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Anthropometric patterns of adiposity, hypertension and diabetes mellitus in older adults of Viçosa, Brazil: A population-based study

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Aim: To identify anthropometric patterns of adiposity and estimate their association with hypertension and diabetes mellitus (DM) in older adults.

Methods: A cross-sectional study with 537 older adults aged ≥60 years was carried out. Weight, height, and waist, hip and calf circumference were measured. The following indices were calculated: a body shape index, body roundness index, conicity index, body adiposity index, body mass index, waist-to-height ratio, waist-to-calf ratio, waist-to-hip ratio and waist-to-hip-to-height ratio. The anthropometric patterns of adiposity were obtained by factor analysis of principal components, and their association with hypertension and DM was identified by multiple Poisson regression with robust variance.

Results: Two anthropometric patterns of adiposity were identified. Pattern 1 and 2 explained approximately 53% and 33% of the total variance, respectively, in both sexes. Pattern 1 indicated of global adiposity, and weight, body mass index and hip circumference were the variables most strongly correlated with this pattern in both sexes. Pattern 2 represented the body fat distribution, being a body shape index the most important variable in this factor. After adjustment by confounding factors, only the pattern 2 remained significantly associated with DM in women.

Conclusions: Only the anthropometric pattern of adiposity central was associated with DM in older women.
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Keywords: central obesity, diabetes mellitus, factor analysis, hypertension, nutrition assessment.

Introduction

Obesity is a worldwide epidemic, which contributes significantly to the increased incidence of diabetes mellitus (DM), cardiovascular atherothrombotic diseases,[1] cancer[2] and inability to carry out activities of daily living.[3]

It is known that aging results in increased total and central adiposity, but it still remains unclear what the best methods and cut-offs are for the definition of obesity in the elderly population.[4] Although studies show that excess weight in older adults is associated with lower mortality, the important role of body fat cannot be disregarded, especially visceral fat, a risk factor for diseases, such as DM and hypertension.[5] Adiposity is assessed with greater accuracy by methods such as dual energy X-ray absorptiometry, computed tomography scan and magnetic resonance imaging, but these are expensive and expose the individual to radiation, making its use unfeasible at the population level. Thus, anthropometry is the most used method in most health services and even in studies with large samples.[6]

Classically, a body mass index (BMI) ≥30 kg/m^2 is the criteria used to define global obesity in individuals aged ≥20 years, of both sexes.[7] Other measures, such as waist circumference, waist-to-hip ratio and waist-to-height ratio, are used to assess the metabolic risk associated with central obesity,[7,8] but there are no cut-off points recommended for the elderly population.[9] New measures of adiposity, such as body shape index,[10] body roundness index,[11] waist-to-calf ratio,[12] waist-to-hip-to-height ratio[13] and body adiposity index,[14] have been proposed, but few

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studies have assessed how adiposity measured by these indices is associated with diseases in older adults.

Among many measures and anthropometric indices, there are still questions about which measure or index better reflects the body adiposity in older adults, and whether it is associated with high-prevalence diseases in older adults, such as hypertension and DM. Therefore, the present study aimed to identify anthropometric adiposity patterns in older adults, and estimate the association of those with hypertension and DM.

Methods

Study population

This was a cross-sectional, population-based study that was part of the "Health conditions, nutrition and use of medication by the elderly in Viçosa (Minas Gerais): a population-based survey" project carried out with non-institutionalized older adults aged 60–98 years who were residents of rural and urban areas of Viçosa in the state of Minas Gerais, Brazil.

In 2008, databases of the municipality showed a target population of 7980 older adults. A 95% confidence level was considered to calculate the sample, with an estimated prevalence of the outcome of 50% and precision of 4%, totaling 559 older adults. This amount was increased by 20% to cover possible losses, totaling a sample of 670 individuals, selected by simple random sampling without replacement. Data were collected by face-to-face interviews carried out in households from June 2009 to December 2009.

Of the 670 randomly selected older adults, 7.3% (n = 49) were excluded from the study because of refusal (n = 24), death (n = 9) and address not found (n = 16). Thus, 621 older adults were interviewed, and 84 of these were excluded from the analysis because of the impossibility of anthropometric measurements by physical limitations (wheelchair and/or presence of limb amputation), totaling a final sample of 537 older adults.

The study was carried out according to the principles of the Declaration of Helsinki, and was approved by the Committee on Ethical Research of the Federal University of Viçosa (Official Letter No.27/2008/CEP/UFV).

Demographic, socioeconomic, lifestyle and anthropometry data

Information about age, sex, income, education (primary school or above was considered equal to 8+ years of schooling), physical activity, smoking and alcohol intake was used for the present study.

The anthropometric assessment (weight, height, waist, hip and calf circumference) followed the standard measurement procedures.[15] The anthropometric measurements were used for calculating the following indexes: a body shape index (ABSI),[10] body roundness index (BRI),[11] conicity index (CI),[16] body adiposity index (BAI),[14] BMI,[7] waist-to-height ratio (WHtR),[8] waist-to-calf ratio (WCR),[12] waist-to-hip ratio (WHR)[7] and waist-to-hip-to-height ratio (WHHR)[13] (Table 1).

DM and hypertension

Hypertension and DM has been identified from the following questions to the older adults or their informant: "Have a doctor or other health professional ever said that you have or have had high blood pressure (hypertension)?"; "Have a doctor or other health professional ever said that you have or had diabetes (sugar in the blood)?".

In order to improve the quality of information, it was requested that the participants presented the packaging or package inserts or prescriptions of medicines in use in the past 15 days that have been classified according to the Anatomical Therapeutic Chemical Index 2015.[17] If the participant was taking insulin and/or oral hypoglycemic agents or antihypertensive,

Table 1 Formulas for anthropometric indices

Anthropometric indices	Formulas
A body shape index ($m^{11/6}.kg^{-2/3}$)	WC (m) / (BMI [kg/m^2]$^{2/3}$ × height [m]$^{1/2}$)
Body roundness index	$364.2-(365.5\times\varepsilon)$, where $\varepsilon=\sqrt{1-\left[\frac{[WC\ (m)/(2\times\pi)]^2}{[0.5\times \text{height}\ (m)]^2}\right]}$
Body adiposity index (%)	HC (cm) / height (m)$^{1.5}$ – 18
Conicity index	WC (m) / (0.109 × √weight [kg] / height [m])
Body mass index (kg/m^2)	Weight (kg) / height (m)^2
Waist-to-height ratio	WC (cm) / height (cm)
Waist-to-calf ratio	WC (cm) / CC (cm)
Waist-to-hip ratio	WC (cm) / HC (cm)
Waist-to-hip-to-height ratio	WC (cm) / HC (cm) / height (cm)

ε, eccentricity; BMI, body mass index; CC, calf circumference; HC, hip circumference; WC, waist circumference.

they were considered diabetic or hypertensive, respectively. The participants' use of medication was confirmed by package and/or prescriptions in 87.6% and 68.5% of those who were classified as hypertensive or diabetic, respectively.

Statistical analysis

Statistical analyses were carried out using STATA version 13.0 (StataCorp, College Station, TX, USA). The consistency and distribution of variables were assessed through histograms, kurtosis, asymmetry measures and the Shapiro–Wilk test. The descriptive analysis consisted of central tendency, dispersion measures and relative frequency according to their distribution. Comparison of anthropometric variables and age between the sexes was carried out using the Student's *t*-test for variables with normal distribution, and the Mann-Whitney *U*-test for variables with skewed distributions. The comparison of categorical variables – education, smoking, physical exercise, alcohol consumption, hypertension and DM – between sexes was carried out using the Pearson chi square test.

Anthropometric patterns of adiposity were obtained by exploratory factor analysis for 14 anthropometric variables: weight, waist, arm, calf and hip circumference, BMI, WHR, WHtR, WHHR, WCR, BAI, BRI, ABSI and CI. Factor analysis was used to identify anthropometric patterns of adiposity. Principal components analysis was used for extraction of factors and orthogonal rotation (varimax option) to derive non-correlated factors. This varimax method attempts to minimize the number of indicators that have high loading on one factor. Two criteria were used to verify the relationship between anthropometric variables and confirm the adequacy of the sample for analysis:[18] (i) visual inspection of the sample correlations, being ideal that most coefficients are >0.30; and (ii) value of Kaiser–Meyer–Olkin, ideal >0.70. A statistical significance level of 0.05 was considered for all tests.

Four criteria were used to determine the number of factors to retain: (i) eigenvalue ≥1 (Kaiser criterion); (ii) examination of scree plot (the Cattell's scree test); (iii) analysis of the proportion of the total variance related to each eigenvalue; and (iv) interpretability of factors. For interpretation of the factor solution, anthropometric indices with a positive factor loading were considered to contribute directly to the factor, whereas anthropometric indices with negative loadings were considered to be inversely correlated with the factor.[18]

The relationship between variables and factors was explained by the factor loadings, and values ≥0.70 were used as a reference to show a strong correlation. Variables with specificity greater than 0.5 were excluded from the factorial model. Loading plots were used to examine the distribution of variables in each factor.[18]

The goodness of fit of the model was also assessed by evaluating the residual matrix. This matrix shows that the matrix of sample correlations was reproduced properly by the correlation matrix estimated by the factor model fitted to the data, when its elements are close to zero.[18]

Factor scores were calculated by the multiple regression approach, and each individual received a factor

Table 2 Characteristics of the study population

Variables		Men (n = 268)	Women (n = 269)	P-value
Age (years)	Mean (SD)	69.56 (7.36)	69.96 (7.41)	0.53†
	<75 years	74.7%	74.7%	0.98‡
	≥75 years	25.3%	25.4%	
Income ($US)	Median (IQR)	645 (255–1189)	255 (255–510)	<0.0001§
Education	<8 years	63.8%	64.3%	0.88‡
	≥8 years	36.2%	35.7%	
Smoking status	Smoker	17.5%	6.3%	<0.001‡
	Ex-smoker	50.0%	19.7%	
	Never smoker	32.5%	74.0%	
Physical inactivity	Yes	26.5%	38.3%	<0.01‡
	No	73.5%	61.7%	
Drinking status	Drinker	49.3%	25.6%	<0.001‡
	Non-drinker	40.3%	24.2%	
	Never drinker	10.4%	50.2%	
Hypertension	Yes	76.1%	83.6%	<0.05‡
	No	23.9%	16.4%	
Diabetes mellitus	Yes	17.5%	29.0%	<0.01‡
	No	82.5%	71.0%	

†Student's *t*-test. ‡Pearson chi square test. §Mann–Whitney *U*-test. IQR, interquartile range; SD, standard deviation.

score for each anthropometric pattern of adiposity. For each pattern, participants were grouped into tertiles of pattern scores.

Poisson regression models with robust variance were used to estimate the associations between tertiles of anthropometric patterns of adiposity scores, and DM and hypertension. The analysis was stratified according to sex, and two models were estimated; one adjusted only by age, and the other further adjusted by the income (categorized according to median), years of schooling (categorized <8 or ≥8 years), smoking status (smoker; ex-smoker, never smoker), drinking status (drinker, non-drinker, never drinker) and physical exercise (yes or no).

Results

Characteristics of participants

The study comprised 268 men and 269 women. The mean age was similar in both sexes, with a predominance of older adults aged <75 years. Men had significantly higher income than women did. More than half of participants of both sexes had a low educational level. The proportion of male smokers or former smokers, who did not practice physical exercise and who drank alcohol, was significantly higher than that of women. In contrast, the prevalence of hypertension and DM was significantly higher for women (Table 2).

Mean values of height, weight, WHR and ABSI were significantly higher for men. BMI, hip and arm circumference, WHtR, WHHR, BRI and BAI were significantly higher among women (Table 3).

Adequacy of the sample

Whereas most of the variables did not have normal distribution, Spearman's correlation was used and it was observed that most of the correlations between the anthropometric variables were statistically significant and >0.30, with a large number of correlations >0.70, for both sexes (data not shown). The sample met the suitability criteria for the factor analysis with equal Kaiser–Meyer–Olkin values and 0.7689 and 0.7662, in the sample of men and women, respectively.

Anthropometric patterns of adiposity and interpretability

In the present study, the Kaiser criterion would lead to the retaining of two factors in men and women. The percentage of explained variance by each factor was similar in both sexes, with values of approximately 53% for factor 1, and 33% for factor 2, compraising to 86% of the total explained variance (Table 4).

The measures and anthropometric indices strongly and positively correlated with factor 1 were those indicators of body mass and central and total fat. Weight, BMI and hip circumference being the most strongly correlated in both sexes. Factor 2 was defined mainly by measures and anthropometric indices indicators of body fat distribution, with ABSI index being the most strongly correlated with this factor in both sexes (Table 4).

The residual matrix showed good goodness of fit of the model, as all the values were close to zero, thus showing that the correlation matrix estimated by the factorial model approached the original sample correlation matrix (data not shown).

Table 3 Mean and standard deviation of anthropometric indices in elderly by sex

Variables	Men (n = 268)		Women (n = 269)		P-value
	Mean	SD	Mean	SD	
Weight (kg)	70.85	14.54	65.39	13.74	<0.001†
Height (cm)	165.46	6.54	152.41	5.91	<0.001‡
Body mass index (kg/m^2)	25.76	4.38	28.10	5.47	<0.001†
Waist circumference (cm)	95.85	12.26	95.76	12.55	0.93†
Hip circumference (cm)	97.46	7.60	102.08	11.55	<0.001†
Arm circumference (cm)	29.75	3.78	31.11	4.44	<0.001‡
Calf circumference (cm)	36.10	3.93	36.08	4.22	0.98†
Waist-to-hip ratio	0.98	0.07	0.94	0.06	<0.001‡
Waist-to-height ratio	0.58	0.07	0.63	0.08	<0.001†
Waist-to-calf ratio	2.66	0.23	2.66	0.27	0.90†
Waist-to-hip-to-height ratio	0.59	0.05	0.62	0.05	<0.001‡
Conicity index	1.35	0.07	1.35	0.08	0.75†
Body adiposity index (%)	27.83	3.41	36.34	6.43	<0.001†
Body roundness index	5.06	1.53	6.24	2.04	<0.001†
A body shape index (m$^{11/6}$. kg$^{2/3}$)	0.086	0.004	0.084	0.00	<0.001‡

†Mann–Whitney *U*-test. ‡Student's *t*-test. SD, standard deviation.

Table 4 Factor-loading matrix for the two anthropometric patterns of adiposity extracted by varimax rotation in older adults by sex

Variables	Factor 1 Global adiposity pattern		Factor 2 Body fat distribution pattern	
	Men	Women	Men	Women
Weight	**0.9224**†	**0.9482**†	0.1697	0.0452
Body mass index	**0.9562**†	**0.9818**†	0.2481	0.0798
Waist circumference	**0.8462**†	**0.8847**†	0.5055	0.4494
Hip circumference	**0.9083**†	**0.9581**†	0.1197	−0.0147
Arm circumference	**0.9180**†	**0.8962**†	0.0923	0.0178
Calf circumference	**0.9232**†	**0.8423**†	−0.0835	−0.2165
Waist-to-hip ratio	0.5110	0.1447	**0.7612**†	**0.8807**†
Waist-to-height ratio	**0.8008**†	**0.8501**†	0.5784	0.4689
Waist-to-calf ratio	0.0750	0.1958	**0.8841**†	**0.8260**†
Waist-to-hip-to-height ratio	0.3179	0.0695	**0.7870**†	**0.7983**†
Conicity index	0.3944	0.3401	**0.8863**†	**0.9054**†
Body adiposity index	**0.6925**†	**0.8680**†	0.2052	0.0237
Body roundness index	**0.8070**†	**0.8528**†	0.5611	0.4486
A body shape index	−0.1361	−0.2181	**0.9132**†	**0.9119**†
Eigenvalues	7.31	7.51	4.66	4.56
Variance explained (%)	52.25	53.62	33.34	32.60

†High loadings within factors.

Anthropometric patterns of adiposity and association with outcomes

The models adjusted by confounding factors showed that there was no association between anthropometric patterns of adiposity and hypertension, in both men and women. The prevalence ratio of DM was significantly higher in older women in the second (Prevalence Ratio (PR) 2.4, 95% CI 1.15–5.01) and third tertile (PR 3.49, 95% CI 1.72–7.09) of fat distribution pattern compared with those of the first tertile, and did not differ between tertiles of global adiposity. In men, none of anthropometric patterns of adiposity was associated with DM (Table 5). The deviance goodness-of-fit test showed proper adjustment of all models tested ($P > 0.05$).

Discussion

Factor analysis of principal components identified two anthropometric patterns of adiposity, represented by factor 1, labeled as global adiposity, and factor 2, labeled as body fat distribution. The two factors together explained >80% of total variance, and the significant contribution of factor 2 (body fat distribution) for the explanation of the total variance. The cumulative percentage shows that the solution obtained in the present analysis was satisfactory, and shows that in the assessment of obesity in older adults the simultaneous use of anthropometric measurements that indicate not only the amount of body fat, but also its distribution, is relevant.[18]

Weight, BMI and hip circumference were variables strongly correlated with the factor 1 (global adiposity pattern). Weight alone does not allow an accurate assessment of nutritional status, with BMI being one of the anthropometric indices most widely used for this purpose. BMI can even be used as adiposity proxy, especially in population studies with large samples or in other situations where there is a need for simple, practical and inexpensive methods.[19] Studies have shown that the magnitude of the prediction error of body fat by BMI in older adults is comparable with other doubly indirect methods, showing that its use at the population level produces relatively acceptable estimates.[20]

The use of BMI in older adults can result in overweight and obesity classification errors as a result of inaccuracies and difficulties of measuring the height and lean body mass reduction that occurs during aging.[21] Nevertheless, a recent study has shown that BMI continues to maintain a strong correlation with body fat, even when there is a change of height and lean body mass observed with increasing age.[19]

Hip circumference could be used as an indicator of total body adiposity, especially in situations where it is not possible to measure the weight and height, but its

Table 5 Associations between tertiles of anthropometrics patterns of adiposity score and hypertension and diabetes mellitus according to sex

	Global adiposity pattern (factor 1)		Fat distribution pattern (factor 2)	
	T2	T3	T2	T3
Men (*n* = 268)				
Hypertension				
Model 1	1.08 (0.77–1.51)	1.01 (0.71–1.43)	1.06 (0.75–1.50)	1.25 (0.89–1.76)
Model 2	1.05 (0.75–1.49)	0.99 (0.68–1.45)	1.07 (0.75–1.53)	1.25 (0.88–1.78)
Diabetes mellitus				
Model 1	1.52 (0.65–3.53)	2.54 (1.16–5.54)	1.18 (0.55–2.57)	2.02 (0.98–4.16)
Model 2	1.34 (0.57–3.16)	2.21 (0.96–5.06)	1.15 (0.52–2.55)	2.05 (0.97–4.35)
Women (*n* = 269)				
Hypertension				
Model 1	1.03 (0.74–1.43)	1.17 (0.85–1.62)	1.06 (0.77–1.47)	1.11 (0.80–1.53)
Model 2	1.06 (0.75–1.48)	1.15 (0.83–1.59)	1.04 (0.75–1.45)	1.04 (0.74–1.46)
Diabetes mellitus				
Model 1	1.20 (0.67–2.15)	1.64 (0.94–2.85)	**2.65 (1.28–5.48)***	**4.06 (2.03–8.15)****
Model 2	1.38 (0.75–2.54)	1.66 (0.93–2.96)	**2.40 (1.15–5.01)*****	**3.49 (1.72–7.09)****

**P*-value: <0.01; ***P*-value: <0.001; ****P*-value: <0.05.
Values are Prevalence Ratios (PR) (95% CI) for hypertension and diabetes mellitus. In all models, the first tertile (T1) of anthropometrics patterns of adiposity score was considered as a reference. Model 1 is adjusted for age. Model 2 is additionally adjusted for median income, education (<8 or ≥8 years), drinking status, smoking status and physical activity. T, tertile.

use is limited because there are no parameters for its classification. It is important to emphasize that studies have shown that in adults and older adults with higher hip circumference values, the incidence of DM is less compared with those with lower values of this independent measurement of waist circumference.[22]

Indicators of body fat distribution represented factor 2, and ABSI was the variable most strongly correlated with this factor. ABSI has been associated with total mortality by cardiovascular diseases and cancer.[23] Studies about its ability to predict diseases, such as DM and hypertension, are scarce, especially in older adults. Furthermore, until now studies have not shown that ABSI is superior in relation to BMI and waist circumference to predict diseases.[24]

Considering the knowledge gaps about ABSI, other measures can be used to assess the body fat distribution in older adults. Regarding the conicity index, for example, studies including adults and older adults have shown that its accuracy to discriminate high coronary risk is higher than other central distribution indicators of fat, such as WHtR, especially in women,[25,26] and similar to WHR.[27]

Although the WHR was not variable strongly correlated with factor 2, it could be used as an indicator of body fat distribution in situations in which obtaining the height is not possible with the advantage of it being obtained quickly and easily compared with the other indices. The waist-to-calf ratio also has the same advantages of WHR, although there is little information on its accuracy to predict cardiometabolic alterations. In the literature, we found only the study by Kim *et al.* that showed a positive association between the waist-to-calf ratio and carotid atherosclerosis in Korean individuals with type 2 DM.[12]

In the present study, multivariate analysis has shown a positive association with DM only in women, independent of confounding factors. Other studies with older adults have shown that anthropometric indicators of body fat distribution are better predictors of DM than those indicators of global adiposity.[27]

Aging not only promotes increased body fat, but also changes in its distribution. This lipodystrophy is characterized by the reduction of subcutaneous fat in the gluteofemoral region that decreases the capacity of subcutaneous adipocytes to act as body fat stores. As a result, there is an increase of circulating free fatty acids that originate in ectopic fat deposits in older adults. This increase of visceral, intrahepatic and intramuscular fat results in insulin resistance and metabolic alterations.[21]

In the present study, central body fat distribution was associated with DM only in women. This is probably because of the difference in body composition and hormone profile of the two sexes. Compared with men, women of reproductive age have a higher accumulation of fat in gluteofemoral region, higher concentrations of adipocytokines (leptin, for example) and higher concentrations of estrogen that converge to a condition of better sensitivity to insulin. Due to menopause, women show decreased production of estrogen, and lipodystrophy is more accentuated than in men, thus favoring insulin resistance and DM.[28]

The knowledge about adiposity assessment and its health risks in older adults are not yet sufficient to indicate which anthropometric indicators would be the most appropriate. In the present study, factor analysis of principal components allowed us to estimate adiposity from a set of measures and anthropometric indices, and relate it to the outcomes of interest in this population. Our results suggest that the indices most strongly correlated with patterns of global adiposity and central distribution of body fat were BMI and ABSI, respectively, in both sexes.

The comparability of our findings with other studies is limited, because so far we have not identified studies in the literature that have used this type of analysis with older adults. Importantly, the results of the present study apply to older adults with similar demographic and socioeconomic characteristics.

The present study has some potential limitations. First, use of self-reported DM and hypertension. Despite the advantage of speed to keep and costs low, this could lead to an underestimation of the prevalence of hypertension and diabetes. However, the literature shows that self-reported DM and hypertension is valid, especially in older adults.[29,30] Second, the cross-sectional study design, thus, causal relationships cannot be concluded.

In conclusion, only the central body fat distribution pattern is associated with DM in women. Our findings show that the assessment of obesity in older adults must include both global indicators of adiposity and body fat distribution, such as BMI and ABSI.

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Disclosure statement

The authors declare no conflict of interest.

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