.05
WHR	0.93 ± 0.08

μ= mean; sd= standard deviation; BMI = Body Mass Index; RFM= relative fat mass WC = waist circumference; WSR = waist-to-stature ratio; WHR= waist-hip ratio; SBP= systolic blood pressure; DBP= diastolic blood pressure.

Table 2 shows the association between anthropometric indicators and changes in systolic blood pressure. Among all the variables evaluated, WHR was the indicator that was best associated with systolic blood pressure. About 34% (R^2 = 0.34) of systolic blood pressure variation was explained by WHR, adjusting for sex and age, and an increase of 0.5 cm in this index (β = 0.571) implied an increase of 1 mmHg systolic blood pressure. In addition, BMI was the only index that did not show a significant association with this outcome.

Table 2. Crude and adjusted analyzes between index and anthropometric indicators and systolic blood pressure in adults with obesity. (n = 63).

	β	sd	Standardized β	Adjusted R^2	p-value	Cohen's F^2	VIF	BIC	AIC*n
BMI									
Crude analysis	0.004	0.004	0.132	0.01	0.299	0.01	1.00	-112.03	-116.32
Adjusted analysis*	0.006	0.003	0.187	0.26	0.100	0.35	1.04	-124.81	-133.38
RFM									
Crude analysis	0.005	0.001	-0.389	0.15	0.002	0.17	1.00	-121.27	-125.55
Adjusted analysis*	0.011	0.004	0.822	0.30	0.011	0.42	6.20	-128.86	-137.43
WC									
Crude analysis	0.004	0.001	0.477	0.22	0.001	0.28	1.00	-127.20	-131.49
Adjusted analysis*	0.003	0.001	0.345	0.33	0.003	0.49	1.09	-131.60	-140.18
WSR									
Crude analysis	0.360	0.244	0.185	0.34	0.146	0.51	1.00	-113.11	-117.40
Adjusted analysis*	0.558	0.209	0.287	0.30	0.010	0.42	1.03	-129.09	-137.66
WHR									
Crude analysis	0.717	0.123	0.595	0.35	0.001	0.53	1.00	-138.51	-142.80
Adjusted analysis*	0.571	0.170	0.474	0.34	0.001	0.51	1.61	-132.86	-141.43

BMI=body mass index; RFM= relative fat mass; WC= waist circumference; WSR = waist-to-stature ratio; WHR= waist-hip ratio; sd=standard deviation; VIF= Variance Inflation Factor; BIC= Bayesian Information Criterion; AIC*n = Akaike Information Criteria; * Model adjusted for sex and age.

For diastolic blood pressure (Table 3), statistically significant associations were identified with all anthropometric indicators, when adjusted for sex and age. The indicator whose best explained the increase in diastolic blood pressure was WC (R^2 = 0.21). For each increase of 0.003 cm in this indicator, there was an increase of 1 mmHg in this outcome.

According to multicollinearity criteria, the regression model presented recommended values (<1.0) for both systolic (Table 2) and diastolic blood pressure (Table 3), demonstrating a strong relationship between variables (VIF close to 1). The BIC and AIC values were satisfactory, reinforcing the quality of the proposed model for all the indicators.

Table 3. Crude and adjusted analyzes between index and anthropometric indicators and diastolic blood pressure in adults with obesity. (n = 63).

	β	Sd	Standardized β	Adjusted R^2	p-value	Cohen's F^2	VIF	BIC	AIC*n
BMI									
Crude analysis	0.006	0.004	0.178	0.03	0.163	0.03	1.00	-105.41	-109.70
Adjusted analysis*	0.008	0.004	0.254	0.13	0.040	0.14	1.04	-107.37	-115.94
RFM									
Crude analysis	-0.002	0.001	-0.165	0.02	0.196	0.02	1.00	-105.12	-109.41
Adjusted analysis*	0.014	0.005	0.977	0.18	0.006	0.21	6.20	-111.10	-119.67
WC									
Crude analysis	0.004	0.001	0.431	0.18	0.001	0.21	1.00	-116.36	-120.65
Adjusted analysis*	0.003	0.001	0.393	0.21	0.002	0.26	1.09	-113.43	-122.01
WSR									
Crude analysis	0.565	0.254	0.273	0.07	0.030	0.07	1.00	-108.30	-112.58
Adjusted analysis*	0.728	0.239	0.352	0.19	0.004	0.23	1.03	-112.01	-120.58
WHR									
Crude analysis	0.557	0.147	0.436	0.19	0.001	0.23	1.00	-116.67	-120.95
Adjusted analysis*	0.531	0.205	0.415	0.16	0.012	0.19	1.61	-109.63	-118.20

BMI= body mass index; RFM= relative fat mass; WC= waist circumference; WSR = waist-to-stature ratio; WHR= waist-hip ratio; sd=standard deviation; VIF= Variance Inflation Factor; BIC= Bayesian Information Criterion; AIC*= Akaike Information Criteria; * Model adjusted for sex and age;

Discussion

The elevation blood pressure was directly associated with the anthropometric indicators investigated and, among them, the WHR and the WC presented the best predictive capacities for elevations in systolic and diastolic blood pressure, respectively.

Body fat, especially in the abdominal region, is an important risk factor for hypertension and other cardiovascular diseases (Oboh & Adedeji, 2011; Selvaraj et al., 2016; Khashayar, Aghaei Meybodi, Rezaei Hemami, & Larijani, 2017). BMI is a highly applicable method in the epidemiological scenario and a very common classify obesity (Momin et al., 2017; Lee, Lim, & Hong, 2018). However, it presents limitations being considered an indirect measure of body fat, and may not adequately reflect the components of body composition and morphological changes that occur with advancing age, demonstrating both poor sensitivity and specificity (Rothman, 2008). Reinforcing such limitations, a Canadian cohort study showed that BMI showed a fragile relationship with all-cause mortality (Padwal, Leslie, Lix, & Majumdar, 2016).

In the present study, BMI was positively associated only with diastolic blood pressure, accounting for only 13% of the model. A study by Zhang et al (2017). found results similar to ours, as those with higher BMI (⩾ 30 kg m^{-2}) presented higher diastolic blood pressure than their peers with lower BMI and increases of 1 mmHg in diastolic blood pressure were identified at each 0.135 kg m^{-2} increase in BMI. Some studies suggest that BMI is more strongly associated with blood pressure compared to WC and WHR. On the other hand, other studies found that some indicators resemble or present higher correlations and predictive capacities of hypertension than BMI (Lee, Huxley, Wildman, & Woodward, 2008; Zhang et al., 2017). A meta-analysis review, which included 88,000 participants from several studies, demonstrated that BMI has a lower discriminatory power for hypertension compared to WC, WHR and WSR in both sexes (Lee et al., 2008). Despite the contradictory effects of discriminatory power for cardiovascular diseases, BMI is traditionally employed in large population studies (Momin et al., 2017; Lee et al., 2018), but in clinical scenario there are restrictions.

The WHR is an important indicator that represents the concentration of body fat in the abdominal and hip region, and the excessive accumulation of fat in this region raises systolic and diastolic blood pressure, being an important indicator of cardiovascular risk (Zhang et al., 2017) and hypertension (Pal, De, Sengupta, Maity, & Dhara, 2014). In the present study, this indicator was associated with changes in blood pressure, with a greater expression of systolic blood pressure, explaining 34% of its variation, whereas in diastolic blood pressure it accounts for only 16% of variation.

A study involving Mexican adults also found this association, indicating that high WHR measures lead to a significant increase in systolic blood pressure of 2 mmHg in men and 1.3 mmHg in women favoring the occurrence of health problems and of early mortality (Gnatiuc et al., 2017). In addition, Zhang et al. (2017) suggests that, when compared to other anthropometric indicators, WHR presents a greater capacity to predict hypertension, allowing better discriminatory power for individuals with chronic diseases.

The WC measurement had a positive association with blood pressure, with an increase of 1mmHg in systolic and diastolic blood pressure, respectively, with each increase of 0.34 cm and 0.39 cm in this indicator. This finding is in line with other studies that also point an association between WC and blood pressure, suggesting a greater riskin those with unhealthy lifestyle (Chen et al., 2015; Gnatiuc et al., 2017; Jahangiry, Ghanbari, Farhangi, Sarbakhsh, & Ponnet, 2017). Every centimeter in the WC, increases of 4 mmHg in systolic blood pressure and 2.1 mmHg in diastolic blood pressure were detected in previous studies (Chen et al., 2015; Taing, Farkouh, Moineddin, Tu, & Jha, 2016). In addition, it is suggested that this indicator explains 29% of change in diastolic blood pressure when adjusted for lifestyle variables (Chowdhury & Roy, 2016). The magnitude of this association varies according to the lifestyle, geographic location and acquired habits of the population, but it seems universal the existence of a consistent association between WC and changes in blood pressure (Vikram et al., 2016; Fu et al., 2018), suggesting, therefore, that the reduction in this anthropometric indicator may be a relevant tool in the prevention of arterial hypertension (Seo & Niu, 2015).

The WHR, in turn, was positively associated with blood pressure, explaining 30% and 19% of variation in systolic and diastolic blood pressure, respectively. High WHR values are linked to lipid and glucose changes, with a consequent increase in cardiovascular risks (Oboh & Adedeji, 2011; Khashayar et al., 2017), associated with increased inflammation and atherosclerosis and early mortality (Tokushige et al., 2017). The findings of Fu et al. (2018) showed that with each increase in WHR measurement the systolic blood pressure rises to 3.9 mmHg, standing out as a better predictor when compared to the other indicators. Additionally, a longitudinal study showed that adults with the highest quartile of WSR (WSR ⩾ 0.54) were 4.51 times more likely to have hypertension compared to those with the lowest quartile (Choi, Koh, & Choi, 2018). Studies suggest the superiority of WSR compared to WHR for the prediction of cardiovascular risks (Meseri, Ucku, & Unal, 2014; Luz, Barbosa, & d'Orsi, 2016; Ononamadu et al., 2017), which contradicts our findings.

The RFM explained 30% of variation in systolic blood pressure and 18% in diastolic blood pressure, presenting a similar predictor when compared to other indicators. At each increase of 0.011 and 0.014 in the RFM, there was an increase of 1 mmHg for systolic and diastolic blood pressure, respectively. Although it is a recent indicator, some studies suggest greater precision when confronted with other indicators (Andreasson, Carlsson, Önnerhag, & Hagström, 2018; Woolcott & Bergman, 2018; Kobo et al., 2019b). A population study with adult and elderly individuals, with age range between 20 and 85 years old, which provided the basis for the development of the RFM equation, showed that this indicator presents a stronger and more accurate relationship than the BMI in different outcomes of health for both men and women (Woolcott & Bergman, 2018). Similarly, a recent study suggested that RFM is superior to BMI to predict liver disease, enhancing its utility in public health (Andreasson et al., 2018). Also, in the comparison of RFM with WC, as obesity criterion for the definition of metabolic syndrome, it was detected that the RFM was able to identify a larger proportion of the population with metabolic syndrome than WC (Kobo et al., 2019a). Although the aforementioned studies presented promising results regarding the use of this indicator over other more classical ones, the present study found no superiority of RFM with respect to the prediction of changes in blood pressure.

It should be noted that the present study involves only individuals with obesity and the inclusion of a new indicator - RFM - that demonstrated a good capacity for explaining changes in blood pressure, showing to be more accurate than BMI, but which is similar to other already published in the literature. However, the absence of a reference method for assessing body composition cannot be neglected for a better exploration of the results, and the fact that RFM is a recent indicator, with little literature to establish comparisons.

Conclusion

In summary, based on our findings, it is concluded that the anthropometric indicators WC, WHR, WSR and RFM are associated with changes in systolic and diastolic blood pressure, whereas BMI is only associated with diastolic blood pressure in adults with obesity, with WHR and WC being the indicators which best explain the variations in systolic blood pressure and diastolic blood pressure, respectively. It is recommended future studies use a reference method to estimate fat percentage for a better exploration of these associations.

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