

Original

Anatomical location for waist circumference measurement in older adults; a preliminary study

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Abstract

Background and objective: Different anatomical locations for measuring waist circumference are described in the literature but the best anatomical location for measuring waist circumference in older adults has yet to be established. Thus, an exploratory study was developed to examine which waist circumference best explains abdominal fat mass in older adults.

Methods: Waist circumference was measured in the ten different anatomical locations from a sample of 51 older adults. The choice of which waist circumference measurement best associated with abdominal fat mass was evaluated with dual-energy X-ray absorptiometry (DXA) measurement of abdominal fat.

Results: Mean waist circumference values varied from 81.9 (standard deviation (SD): 8.7) cm and 91.5 (SD: 11.2) cm for women and between 95.7 (SD: 8.2) cm and 101.5 (SD: 10.4) cm for men, according to the different anatomical locations. The coefficients of determination of the linear regression model varied from 0.545 to 0.698 ($p < 0.001$) and the standardised coefficients varied from 0.738 and 0.836 ($p < 0.001$). The anatomical landmark situated 2.5 cm above the umbilicus was the waist circumference measurement that associated best with abdominal fat mass measured by DXA.

Conclusion: This exploratory study contributes to the recognition that the anatomical location where the waist circumference measurement is taken gives considerably different results. The waist circumference measurement 2.5 cm above the umbilicus was the best surrogate measure of abdominal fat in this older adult's sample.

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Key words: *Waist circumference. Anatomical location for measurement. Abdominal fat mass. Dual energy X-ray absorptiometry. Older adults.*

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LOCALIZACIÓN ANATÓMICA PARA MEDICIÓN DE LA CIRCUNFERENCIA DE LA CINTURA EN ANCIANOS; ESTUDIO PRELIMINAR

Resumen

Fundamento y objetivo: La literatura describe diferentes localizaciones anatómicas para medir la circunferencia de la cintura. Sin embargo, la mejor localización anatómica para tal medición en ancianos aun no se ha establecido. El presente estudio exploratorio pretende determinar cuál es el lugar anatómico que se asocia mejor entre la medida del perímetro de la cintura y el tejido adiposo abdominal en esta población.

Método: Se midió la circunferencia de la cintura en diez lugares anatómicos diferentes, en una muestra de 51 ancianos. El tejido adiposo abdominal se determinó mediante absorciometría de doble energía de rayos X (DXA).

Resultados: Los valores medios de la circunferencia de cintura, teniendo en cuenta las mediciones en distintos lugares anatómicos, variaron de 81,9 cm (desviación estándar (DE): 8,7) a 91,5 cm (DE: 11,2) entre las mujeres y de 95,7 cm (DE: 8,2) a 101,5 cm (DE: 10,4) entre los hombres. Los coeficientes de determinación del modelo de regresión lineal variaron entre 0,545 y 0,698 ($p < 0,001$) y los coeficientes estandarizados variaron entre 0,738 y 0,836 ($p < 0,001$). El punto de referencia anatómico situado a 2,5 cm por encima del ombligo ha sido la medición de la circunferencia de cintura que mejor se asocia con el tejido adiposo abdominal medida por DXA.

Conclusión: Este estudio exploratorio demuestra que la localización anatómica donde se realiza la medición de circunferencia de la cintura influye en los resultados que se obtienen. La medición a 2,5 cm por encima del ombligo se ha mostrado como el mejor indicador del tejido adiposo en esta muestra de ancianos.

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Palabras clave: *Circunferencia de la cintura. Localización anatómica para la medición. Tejido adiposo. Abdominal. Absorciometría de doble energía de rayos X. Ancianos.*

Abbreviations

BMI: Body mass index.
DXA: Dual-energy X-ray absorptiometry.
L1: First lumbar vertebrae.
L4: Fourth lumbar vertebrae.
NSC: Non-standardised coefficients.
 R^2 : Coefficients of determination.
SD: Standard deviation.
SC: Standardised coefficients.
WC: Waist circumference.
%BF: Percentage body fat.

Introduction

The prevalence of obesity in older adults is increasing worldwide.¹ There is a considerable amount of evidence showing that obesity-related complications are linked more to body fat distribution than total body fat.² Abdominal visceral fat is different from fat present in subcutaneous areas. The type of adipocytes, their endocrine function, lipolytic activity, presence of inflammatory cells, response to insulin and other hormones differ between subcutaneous adipose tissue and visceral adipose tissue.^{3,4} Visceral fat accumulation is associated with dyslipidemia and high blood glucose clustering in the older adults.⁵

Visceral adipose tissue is directly and accurately measured by magnetic resonance imaging or computerized tomography scans.² Dual-energy X-ray absorptiometry (DXA) overcomes the unavailability, radiation and costs of this equipment allowing for separation of the body into regions of interest, including the abdominal region.⁶ However, due to technical demands,⁷ waist circumference is widely used as a surrogate marker of visceral adiposity. This indirect measurement cannot differentiate between visceral and subcutaneous adipose tissue but it is more strongly correlated with visceral than subcutaneous adipose tissue⁸ and is also a well established predictor of cardiovascular disease risk and metabolic disturbances.⁹

Despite its recognized utility, there is no consensus on the best anatomical location for measurement and several locations can be identified.¹⁰⁻¹⁹ Measurement site influences the magnitude of waist circumference and the prevalence of abdominal obesity²⁰ according to the recommended thresholds established by the World Health Organization, > 88 cm for women and > 102 cm for men, for defining type 2 diabetes, hypertension and cardiovascular disease risk.²¹ Moreover, these thresholds may not have the same clinical utility at all anatomical locations of waist circumference measurement.²² Thus, an exploratory study was developed to examine which anatomical location best explains abdominal fat mass measured by DXA in older adults.

Methods

Subjects and design

An exploratory cross-sectional study was conducted, between November 2009 and June 2010, comparing the association between waist circumference measurements and DXA abdominal fat mass as reference among older adults.

The sample comprised of 51 caucasian individuals, aged between 60 and 84 years old, engaged in an exercise program at the Research Centre in Physical Activity, Health and Leisure of the Faculty of Sports, University of Porto. The study was conducted according to the guidelines laid down in the Declaration of Helsinki.²³ All the participants were informed of the study purposes as well as the different procedures. Verbal informed consent from all the subjects was witnessed and formally recorded.

Data collection

Height (m) was measured with the individuals barefooted, using a stadiometer (Seca 708®; Seca Limited, Birmingham, UK), with a resolution of 0.001 m.²⁴ Body mass (kg) was measured by a scale (Seca®), resolution of 0.1 kg, with the individuals barefooted and wearing light clothes.²⁴ Body mass index (BMI) was calculated using the standard formula [mass (kg)/height² (m)].

Ten different sites for measuring waist circumference are described in the literature (table I)¹⁰⁻¹⁹. For some of those sites more than one reference was found and so the reference with the more complete procedure was chosen. The circumference at the trunk bending point²⁵ was also identified but not used due to the difficulty of the technician in finding this anatomical landmark within this sample of older adults.

Waist circumference was measured in the ten different anatomical locations (table I) by the same trained technician with a Rosscraft® tape, at the end of a normal expiration.

Total and abdominal body fat were evaluated in a three-compartment model with a DXA equipment (Hologic QDR-4500®). Body composition was estimated by QDR Software for Windows XP, version 12.4 (from Hologic, Inc., Bedford, MA, USA). All scans were performed by the same trained technician using standard procedures as described in the Hologic Users Manual. Complete body DXA scans were made with scan time of approximately 8 minutes. The percentage body fat (%BF) determined by the system represents [fat mass (g)/total mass (g) x 100]. After analysis of the whole body scan, to define abdominal region and to determine abdominal fat mass, a quadrilateral box was manually drawn by the same technician around the first (L1) and the fourth (L4) lumbar vertebrae region bounded inferiorly by the horizontal line

Table I
Ten different anatomical locations for waist circumference (WC) measurement described in the literature

Designation	Description	Reference
WC ₁	Narrowest point between the iliac crest and the lower rib margin	10
WC ₂	Midway between the lower rib margin and the iliac crest	11
WC ₃	Narrowest point between the umbilicus and the xiphoid process	12
WC ₄	One-third of the distance between the xiphoid process and the umbilicus	13
WC ₅	Midway between the xiphoid process and the umbilicus	14
WC ₆	Widest diameter between the xiphoid process and the iliac crest	15
WC ₇	At the level of the iliac crest	16
WC ₈	At the level of the umbilicus	17
WC ₉	2.5 cm above the umbilicus	18
WC ₁₀	At the lower border of the 10 th rib	19

identifying the L4/L5 vertebral space and superiorly by the horizontal line identifying the 12th thoracic vertebra/L1 vertebral space.⁶

Data analysis

The normal distribution of the variables was tested using the Kolmogorov-Smirnov test. Means and standard deviations were calculated for the quantitative and continua variables and frequencies were calculated to describe categorical variables. The mean values of %BF determined by DXA were compared with Coin et al.²⁶ reference values, according to the gender and age. As all quantitative and continua variables followed a normal distribution, the choice of which waist circumference measurement (independent variables) best explained abdominal fat mass (dependent variable) was evaluated with DXA using a linear regression model. The adopted level of statistical significance was $p < 0.05$. All the statistical analyses were carried out using the Software Package for Social Sciences for Windows, version 14.0 (SPSS, Inc., Chicago, IL, USA) and Microsoft Excel, version 2007 (Microsoft, Redmond, WA).

Results

Descriptive statistics of the sample are presented in table II. Although mean BMI for women and men was in the overweight category, and 23 individuals (45.1%) were overweight and 17 (33.3%) were obese, the mean %BF determined by DXA was within the tabled normal body fat reference values for both genders.²⁶ In fact, regarding individual %BF values, all women and 14 men (70%) were in the normal %BF range, while 5 men (25%) were below and one man (5%) was above the %BF normal range.

Women presented a higher %BF ($p < 0.001$) and a higher % abdominal fat ($p = 0.044$) than men. However, men presented higher waist circumferences

Table II
Characteristics of the sample

Variable	Women (n = 31)		Men (n = 20)	
	Mean	SD	Mean	SD
Age (years)	69.4	5.9	68.6	5.1
Mass (kg)	63.8	9.0	79.8	10.1
Height (cm)	152.1	5.1	166.5	4.1
BMI (kg/m ²)	27.6	3.7	28.8	3.5
DXA BF (%)	38.0	5.4	26.4	5.2
DXA abdominal BF (%)	35.1	7.8	30.3	8.4
DXA abdominal BF (g)	2,867.6	981.6	3,249.4	1,374.4
Waist circumference (cm)				
WC ₁	83.6	10.2	97.4	9.8
WC ₂	85.6	10.0	98.0	10.0
WC ₃	81.9	8.7	95.7	8.2
WC ₄	86.8	10.7	99.5	11.1
WC ₅	83.9	9.2	98.5	10.0
WC ₆	88.6	10.0	101.5	10.4
WC ₇	90.0	9.6	99.9	9.9
WC ₈	91.5	11.2	99.3	9.1
WC ₉	89.6	11.6	99.6	10.0
WC ₁₀	82.3	8.3	97.4	8.3

BMI: Body mass index; DXA: Dual-energy X-ray absorptiometry; BF: Body fat; SD: Standard deviation.

($p < 0.012$) than women. No differences were found between genders for abdominal fat mass ($p = 0.289$).

As expected, measurement at different anatomical locations rendered different waist circumference values. Mean varied from 81.9 (standard deviation (SD): 8.7) cm and 91.5 (SD: 11.2) cm for women and between 95.7 (SD: 8.2) cm and 101.5 (SD: 10.4) cm for men, according to the anatomical location (table II). In fact, the proportion of older adults in the high disease risk category defined by waist circumference thresholds, > 88 cm for women and > 102 cm for men,²¹ varied with the measurement site as well (fig. 1). Waist circumference measurement 2.5 cm above the umbilicus¹⁸ identified 61% of women in the high disease risk. On the contrary, measurement in the

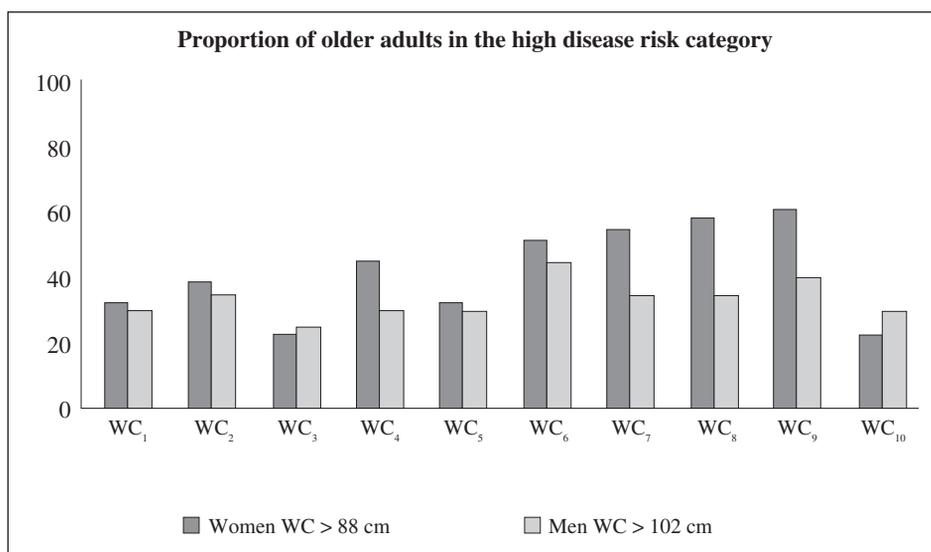


Fig. 1.—Proportion of older adults in the high disease risk category defined by waist circumference (WC) thresholds (> 88 cm for women and > 102 cm for men) according to the different anatomical locations for measurement.

Table III
Coefficients of determination (R^2) of the linear regression model for the relation between dual-energy X-ray absorptiometry (DXA) abdominal fat mass (g) and waist circumference measurement (WC) (cm)

Waist circumference*	Total (n = 51)	Women (n = 31)	Men (n = 20)
WC ₁	0.631	0.752	0.791
WC ₂	0.657	0.770	0.763
WC ₃	0.574	0.783	0.727
WC ₄	0.657	0.771	0.721
WC ₅	0.597	0.779	0.718
WC ₆	0.648	0.758	0.757
WC ₇	0.683	0.734	0.766
WC ₈	0.667	0.677	0.793
WC ₉	0.698	0.776	0.770
WC ₁₀	0.545	0.813	0.714

* $p < 0.001$ (for all R^2).

narrowest point between the umbilicus and the xiphoid process¹² and at the lower border of the 10th rib¹⁹ identified only 23% of women in the high category risk. Measurement at the widest diameter between the xiphoid process and the iliac crest¹⁵ identified 45% of men in the high category risk while measurement at the narrowest point between the umbilicus and the xiphoid process¹² identified only 25% of them in the high category risk (fig. 1).

The coefficients of determination (R^2) of the linear regression model for the relation between abdominal fat mass (g) and the different waist circumference measurement (cm) are presented in table III and in figure 2. The R^2 were all statistically significant ($p < 0.001$) and varied from 0.545 to 0.698 for the total sample. The non-standardised coefficients (NSC) and the standardised coefficients (SC) for this linear regression model are presented in table IV. The NSC varied from 75.13 to 88.37 and the SC varied from 0.738 and

0.836 and they were all statistically significant ($p < 0.001$). The anatomical landmark situated 2.5 cm above the umbilicus¹⁸ was the waist circumference measurement that associated best with abdominal fat mass measured by DXA, explaining the variance of 69.8% and presenting a SC equal to 0.836. However, measurement at the level of the iliac crest¹⁶ and at the level of the umbilicus¹⁷ gave very close results. Otherwise, measurement of waist circumference at the lower border of the 10th rib¹⁹ was the one that associated worst with abdominal fat mass (tables III and IV, fig. 2).

In order to understand if the preferable measurement site was different for women and men, we stratified the sample by gender. The R^2 and the SC increased as the dispersion of the data decreased, also suggesting that ideal measurement site varies with gender. Measurement of waist circumference at the lower border of the 10th rib¹⁹ was the anatomical location that associated best with abdominal fat mass for women and that asso-

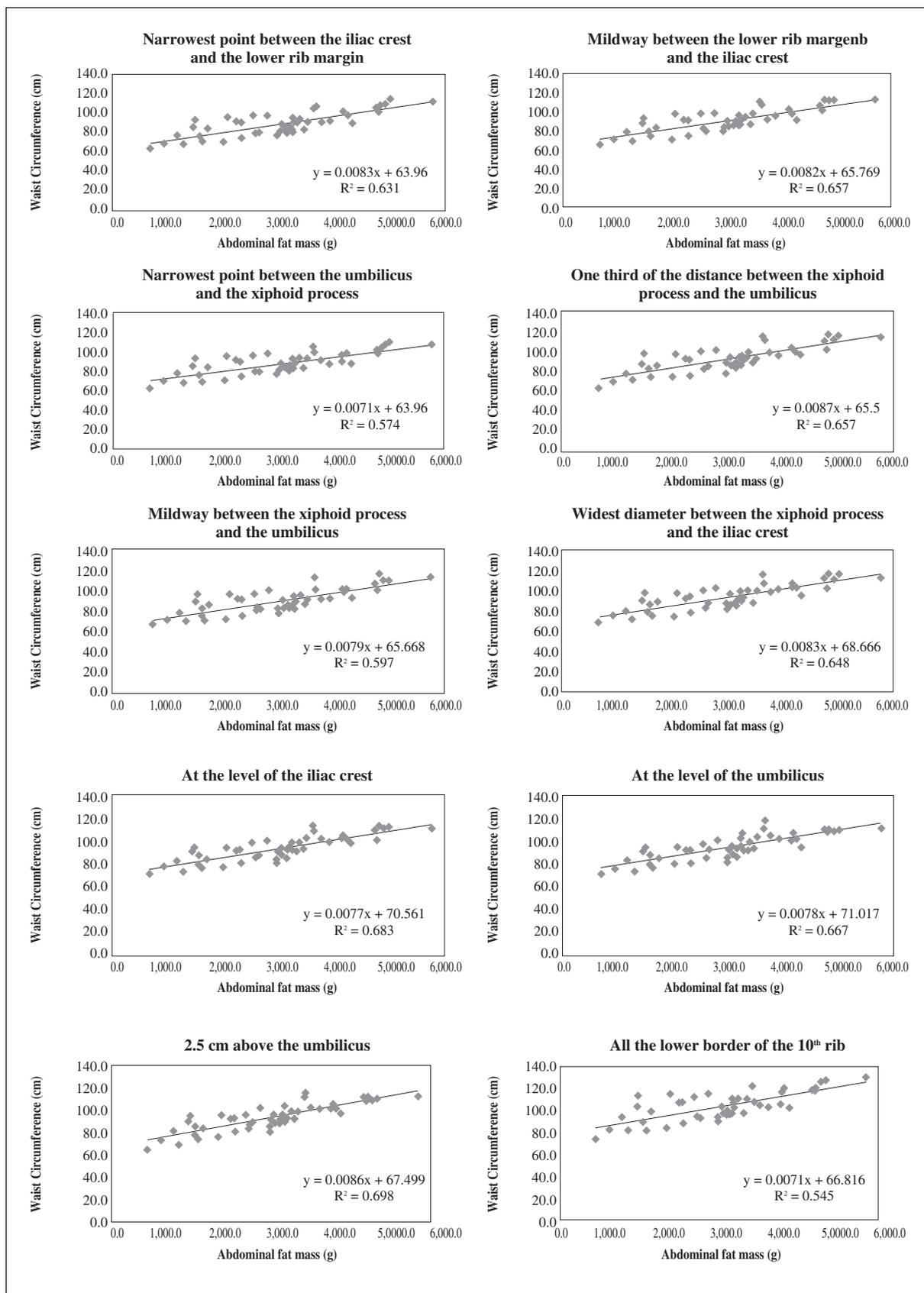


Fig. 2.—Scatter plots displaying the association between dual-energy X-ray absorptiometry (DXA) abdominal fat mass (g) and waist circumference measurement (cm).

Table IV
Non-standardised coefficientys (NSC) and standardised coefficients (SC) of the linear regression model for the relation between dual-energy X-ray absorptiometry (DXA) abdominal fat mass (g) and waist circumference measurement (WC) (cm)

Waist circumference*	Total (n = 51)		Women (n = 31)		Men (n = 20)	
	NSC	SC	NSC	SC	NSC	SC
WC ₁	75.92	0.794	83.47	0.867	124.16	0.889
WC ₂	80.26	0.811	85.97	0.878	119.89	0.874
WC ₃	80.66	0.758	99.43	0.885	143.12	0.852
WC ₄	75.43	0.810	80.73	0.878	105.62	0.849
WC ₅	75.13	0.773	94.01	0.883	116.20	0.847
WC ₆	78.23	0.805	85.73	0.871	115.23	0.870
WC ₇	88.37	0.826	87.35	0.857	121.87	0.875
WC ₈	85.66	0.817	72.39	0.823	134.47	0.891
WC ₉	80.96	0.836	74.81	0.881	121.16	0.878
WC ₁₀	76.82	0.738	107.16	0.902	140.53	0.845

*p < 0.001 (for all NSC and SC).

ciated worst for men. Measurement at the level of the umbilicus¹⁷ was the circumference that associated worst with abdominal fat for women and measurement in the narrowest point between the iliac crest and the lower rib margin¹⁰ was the circumference that associated best with abdominal fat for men (tables III and IV).

Discussion

Waist circumference is a widely-used surrogate marker of visceral adiposity and a well established predictor of the risk of cardiovascular disease and metabolic disturbances.⁹ However, at least ten different anatomical locations to perform this measurement are described in the literature.¹⁰⁻¹⁹ We therefore evaluated these ten waist circumference measurements in order to ascertain which best explained abdominal fat mass, using an exploratory study.

DXA abdominal region, defined as the L1-L4 region compared with computerized tomography proved to be both reliable and accurate method to determine abdominal obesity.⁶ Our results showed that the waist circumference values obtained from the several anatomical locations differed in a substantial way, and therefore, influenced the proportion of individuals in the established category of risk for abdominal obesity. The anatomical landmark situated 2.5 cm above the umbilicus¹⁸ was the one that associated best with abdominal fat mass in this sample of older adults, thus explaining the variance of 69.8% and showing the highest standardised coefficient.

Despite the higher %BF and higher % abdominal fat in women, men had higher waist circumferences and there was no difference in abdominal fat mass between genders. However, the linear regression revealed that the preferable anatomical location for measuring waist circumference was not the same for women and men.

Although small, this sample size allowed the identification of significant associations. This study contributes to the recognition that the anatomical location where the measurement is taken gives considerably different results therefore emphasizing the need to standardize the procedure. To our knowledge, this is the first study to compare all these different anatomical locations for waist circumference measurement described in the literature and to determine which associated best with abdominal fat mass. However, in two previous studies, Mason and Katzmarzyk discussed the importance of the measurement site. The authors measured waist circumference at the superior border of the iliac crest, midpoint between the iliac crest and the lowest rib, umbilicus, and minimal waist, in community-dwelling adults aged 20-67 years.^{20,22} In 542 individuals, they verified that waist circumference measurements made at all anatomic sites were highly correlated with each other ($r > 0.948$, $p < 0.0001$). In women, the mean waist circumference for all sites were significantly different from each other ($p < 0.008$), with the exception of the iliac crest and midpoint between the iliac crest and the lowest rib. In contrast, no significant differences between sites were found in men. Measurement site had an influence on the prevalence of abdominal obesity (> 88/102 cm), ranging from 23 to 34% in men and from 31 to 55% in women.²⁰ Our results are in accordance with this finding. The authors also calculated the sensitivity and specificity of waist circumference thresholds for detecting individuals with risk factor clustering (≥ 2 risk factors) for each waist circumference measurement site in 520 adults. Waist circumference > 88 cm for women and > 102 cm for men at the umbilicus showed the greatest sensitivity for all outcomes, whereas measurements at the minimal waist had the best specificity. The sensitivity of waist circumference > 88 cm or > 102 cm for detecting ≥ 2 risk factors ranged from 75 to 89% in women and from

48 to 59% in men, and specificity ranged from 52 to 79% in women and from 77 to 88% in men, across measurement sites. Therefore the authors concluded that recommended waist circumference thresholds may not have the same clinical utility at all anatomical locations of waist circumference measurement.²² Our results are in agreement with this finding as well.

Several studies reported high and significant correlations between abdominal fat quantified with DXA and waist circumference measured midway between the lower rib margin and the iliac crest in individuals aged 14-65 years (r : 0.65-0.96, $p < 0.001$)²⁷⁻²⁹ and a good agreement between DXA measures of fatness and waist circumference in adults aged 50-79 years.³⁰ Although we used DXA as the reference method, we are aware of its limitations. In a study conducted in 152 healthy adults, %BF determined by DXA was significantly lower compared with the criterion four compartment model approach.³¹ Also, DXA and waist circumferences have inherent methodological characteristics and differences that may have influenced the results. Waist circumference measurement is taken at the end of a normal expiration while DXA scans take approximately 8 minutes and evidently during this period individuals inhale and exhale. Moreover, individuals are lying down during the DXA scans and waist circumference is measured with the individuals standing. The effect of gravity may then account for the differences between methods as well.

The lack of a random sample selection can be recognized as a study limitation. Our sample was composed of moderately active caucasian older adults who exercised at least 50 minutes for two days a week, therefore, results are not transposable to other age and ethnic groups. Furthermore, the age span of participants is wide. Further studies should include larger samples that would allow presenting its results according different age strata, ≤ 70 and > 70 years old individuals and also including other age and ethnical groups. Finally, the association of waist circumference measurement with abdominal visceral fat measured by magnetic resonance imaging or computerized tomography scans would allow a better recognition of the clinical risk.

Further research should explore which waist circumference measurement associates best with the clinical risk of abdominal adiposity, as cardiometabolic risk factors like glycaemia, blood pressure, LDL and HDL cholesterol or triacilglycerols were not analysed. Also, it remains unknown if the recommended waist circumference thresholds are suitable for defining type 2 diabetes, hypertension and cardiovascular disease risk for each one of waist circumference anatomical locations used.

Conclusion

Waist circumference measurement 2.5 cm above the umbilicus¹⁸ was the best surrogate measure of abdominal

fat in this older individual's sample. The measurement at the level of the iliac crest¹⁶ and at the level of the umbilicus¹⁷ gave very close results, and therefore the possibility that these two measurements could also be recommended for measuring waist circumference in older adults should be considered. This is an exploratory study which contributes to the recognition that the anatomical location where the waist circumference measurement is taken gives considerably different results and therefore highlights the importance to standardize the procedure.

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