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RESEARCH ARTICLE

Body Adiposity Index is Worse than Body Mass Index when Evaluating the Factors Associated with Adiposity in Elderly People

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Abstract

Background: Body Mass Index (BMI) is an easily measurable indicator of body fat and with low cost. However, as an indicator of risk of development of chronic diseases in the elderly, it has limitations, as it does not reflect mainly the regional distribution of fat that occurs with the aging process. As an alternative to BMI, the Body Adiposity Index (BAI) has been proposed. This index showed a high correlation with the measurement of body fat in adults indicating that it could replace BMI. However, BAI is still understudied in the elderly.

Objective: To determine factors associated with adiposity in elderly people, according to sex and in accordance with two anthropometric indices, Body Mass Index (BMI) and Body Adiposity Index (BAI).

Methods: We used cross-sectional data from 532 participants (261 women, aged 60 to 94 years) who were randomly recruited from Viçosa, Minas Gerais, and Brazil. Adiposity was defined using Body Mass Index (weight (kg)/height (m)^2) and Body Adiposity Index (hip circumference (cm)/height (m)$^{1.5}$) - 18). The associations between the two indexes (BMI and BAI) and factors associated with adiposity (socio-demographic variables, lifestyle characteristics, health status, waist circumference and functional capacity) were explored using linear regression.

Results: In men, with the exception of age and alcohol, the variables associated with BMI were also associated with the BAI. In women, we observed that the same variables were associated with BMI and BAI. However, the coefficient of determination of the final models of multiple linear regressions was higher for BMI.

Conclusion: The BAI was worse than BMI when evaluated the factors associated with adiposity in elderly people.

Keywords

Body mass index, Body adiposity index, Adiposity, Aged

Introduction

In the elderly, obesity is associated with accelerated loss of cognitive function, frailty and functional disability and premature death from Cardiovascular Disease (CVD), diabetes, cancer and musculoskeletal diseases and other chronic non-communicable diseases [1]. These diseases affect both quality of life and longevity and generate high costs to health systems.

Due to the accelerated process of population aging in the world and the concomitant increase in the prevalence of overweight and obesity, it is necessary to investigate factors that determine or are associated with increased weight in order to implement interventions more effective in the treatment/prevention of this condition [2].

The World Health Organization (WHO) recommended BMI as is an easily measurable indicator of body fat and with low cost [3]. The index is highly correlated with measures of total body fat in adults of both sexes, as well as other anthropometric indexes of subcutaneous and abdominal fat. However, as an indicator of risk of development of chronic diseases in the elderly, it has limitations, as it does not reflect mainly the regional distribution of fat that occurs with the aging process. As an alternative to BMI, the Body Adiposity Index (BAI) has been proposed [4].

As an alternative, has been proposed the Body Adiposity Index (BAI) based on height and hip circumference (BAI = (hip circumference (cm)/height (m) 1.5) - 18). This

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index showed a high correlation with the measurement of body fat in adults by *Dual-energy X-ray Absorptiometry* (DXA) in African Americans and Mexican Americans [5], indicating that it could replace BMI.

However, studies carried out in populations with different ethnic groups consistently reveal that the BAI tends to overestimate fatness in individuals with a lower percentage of body fat and underestimate body fat in those with higher adiposity [6-8]. Furthermore, BAI has better ability to predict body fat in the elderly compared to BMI only when data are not stratified by gender [6]. Nevertheless, little is known about the best indirect measures to predict factors associated with adiposity in populations, especially in the elderly [9,10].

Therefore, the purpose of this study was to determine the factors associated with adiposity in the elderly, stratified by sex, using as outcome the adiposity assessed according to two anthropometric indices, BMI and BAI.

Methods

Experimental design, target population and sample

This is a population-based, cross-sectional study, conducted utilizing a random sample of the elderly, living in Viçosa, Brazil.

The target population for this study consisted of elderly people aged 60 years or older, living in urban and rural Vicosa (MG). This group was surveyed during ''The National Campaign for Elderly Vaccination'' from April to May 2008. With the aim of identifying non-participants in the vaccination campaign, the campaign's database was merged with other databases, namely: Database of the Viçosa's, Federal University employees, active and retired, the registers of the municipality's health services, such as Elderly Health Program (PSF), Physiotherapy service, the Center of Women's Health, Psychosocial Services, Care Unit, Hiperdia and the Polyclinic. This merged data aimed to identify older people who had not participated in the 2008 vaccination campaign to complement the database. After combination of these lists, 7980 people aged 60 and over were identified and this number formed the basis for obtaining the sample. We excluded institutionalized elderly from the sample.

The sample size calculation was performed considering the reference population of 7980 elderly, confidence level of 95% and estimated prevalence of the outcome of 50%, 4.0% of variability and 20% of losses for the initial sample of 670 elderly, selected by the simple random sampling method. This loss was incurred due to refusal (3.6%), address not being located (1.2%), death (1.3%), change of address (1.2%) and inability to directly measure the height (10.4%). Thus, 621 elderly were actually assessed. Further details regarding the methodology of the project can be obtained in Nascimento, et al. [11].

Study variables

The dependents variables of this study were adiposity measured by the Body Mass Index (BMI) and the Body Adiposity Index (BAI).

The independent variables were: age (years and age range), sex (male and female), education (never studied; studied until the early elementary grades; final grades of elementary school or more), individual income (quartiles), co-habitation (live alone and do not live alone), practice of physical activities (yes or no), smoking (no history of smoking; former smoker; current smoker), alcohol consumption (yes, no and ex-alcoholic), functional capacity (adequate or inadequate), waist circumference (changed and unchanged) and self-reported morbidities (diabetes, hypertension, dyslipidemia and musculoskeletal disorders).

Data collection

A trained team interviewed the elderly in their own homes, under the supervision of the study investigators. The interview included a semi-structured questionnaire. If the elderly reported difficulty in reporting the information requested, the caregiver was asked to answer.

We obtained income from the sum of the individual yields of each elderly respondent considering retirement, pension or any other income and divided into quartiles.

The following anthropometric measurements were obtained using the standard procedures [12]. Weight was measured on portable scale (digital electronic) with a capacity of 199.95 kg and 50 gram accuracy (model LC 200 pp, Marte Scales and Precision Instruments Ltd., Brazil). Height was measured using a portable stadiometer, with a maximum calibration of 2.13 m to the nearest 0.1 mm (brand Altura Exata, Brazil). Hip circumference was measured at the most prominent gluteal region.

We calculate Body Mass Index (BMI) and the Body Adiposity Index (BAI) as (hip circumference (cm)/height $(m)^{1.5}$) - 18.

Individuals who did not have data regarding height, weight, and hip circumference (n = 75) were excluded from the sample. Outliers with BAI greater than 50.0 (n = 14) were also excluded after analysis using the box plot chart.

Data analysis

The dependent variables were tested for normality using the Shapiro-Wilk test and as they had no normal distribution they were log-transformed.

A descriptive analysis of the data was performed. Later, the student's t test was applied and the analysis of variance was complemented with Bonferroni test to determine the effect of each independent variable on BMI and BAI.

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Table 1: Distribution of Body Mass Index and Body Adiposity Index, according to sociodemographic, behavioral and health variables, Viçosa, 2009.

	Male							Female						
		BAI			BMI				BAI			BMI		
Variables	**N (%)**	**Average**	**SD**	**p-value**	**Average**	**SD**	**p-value**	**N (%)**	**Average**	**SD**	**p-value**	**Average**	**SD**	**p-value**
Age														
60-69	147 (54.24)	27.82	3.61	0.955	26.41[a]	4.74	**0.007***	148 (56.70)	35.90	5.32	0.355	27.32[a]	4.97	**< 0.001***
70-79	98 (36.16)	27.84	3.12		25.18[b]	3.75		85 (32.57)	35.15	4.87		26.05[a]	4.20	
80 or more	26 (9.59)	27.62	3.28		23.82[a]	4.01		28 (10.73)	34.66	4.45		24.68[b]	3.75	
Scholarity														
Never studied	30 (11.11)	28.17	2.86	0.699	25.16[a]	5.10	**0.056***	41 (15.71)	36.67	4.59	0.226	28.10	4.47	0.705
0-4 years of study	171 (63.33)	27.86	2.55		25.39[a]	4.35		171 (65.52)	35.44	5.34		27.49	4.82	
5 or more years of study	69 (25.56)	27.56	3.28		26.82[c]	4.41		49 (18.77)	34.85	4.47		27.30	4.97	
Income														
< R$465,00 (Q1)	12 (4.44)	28.93	3.16	0.478	25.83[a]	3.36	**< 0.001***	54 (20.93)	36.09	5.45	0.344	28.12	4.46	0.607
R$465,00 - R$599,00 (Q2)	77 (28.52)	27.47	3.46		23.97[c]	4.57		110 (42.64)	35.92	5.70		27.44	5.45	
R$600,00 - R$1599,00 (Q3)	69 (25.56)	27.71	3.48		26.17[b]	3.95		63 (24.42)	34.91	3.88		27.75	3.99	
≥ R$1600,00 (Q4)	112 (41.48)	28.00	3.35		26.91[c]	4.23		31 (12.02)	34.56	4.18		26.72	4.36	
Smoking														
Never smoked	87 (32.10)	28.28[a]	3.74	**< 0.001***	26.21[a]	4.75	**< 0.001***	192 (73.56)	35.45	5.06	0.558	27.50	4.79	0.497
Ex-smoker	137 (50.55)	28.16[a]	3.24		26.17[a]	4.13		53 (20.31)	36.08	5.39		28.05	4.88	
Currently smoker	47 (17.34)	25.95[b]	2.50		23.51[b]	3.91		16 (6.13)	34.62	4.49		26.58	4.40	
Physical activity														
No	199 (73.43)	27.61	3.45	0.109	25.45	4.45	0.092	160 (61.30)	35.83	5.01	0.222	27.74	4.93	0.420
Yes	72 (26.57)	28.36	3.20		26.47	4.21		101 (38.70)	35.04	5.20		27.25	4.53	
Diabetes														
No	224 (82.66)	27.72	3.35	0.345	25.34	4.26	**0.002***	189 (72.41)	35.15	5.04	0.051	27.16	4.83	**0.036***
Yes	47 (17.34)	28.24	3.62		27.54	4.68		72 (27.59)	36.52	5.11		28.55	4.53	
Hypertension														
No	79 (29.15)	27.45	2.72	0.257	24.93	3.82	0.0586	54 (20.69)	33.48	4.40	**< 0.001***	25.56	3.97	**< 0.001***
Yes	192 (70.85)	27.96	3.64		26.05	4.59		207 (79.31)	36.06	5.13		28.07	4.85	
Dyslipidemia														
No	146 (53.87)	27.08	2.91	**< 0.001***	24.50	3.73	**< 0.001***	83 (31.80)	35.08	5.17	0.327	26.98	4.80	0.195
Yes	125 (46.13)	28.67	3.72		27.15	4.71		178 (68.20)	35.74	5.05		27.81	4.76	
Musculoskeletal diseases														
No	235 (86.72)	27.73	3.59	0.299	25.70	4.67	0.8256	171 (65.52)	34.61	5.04	**< 0.001***	26.63	4.52	**< 0.001***
Yes	36 (13.28)	28.36	3.37		25.87	4.37		90 (34.48)	37.26	4.89		29.30	4.78	

BAI: Body Adiposity Index; BMI: Body Mass Index; SD: Standard Deviation; *Values followed by the same letter did not differ in the Bonferroni test (a,b,c).

Multiple linear regressions were used to verify the adjusted effects of the independent variables. The variables that in the bivariate analysis were associated with the dependent variable ($p < 0.20$) were included in the model. Models were age-adjusted. The final model was obtained using the "backwards" method, with the significance test of the elimination of the variable in each stage. The variables that associated with the variable dependent ($p < 0.05$) remained in the final model. We used STATA version 13.0 (STATA Corp., Texas, USA) and all analyses were performed considering a significant level of 5%.

Ethical procedures

The interview was conducted after signing the consent form by the elderly or their caregivers, and the study protocol was approved by the Ethics Committee on Human Research of the Universidade Federal de Viçosa - Case No. 027/2008.

Results

For the present article, 532 elderly aged 60 and 94 years have been effectively studied. The majority of whom were male (50.9%). Most elderly patient was aged up to 69 years (55.5%) and lived with a partner or other people (89.1%). Regarding socioeconomic factors, 77.8% of the elderly had up to 4 years of education and 52.1% had an income higher than the 2nd quartile (R$ 600,00).

Among the chronic diseases reported by the elderly, hypertension and dyslipidemia were more frequent (75.0% and 57.0%, respectively), while women had higher proportions. Most participants did not exercise (67.48%) and smoking was more common in men.

In Bivariate analyzes it was observed higher average BMI in women aged between 60 and 69 years with hypertension, diabetes and musculoskeletal diseases. For BAI, women who had hypertension and musculoskeletal disorders had the highest averages (Table 1).

For men, however, the highest means BMI were observed in that aged 60 to 69 years, in the highest quartile of income, no smoking habit, with alcohol consumption, with diabetes and dyslipidemia. For BAI, the highest averages were men who had never smoked and who had dyslipidemia (Table 1). In the present analysis, it we not found any statistically significant differences between the means of individuals of both sexes, for education and physical activity using both anthropometric indices.

We observed that most explanatory variables were associated with BMI compared to BAI in both sexes, with the biggest difference for men.

Observing the gross and adjusted effects of the explanatory variables that remained in the final regression model for men, it appears that with the exception of age, the variables associated with BMI were also associated with the BAI. Still considering BMI, except for age, which showed no modification, smoking and dyslipidemia had an increased effect in relation to gross analysis. For the BAI, no variable showed different effects (Table 2 and Table 3).

In women, it was observed that the same variables were associated with BMI and BAI. With the exception of age, which had its effect increased after adjustment, other variables decreased their explanatory effect in the final model (Table 4 and Table 5).

The coefficient of determination (R^2) obtained in the adjusted model for BAI indicates that 10.19% of the total variability in adiposity in men is explained by age, smoking and dyslipidemia while 10.31% of the total

Table 2: Coefficients of linear regression, confidence intervals and p-values for the association of independent variables with Body Adiposity Index (BAI) in elderly men, Viçosa, MG, 2009.

	β	CI 95%	Adjusted β	CI 95%	p-value
Age					
	0	-0.002 to 0.002	0.000	-0.002 to 0.002	0.952
Income					
< R$465,00 (Q1)	0	-			*
R$465,00 - R$599,00 (Q2)	-0.055	-0.129 to 0.019			
R$600,00 - R$1599,00 (Q3)	-0.045	-0.119 to 0.029			
≥ R$1600,00 (Q4)	-0.034	-0.106 to 0.038			
Smoking					
Never smoked	0	-	0	-	0
Ex-smoker	-0.002	-0.034 to 0.029	-0.010	-0.041 to 0.022	
Currently smoker	-0.08	-0.123 to -0.040	-0.077	-0.118 to -0.036	
Physical activity					
No	0	-			*
Yes	0.028	0.004 to 0.061			
Dyslipidemia					
No	0	-	0	-	0.001
Yes	0.054	0.026 to 0.083	0.047	-0.076 to 0.019	

β: univariated regression coeficiente; Adjusted β: multivariate regression coefficient; *Variables that did not remain in the regression model.

Table 3: Coefficients of linear regression, confidence intervals and p-values for Body Mass Index (BMI) of elderly men, according to independent variables, Viçosa, MG, 2009.

	β	CI 95%	Adjusted β	CI 95%	p-value
Age					
	-0.005	-0.008 to -0.003	-0.005	-0.007 to -0.002	0.000
Income					
< R$465,00 (Q1)	0	-			*
R$465,00 - R$599,00 (Q2)	0.085	-0.184 to 0.143			
R$600,00 - R$1599,00 (Q3)	0.013	-0.113 to 0.087			
≥ R$1600,00 (Q4)	0.037	-0.060 to 0.134			
Scholarity					
Never studied	0	-			*
0-4 years of study	0.014	-0.052 to 0.080			
5 or more years of study	0.07	-0.003 to 0.143			
Smoking					
Never smoked	0	-	-	-	0
Ex-smoker	0.002	-0.042 to 0.047	-0.013	-0.056 to 0.029	
Currently smoker	-0.106	-0.165 to -0.047	-0.107	-0.164 to -0.051	
Alcohol use					
No	0	-	0		0.03
Ex user	-0.056	-0.099 to -0.134	-0.044	-0.083 to -0.004	
Yes	-0.046	-0.115 to 0.226	-0.051	-0.116 to 0.014	
Physical activity					
No	0	-			*
Yes	0.042	-0.004 to 0.087			
Dyslipidemia					
No	0	-	-	-	0
Yes	0.1	0.061 to 0.139	0.083	0.045 to 0.121	
Diabetes					
No	0	-			*
Yes	0.08	0.037 to 0.085			
Hypertension					
No	0	-			*
Yes	0.041	-0.004 to 0.085			

β: univariated regression coeficiente; Adjusted β: multivariate regression coefficient; *Variables that did not remain in the regression model.

Table 4: Coefficients of linear regression, confidence intervals and p-values for the Body Adiposity Index (BAI) of older women, according to independent variables. Viçosa, MG, 2009.

	β	CI 95%	Adjusted β	CI 95%	p-value
Age					
	-0.002	-0.005 to -0.000	-0.003	-0.005 to 0.000	0.021
Scholarity					
Never studied	0	-			*
0-4 years of study	-0.037	-0.087 to 0.012			
5 or more years of study	-0.051	-0.111 to 0.009			
Physical exercise					
No	0	-			*
Yes	-0.024	-0.059 to 0.012			
Diabetes					
No	0	-			*
Yes	0.039	0.000 to 0.078			
Hypertension					
No	0	-	0	-	0.005
Yes	0.073	-0.018 to 0.115	0.061	0.019 to 0.104	
Musculoskeletal diseases					
No	0	-	0	-	0.001
Yes	0.075	-0.388 to 0.110	0.063	0.027 to 0.099	

β: univariated regression coeficiente; Adjusted β: multivariate regression coefficient; *Variables that did not remain in the regression model.

Table 5: Coefficients of linear regression, confidence intervals and p-values for Body Mass Index (BMI) of older women, according to independent variables, Viçosa, MG, 2009.

	β	CI 95%	Adjusted β	CI 95%	p-value
Age					
	-0.005	-0.008 to -0.002	-0.006	-0.009 to -0.003	0.000
Diabetes					
No	0	-			*
Yes	0.052	0.005 to 0.100			
Hypertension					
No	0	-	-	-	0.002
Yes	0.091	0.038 to 0.143	0.08	0.029 to 0.131	
Musculoskeletal diseases					
No	0	-	-	-	0
Yes	0.032	0.054 to 0.141	0.083	0.040 to 0.126	
Dyslipidemia					
No	0	-			*
Yes	0.097	-0.013 to 0.141			

β: univariated regression coeficiente; Adjusted β: multivariate regression coefficient; *Variables that did not remain in the regression model.

variability in adiposity in women is explained by age, hypertension and musculoskeletal diseases. For BMI, the adjusted model showed that 17.71% of the total variability in adiposity in men is explained by age, smoking, alcohol use and dyslipidemia and 14.90% of the variability in women is explained by age, hypertension, and musculoskeletal diseases. BAI had lower coefficient of determination in relation to BMI for both sexes. Factors associated with BMI best explain the variation, and it is emphasized that these factors were the same for BAI.

All the above analyses met the criteria for use of multiple linear regression model, i.e., waste presented normal distribution and homogeneous variances. Few aberrant and influential points were detected and there was no indication of co linearity.

Discussion

The results showed that the factors associated with adiposity in the elderly are different in men compared to that observed in women. These findings reinforce the need that, in congener studies, the analysis of associated factors be stratified by sex for a greater clarity of results and more appropriate planning on intervention for the different groups.

Among the individual factors investigated in the present study it was revealed that the age group of 60 to 69 contained the highest average BMI in both sexes, whereas an association was found for the BAI only in women, in simple linear regression, using age in years. The result was expected because aging provides significant changes in weight and body composition, reducing muscle mass and redistributing body fat [4,13]. The weight decreases with age in men, when they are around 65-years-old and in women, about ten years later [4]. This behavior is described by national and international studies [14-16]. The decline in the prevalence of obesity in people older than 70 years may also be due to selective mortality of people in their 50 to 69 years, so that relatively few obese people survive to older ages.

The lack of association between physical activity and obesity may have occurred because, in the present study, physical activity has been investigated only in leisure. Use of this indicator may underestimate the total physical activity by disregarding its other dimensions performed at work, transportation and home [17]. However, physical activity performed during leisure time may represent the adoption of a healthy lifestyle and be the subject of public health policies. Another reason may be due to the study design which does not distinguish behavioral changes caused by high adiposity already existing.

Among women, the associations with diabetes risk were relatively similar for BAI and BMI, but considerably weaker compared to waist circumference. Corroborating the results, Receiver Operating Characteristic (ROC) curve analysis showed discrimination generally superior to BMI or waist circumference compared to BAI for this morbidity [18].

Because this was a cross-sectional study, one cannot distinguish whether the factors associated with adiposity are causes or consequences of the disease itself.

It was observed that more variables were associated with the BMI compared to the BAI in men. Additionally, all variables associated with the BAI were also associated with BMI in both sexes, after multiple regression analysis. Although BAI presents a good performance as a predictor of total body fat percentage [5,19], it was verified that it was no better than BMI for predicting the associated factors and health outcomes in the elderly. BMI showed better performance when assessing adiposity since it had a higher coefficient of determination than BAI.

The main methodological limitation of this study is its cross-sectional design that makes it impossible to identify the causal links among events. Another important limitation is the use of stepwise regression, which often eliminates redundant variables from its model, may thus be ruling out an important part of the explanation of the phenomena studied and lead to greatly inflated Type I error rates (i.e., the probability of erroneously rejecting a true null hypothesis) [20,21]. Moreover, it was not possible to assess the dietary habits of elderly preventing further inferences about the lifestyle in adiposity.

Self-reported information was used to detect the presence of morbidity in the elderly evaluated. However, this practice is recommended by the World Health Organization [22] and studies have proved that the information obtained about the presence of chronic diseases show good concordance with medical records or clinical examinations [23,24]. Thus, BAI is less useful not only than BMI but also than other adiposity indexes such as Waist-to-Height Ratio (WHtR), Waist Hip Ratio (WHR) and Waist Circumference (WC). Third, age, gender and smoking have been associated with the development of CVD risk factors [18,25,26]. While these have been accounted for by the adjustment for these factors in the analysis, other factors known to influence the development of CVD risk factors such as dietary habits and family history have not been accounted for. Further studies of a prospective nature would be required to confirm the findings of this study.

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Competing Interests

The authors declare that they have no competing interests.

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