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Accuracy of BMI and waist circumference cut-off points to predict obesity in older adults

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Abstract *The main objectives were to analyse the validity and accuracy of Body Mass Index (BMI) and Waist Circumference (WC) to evaluate obesity by excess of body fat in older adults and to identify more adequate cut-off points for this age group. The recommended cut-off points for BMI (25, 27 or 30 kg/m²) and WC (≥ 102 cm for men and ≥ 88 cm for women or ≥ 90cm for men and ≥ 80 cm for women) were compared to the total body densitometry. BF was defined by a value higher than the 90th percentile. Out of the 132 participants, 61% were women and aged between 60 and 91 years. The recommended cut-off points of BMI ≥ 25kg/m² and BMI ≥ 27 kg/m² showed similar performances. BMI ≥ 30 kg/m² showed high specificity but low sensitivity to identify BF in men and better performance in women. Conventional WC cut-off points showed low sensitivity and specificity. Based on our analyses, new cut-off points for BMI (25 kg/m² for men and 26.6 kg/m² for women) and WC (98.8 cm for men and 77.8cm for women) were proposed. The new cut-off points showed sensitivity and specificity values > 74% and accuracy > 76%. The areas under the curve (ROC) were > 0.86. The new BMI and WC cut-off points proposed in the present study for the diagnosis of obesity in older adults showed the best levels of sensitivity and specificity for this age group.*

Keywords *Sensitivity and Specificity, Obesity, Body composition, Ageing*

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Introduction

Obesity remains one of the main public health challenges reaching pandemic levels[1] and is associated to clinical complications and various chronic conditions[2]. Despite being extensively investigated, there is still a lack of consensus on the most appropriate method for its diagnosis among older adults. The Body Mass Index (BMI) and waist circumference (WC) are the most widely used methods to identify global and central obesity respectively. Therefore, there is a clear need for studies to evaluate their capacity to predict capacity in order to obtain a consensus on their diagnostic cut-off points for the different population age groups. Evidence from the general adult population showed that BMI has high specificity level but low sensitivity[3] to identify adiposity[4].

The applicability and accuracy of using the same diagnostic cut-off points for both adults and older adults are inappropriate and not accepted widely[4] due to the aging related body composition changes such as body fat redistribution and muscle mass and bone density reductions. There are only few studies that investigated the predicted capability of BMI for cardiovascular risk[5] and body fat diagnosis[6] in older adults. In addition, they did not propose a cut-off for this age group[4]. Therefore, because of population ageing is a major challenge it becomes important to establish more accurate cut-off points to predict body fat in older adults in the public health arena as well as in clinical settings. This way, there would be improvements in nutritional diagnosis and the planning of interventions.

Regarding the WC, the cut-off points to predict metabolic risk showed gender differences in different populations[4,7]. A recent meta-analysis demonstrated an increased mortality risk in older adults with increased WC even between different BMI categories, suggesting the need to re-evaluate the WC values in older adults[8].Therefore, based on the available evidence, the present study aimed at analysing the validity and accuracy of both BMI and WC in predicting excess body fat and identifying more accurate and appropriate cut-off points for older Brazilian adults.

Methods

The present study is a subsample of the cohort "Situação de Saúde e Indicadores Antropométricos para Avaliação do Estado Nutricional de Idosos Usuários do Sistema Único de Saúde de Goiânia" or "Projeto Idosos Goiânia" that started in 2008 with a probabilistic sample of 418 community-dwelling older adults aged 60 and older residing in the city of Goiania, Goias. The Projeto Idosos Goiânia only included those individuals aged 60 or older who attended at least an outpatient consultation twelve months before the baseline data collection date. This inclusion criteria allowed the researchers to establish whether the participants were users of the Brazilian Unified Health Service (SUS). A more detailed description of the cohort study can be found elsewhere[9-11].

The sample size calculation was estimated based on two-sided test of significance $\alpha = 0.05$, ß = 0.05, power of 95% and an expected correlation coefficient of 0.35, resulting in a sample of at least 100 individuals[12]. In order to have a balanced proportion of men and women as well as different BMI categories,132 individuals were randomly selected. For the random selection only those individuals who fulfilled the criteria for the Dual Energy X-Ray Absorptiometry - DEXA (Total Body Densitometry) were eligible i.e. weight < 100kg (equipment maximum capacity), not having a pacemaker and provided an informed consent. The participants were initially contacted by telephone and informed about this stage of the study. The selected participants were informed about all interview procedures and fasting before the health examination i.e. DEXA. At the examination date, the participants were driven to the clinic and the assessments were carried out by trained and well qualified technicians leading to more reliable and accurate estimates.

The following measurements were performed: weight, height, body mass index (BMI), waist circumference (WC) and body fat percentage (%BF). Weigh was recorded to the nearest 0.1 kgusing a portable electronic digital scale (Tanita®) and height was measured using a measuring tapeto the nearest 0.1 cm[13]. BMI was subsequently derived using the standard formula: weight divided by height squared (kg/m^2) and categorized into: 1) overweight = BMI ≥ 25 kg/m^2 and obesity = BMI ≥ 30 Kg/m^2; according to theWorld Health Organization[14], 2)excess weight = BMI > 27 kg/m^2, classification used by the Nutrition Screening Initiative[15], and also recommended by other authors[16].

During the health examination, two measurements of waist circumference were taken at the midpoint between the lower rib and the iliac crest using measuring tape with a 0.1cm level of precision[17]. The identification of the anatomic points

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for the anthropometric measurements were done using standard procedures[17]. Next, WC was categorised according to the following cut-off points: 1) ≥ 94 cm for menand ≥ 80 cm for women, recommended by the World Health Organization[14]; 2)≥ 102 for men and ≥ 88 cmfor women recommended by the National Institutes of Health and the National Cholesterol Education Program[18-20]; 3) higher than 90 cm and 80 cm for men and women respectively, proposed by the International Diabetes Federation[21].

Body fat was measured in a specialised image clinic using the DEXA (Lunar®, DPX-MD PLUS, program 7.52.002 DPX-L). During the examination, the participants were wearing a light apron and no metals such as jewellery. The excess body fat was defined using the 90th percentile of the sample stratified by gender and age group[22], following the criteria previously published[23].

All statistical analyses were performed using the STATA, SE version 12.0. The normality of variables was tested using the Shapiro-Wilk test. The Pearson Chi-squared test was used to test differences in proportions by gender with a 5% significance level.

A Receiver Operating Characteristic (ROC) was performed to analyse the variations in sensitivity and specificity values of different WC cut -off points in relation to the gold standard measure. Next, WC cut-off values were calculated with their corresponding confidence intervals for sensitivity, specificity and accuracy taking into account a minimum sensitivity and specificity of 60% and total area under the ROC curve greater than 0.70.

The project was approved by the Ethics Committee of the Federal University of Goias. All participants were informed about the research objectives and provided a signed informed consent form.

Results

The sample was comprised of 132 older adults aged between 60 and 91 years. Overall, there were more participants from the age group 60-69 (52.3%) and women (60.6%). The average BMI values were 25.7 ± 4.0 kg/m^2 for men and 27.4 ± 5.7 kg/m^2 for women. WC average values were 95.7 ±11,5 cm and 93.7 ±14,5 cm for men and women, respectively. The average body fat percentage was 30.2 ± 8,6% in men and 42.8 ± 9,0% in women. These variables were normally distributed according to the Shapiro-Wilk test. Women had higher total and central obesity according to the WHO and NCEP criteria as well as percentage of body fat (Table 1).

Table 2 shows the performance of the different cut-off points to predict excess body fat. BMI ≥ 25 kg/m^2 and ≥ 27 kg/m^2 showed similar prediction performance in both men and women. The cut-off point of ≥ 30 kg/m^2 showed high specificity but low specificity sensitivity i.e. 25% in men, with a better prediction of elevated body fat percentage in women. The predict capability for WC was similar for all the different cut-off points assessed. However, the specificity was higher for men i.e. 91.7% and higher sensitivity for women (84.4%) when considering the highest cut-off points.

Regarding the proposed cut-off points by the present study based on the ROC curve, the BMI and WC values with the best sensitivity, specificity and accuracy values were 25 kg/m^2 and 98.8 cm for men, 26.6 kg/m^2 and 90.5 cm for women (Table 3).

Lastly, the area under the curve (Figures 1 and 2) showed that the capacity to detect correctly the presence or absence of excess body fat was 88% for both BMI and WC in men and 89% (BMI) and 86% (WC) in women. All the 95% confident intervals' lower limits were above 0.78.

Discussion

The present study proposes new cut-off points for BMI and waist circumference (WC)to diagnosis obesity in older adults. Our main findings showed that the most accurate cut-off points to evaluate excess body fat in older adults were BMI≥ 25 kg/m^2 and WC ≥ 98,8 cm in men; and BMI ≥ 26,6 kg/m^2 and WC ≥ 90,5 cm in women. These cut-off points showed higher levels of accuracy i.e. between 76.2 and 84.3% to identify excess body fat/obesity in older men and women. Our findings represent an important contribution to research on anthropometry, ageing and morbidity since there is large controversy on the predict capacity of BMI and WC in older adults[3,4]. The adoption of the same cut-off point for obesity across different age groups from different populations is highly criticised because of considerable physiologic age-related changes in body composition. Therefore, the present study brings new evidence to shade some light on the current controversy.

The performance analysis of the existing cut-off points for WC carried out in the present

Table 1. Excess body weight, obesity and central obesity by sex in older adults using different cut-off points for BMI, WC and percentage of body fat. Goiânia, Brazil (n = 132).

Variables	Sex				p[T]
	Men (n = 52)		Women (n = 80)		
	n	%	n	%	
Body Mass Index (BMI)					
≥ 25 kg/m2 (overweight)	31	59.62	45	56.25	0.705
> 27 kg/m2 (excess weight)	20	38.46	38	47.50	0.310
≥ 30 kg/m2 (obesity)	7	13.46	25	31.25	0.020
Waist circumference (WC)					
WHO (≥ 94 cm,men; ≥ 80 cm, women)	33	64.71	65	81.25	0.033
NCEP (≥ 102 men and ≥ 88 cm women)	17	33.33	49	61.25	0.002
IDF (≥ 90 menand ≥ 80 women)	38	74.51	65	81.25	0.363
Percentage of Body Fat (%BF)					
>90thPercentile	28	53.85	45	56.25	0.010

*Missing datafor 1 male participant. WHO (World Health Organization): ≥ 94 cm men e ≥ 80 cm women; NCEP (National Cholesterol Education Program): ≥ 102 men e ≥ 88 cm women; IDF (International Diabetes Federation): ≥ 90 men e ≥ 80 women; ŦPearson Chi-squaredtest.

Table 2. Predictive capability for different BMI and WC cut-off points currently recommended to detect body fat in older men and women, Goiânia, Brazil. (n = 132).

Variables	Sensitivity (95% CI)	Specificity (95% CI)	VPP (%)	NVP (%)	Accuracy (%)
Men (n = 52)					
BMI categories					
Overweight (≥ 25 kg/m2)	89.3 (77.8; 100.7)	75.0 (57.7; 92.3)	80.6	85.7	82.7
Excess weight (> 27 kg/m2)	60.7 (42.6; 78.8)	87.5 (74.3; 100.7)	85.0	65.6	73.1
Obesity (≥ 30kg/m2)	25.0 (9.0; 41.0)	100.0 (100.0; 100.0)	100.0	53.3	59.6
WC* (cm)					
≥ 90	96.3 (89.2; 103.4)	50.0 (30.0; 70.0)	68.4	92.3	74.5
≥ 94	85.2 (71.8; 98.6)	58.3 (38.6; 78.1)	69.7	77.8	72.5
≥ 102	55.6 (36.8; 74.3)	91.7 (80.6; 102.7)	88.2	64.7	72.5
Women (n = 80)					
BMI Categories					
Overweight (≥ 25 kg/m2)	82.2 (71.1; 93.4)	77.1 (63.2; 91.1)	82.2	77.1	80.0
Excess weight (> 27 kg/m2)	73.3 (80.4; 86.3)	85.7 (74.1; 97.3)	86.8	71.4	78.8
Obesity (≥ 30kg/m2)	53.3 (38.8; 67.9)	97.1 (91.6; 102.7)	96.0	61.8	72.5
WC (cm)					
≥ 80**	97.8 (93.5; 102.1)	40.0 (23.8; 56.2)	67.7	93.3	72.5
≥ 88	84.4 (73.9; 95.0)	68.6 (53.2; 84.0)	77.6	77.4	77.5

*Missing data for 1 male. BMI: Body Mass Index; WC: waist circumference; PPV:positive predictive value; NPV: negative predictive value **Alterti et al[51]; IDF(International Diabetes Federation)[33]; WHO (World Health Organization)[24]

study revelled a level of accuracy lower than 74% as well as lower values for specificity and sensitivity[4]. The BMI ≥ 30kg/m^2 also showed a poorer performance, sensitivity of 25% in men and 53% in women. These findings corroborate evidence from Australia, North America, China and from a meta-analysis including twenty five studies with 31,968 individuals[3,6,24]. Despite all the controversy surrounding the use of a BMI ≥ 30kg/m^2 as the cut-off point for obesity in older adults,

Table 3. BMI and WC cut-off points capability to diagnosis obesity in older men and women obtained by the ROC curve, Goiânia, Brazil. (n = 132).

	Cut-off point	Sensitivity (95% CI)	Specificity (95% CI)	Accuracy (%)
Men (n = 52)				
BMI	25.0	89.3 (77.8; 110.7)	75.0 (57.7; 92.3)	82.7
WC*	98.8	81.5 (68.0; 96.1)	87.5 (74.3; 100.7)	84.3
Women (n = 80)				
BMI	26.6	82.2 (71.1; 93.4)	85.7 (74.1; 97,3)	83.7
WC	90.5	77.8 (63.0; 88.1)	74.3 (59.8; 88,8)	76.2

*Missing data for 1 male participant. BMI: Body Mass Index; WC: waist circumference.

some international institutions still recommend its use for such purpose[14].

High BMI cut-off points, such as 30 kg/m^2, are not appropriate to identify older obese adults due to their low sensitivity. Our findings together with the ones from another study[25], showed that BMI values of 27 kg/m^2 and 25 kg/m^2 have higher sensitivity and are more accurate. This could be attributed to increases in body fat and reductions in muscle and bone masses that occur during ageing. These changes are more pronounced in women[25]. Therefore, BMI and WC cut-off points should consider such differences. On the other hand, the performance analysis of lower BMI values (25 kg/m^2 and 27 kg/m^2) showed better balance between sensitivity and specificity as well as better accuracy.

Central obesity has been recommended as one of the best anthropometric predictors for visceral adiposity and metabolic syndrome risk[14,26]. Its association to mortality and risk factors is stronger compared BMI[8,26]. However, due to age related variations in body composition, research on WC performance in older adults are needed since this age group is associated with more negative health outcomes[7,8,27]. Thus, it is important to establish specific cut-off points for excess body fat later in life[8,28].

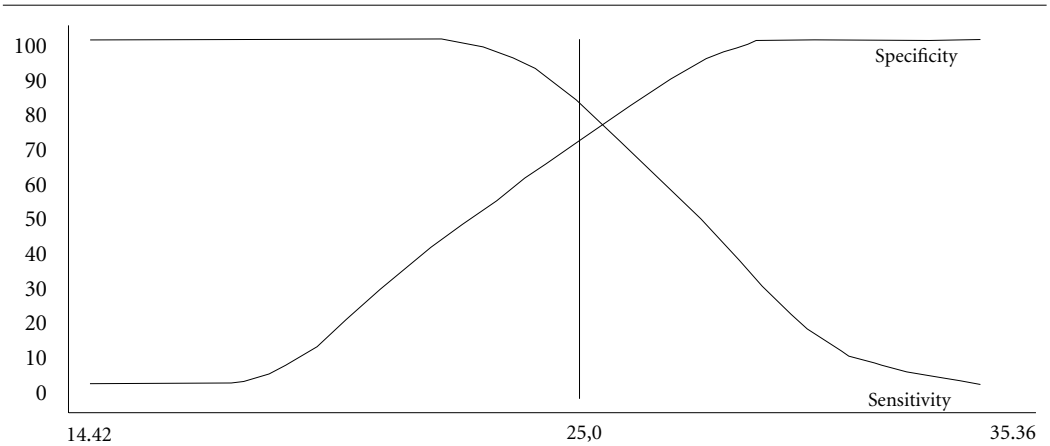
The WC cut-off points analysed in the present study showed that ≥ 90 cm for men and ≥ 80 cm for women (IDF)[29] and WC ≥ 102 cm for men and ≥ 88 cm for women (NCEP) were more accurate. On the other hand, the WHO cut-off points of ≥ 94 cm for men and ≥ 80 cm for women showed low specificity in both men and women and, consequently, a higher percentage of false-positive cases. Therefore, even the IDF cut -offs mentioned above i.e. 90 cm for men and 80 cm for women should not be used for women[29]. Furthermore, a study with 3,435 Tunisian adults found that the best cut-off form men was 85 cm and 79 cm for women, since these values had high specificity and sensitivity[30].

Studies with Asian[31], Korean and Chinese[4,18] populations found different cut-off points, highlighting the importance of our findings suggesting cut-off points specific for older Brazilian adults.

Brazilian studies that evaluated both anthropometric parameters i.e. WC and BMI in older adults and their capacity to predict obesity[5,6,25] and cardiovascular risk[5] found a great variation of recommended cut-off points for BMI and WC with different sensitivity and specificity values[5]. The cut-off points proposed in the present study are similar to the ones suggested by Barbosa et al.[25] having, overall, better sensitivity, specificity and accuracy. Differences found between international studies as well as between different regions within the same country, could be explained by the differences in outcomes used, analytical approach, presentation of the findings and heterogeneity of each population.

Our proposed cut-off points could potentially be used in older Brazilian adults from different regions within Brazil and also in other South American countries. This last point is particularly important since the cut-off points currently recommended in this region have been based on populations from Europe and North America[21,29]. The current cut-off points for BMI used to diagnose obesity have high specificity but a sensitivity value lower than 50%. Our findings reinforce the ones from international studies that criticise the existing cut-offs since they ignore the body fat gain related to ageing.

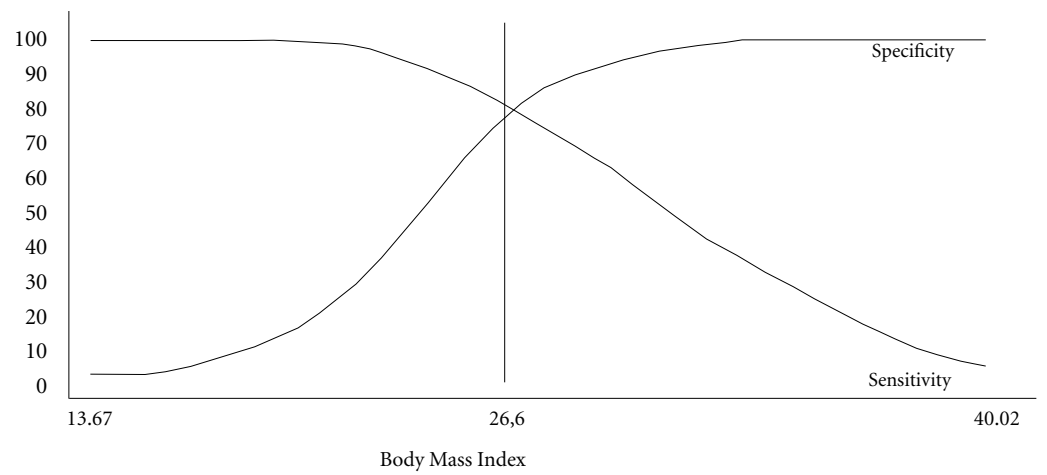
Therefore, our results seek to help the process of establishing more sensitive and specific



Area under the ROC curve: 0.8817 (0.79199; 0.97140).

Figure 1. ROC curve to identify better BMI cut-off points to diagnosis excess body fat in older men and women. Goiânia, Brazil. (n = 132).

Figure 1a. Men.

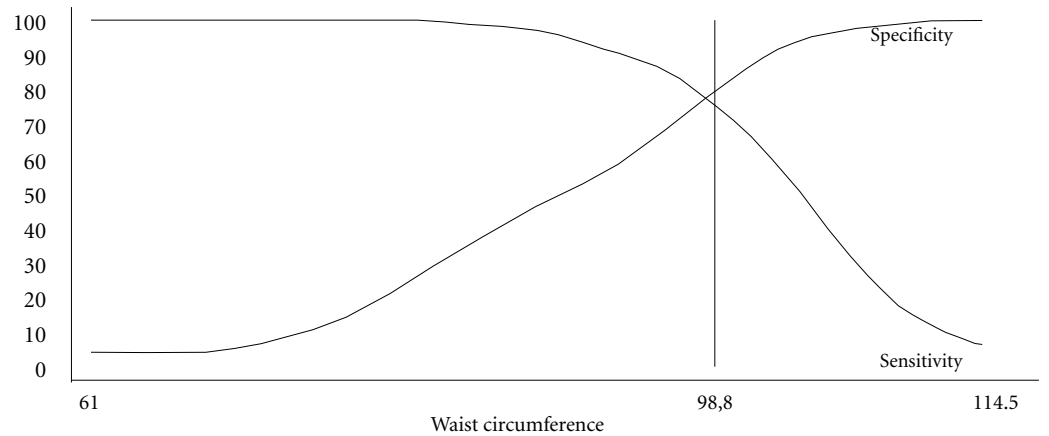


Area under the ROC curve: 0.8927 (0.82524; 0.96016).

Figure 1b. Women.

WC cut-off points leading to improvements in the diagnosis of obesity in older Brazilian adults by using simple anthropometric measures. This way, they would also contribute to the development of strategies for prevention and treatment of obesity associated morbidities.

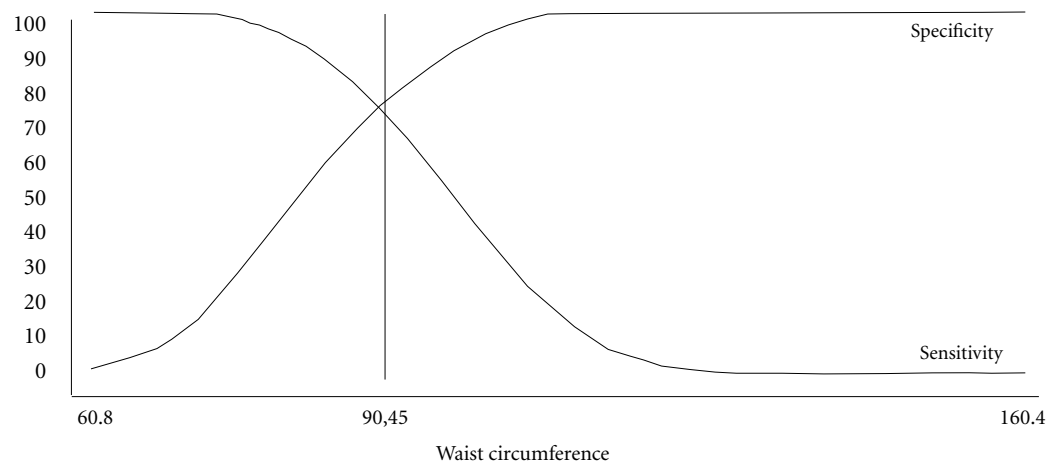
One of the potential limitations of the present study could be its small sample size. However, because it was designed to test the accuracy and validation of anthropometric measures the number of participants investigated was sufficient according to the power calculation performed *a priori*. It is worth mentioning that the gold standard used i.e. total body densitometry is a high precision technique to diagnose body composition. This fact increases the validity of the comparisons of the anthropometric measures used and our findings.



Area under the ROC curve: 0.8812 (0.78779; 0.97455).

Figure 2. ROC curve to identify better WC cut-off points to diagnosis excess body fat in older men and women. Goiânia, Brazil. (n = 132).

Figure 2a. Men.



Area under the ROC curve: 0.8600 (0.78156; 0.93844).

Figure 2b. Women.

Based on our findings, the cut-off points of 25kg/m^2 and 98.8cm for men and 26.6 kg/m^2 and 90.5cm for women are recommended to evaluate excess body fat/obesity specifically in older adults. The use of more accurate BMI and WC cut-offs in the health services as well as in the family health strategy program could potentially enhance the diagnosis of obesity in older adults. The importance of establishing accurate cut-off points is the fact that their operational simplicity and good accuracy are great advantages for health settings. Furthermore, they allow getting a better understanding of obesity in specific population groups in epidemiological research.

Collaborations

EA Silveira - Elaboration of the study design, data collection and analysis, literature review, writing of the manuscript and final review. V Pagotto - Data collection, review of statistical analysis, writing of the manuscript and final review. LS Barbosa - Elaboration of the study design, data collection and analysis, writing of the manuscript and final review. GG Pena - literature review, writing of the manuscript and final review. JG Velasquez-Melendez - review of statistical analysis, writing of the manuscript and final review.

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