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Degree of association between the body mass index (BMI), waist-hip ratio (WHR), waist-height ratio (WHtR), body adiposity index (BAI) and conicity index (CI) in physically active older adults

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SUMMARY

Background: Aging is the main factor in the eventual development of cardiovascular disease (CVD) the prevalence of which is increasing progressively along with life expectancy. Therefore, it is essential to identify the most effective indicators for predicting the possible development of CVD. Anthropometric indices provide useful information for CVD risk evaluation. These are widely used for the simplicity of their estimates and their high correlation in the positive identification of CVD. The most used in the general population are the body mass index (BMI), the waist to hip ratio (WHR) and waist to height ratio (WHtR), body adiposity index (BAI) and conicity index (CI). However, the behavior and association of such indices in physically active people over 65 years of age is not well established.
Purpose: To analyze the behavior and association of the BMI, WHR, WHtR, BAI and CI in a group of active people over 65 years of age.
Methods: A group of 608 European participants with a mean age of 68.05 ± 5.43yrs, composed of 74.2% female and 28.5% male, was randomly selected and evaluated for anthropometric parameters and body composition by a bio-impedance measuring device with four electrode sensor systems. A descriptive analysis was completed via measures of central tendency (mean and standard deviation) and percentage analysis. As the distribution of the sample was normal (parametric), an association analysis was carried out through the Pearson correlation coefficient (r), in order to determine the relationship between anthropometric and body composition indices. A P value of <0.05 was considered to indicate statistical significance.
Results: The results show that BMI, BAI and WHtR are significantly related to % body fat (Fat %), with BMI reaching the highest correlation ($r = 0.612$), followed by BAI ($r = 0.556$) and WHtR ($r = 0.521$). When the association between indices is considered, the WHtR and BAI and WHtR and BMI are those with the highest significant correlation ($r = 0.981$ and $r = 0{,}789$, respectively). As for the effects of gender, good to strong correlations were found between the BMI and the WHtR ($r = 0.731$ for female, $r = 0.568$ for male) and between the WHtR and the BAI ($r = 0.989$ for female, $r = 0.985$ for male).
Conclusion: The most accurate anthropometric index for indicating the level of body fat present in an active population of 65 years of age or over seems to be the BMI, followed by the BAI and WHtR. However, the degree of association between body fat and anthropometric parameters seems to be conditioned by gender.

1. Introduction

Currently, the aging population is a social phenomenon with one of the greatest impacts so far this century. The world is

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undergoing a demographic transformation, with the number of people over 60 years of age expected to increase from 600 million to almost 2 billion by 2050, from 10% to 21% [1]. There are numerous definitions of aging [2–4] which label it, amongst other things, as a complex, dynamic, multi-factorial process inherent to all human beings. Aging is the main factor in the occurrence of cardiovascular disease (CVD), the prevalence of which is progressively rising due in large part to the increase in life expectancy worldwide. CVD is one of the main causes of mortality and morbidity, and is the most frequent reason for hospitalization; it is also the third leading cause of death and the main cause of disability in the adult population around the world [5]. CVD is generally related to the excessive accumulation of body fat, the presence of which can be assessed through anthropometric measurements and/or body composition analysis [6,7].

The prevalence of obesity in the world today has reached epidemic proportions [8] and this is a major problem since excess adiposity is strongly associated with CVD risk factors such as hypertension, diabetes mellitus, and dyslipidemia [9,10] Early detection and the identification of groups at risk is key in the fight to reduce the consequences of these health problems. In this context, therefore, adiposity must be measured, and it is essential to establish the anthropometric indices that allow us to detect with greater accuracy the possible development of CVD, with the aim of reducing its incidence. Anthropometric indices are values of body dimension and composition, commonly used for the nutritional diagnosis of an individual, though they also offer useful information for the evaluation of the risk of CVD [11] due to the existence and distribution of excess fat. The ease of calculation of these indices, and their high correlation in the identification of CVD has generalized their use in this area.

Currently the most widely used anthropometric indices in the general population are the body mass index (BMI), the waist to hip ratio (WHR) and waist to height ratio (WHR), body adiposity index (BAI) and conicity index (CI).

The BMI is a widely used parameter in obesity assessment, and is used by the WHO as a simple and practical epidemiological measure to identify overweight or obese people in different populations and of different ages [12]. The WHR is an important anthropometric index in the assessment of cardiovascular and endocrine risks in young populations [13]. The WHtR is a parameter that reflects the distribution of body fat and analyses the presence of abdominal fat in relation to other parts of the body. It is used as a predictor of obesity-related CVD. Higher values of WHtR indicate an increased risk of CVD [14]. In 2011, the BAI was proposed [15]. This is an index based on hip circumference and height, and was developed with a view to providing an estimate of the percentage (%) of body adiposity. Last but not least is the CI, which indicates adiposity in relation to height, weight and waist circumference [16].

Issues around obesity are more closely related to visceral adiposity than to general adiposity [9]. The BMI is currently the most widely used measure of obesity. However, the BMI is unable to differentiate between lean mass and fat mass, and hence it is limited by differences in body adiposity for a given BMI across age, gender and ethnicity [17,18]. In addition, the BMI does not consider body fat distribution, which is a major limitation as there are suggestions that the metabolism is affected by this [18].

The waist circumference (WC) has been proposed as the most accurate of the anthropometric measurements, with an excellent correlation between abdominal imaging and a high association with CVD risk factors, mainly diabetes [9,19,20]. WC does not take height differences into account, however, so the risk of potential over or under-evaluation for tall and short individuals must be considered [21]. Research proposed the WHtR as a valid alternative to WC. In fact, this ratio has shown to be a good indicator of abdominal adiposity [22] and a better predictor of CVD risk factors [21,23–25].

All of the above indices are strongly related to body adiposity, despite being different concepts [26,27]. Therefore, determining which index is the most suitable as a predictor of CVD risk factor in older adults remains controversial despite years of research. Therefore, since there is currently no consensus on which is the best anthropometric indicator for measuring adiposity, the aim of this study is to analyze the behavior and degree of association of BMI, WHR, WHtR, BAI and CI with body fat in a group of active people over 65 years of age.

2. Methods

2.1. Participants

This was a retrospective study based on existing data, which were provided from a health screening conducted in 2021 and 2022. 608 European older adults [86 Portuguese (men = 47.3%; women = 52.7%), 78 Bulgarians (men = 11.8%; women = 88.2%), 122 Italians (men = 25.6%; women = 74.4%),25 Slovenians (men = 18.9%; women = 81.1%), 94 Hungarians (men = 23.3%; women = 76.7%), and 122 Spanish (men = 23.5%; women = 76.5%)] with a mean age of 68.05 ± 5.43; 74.2% being women, who were enrolled in the In Common Sport Plus project, participated in these research. All the subjects were evaluated four times during a two-year period, obtaining a total of 2432 evaluations of cineanthropometric parameters and body composition. Incomplete data were excluded (n = 222), resulting in a final sample of 2210 assessments. Because no new data was collected, there was no informed consent process for this study. Data was collected and analyzed in such a way that subjects cannot be identified, directly or through subject-linked identifiers. In this study, the ethical standards contained in the Declaration of Helsinki were followed, and this study was approved by the Ethics Committee of the Polytechnic Institute of Viana do Castelo (IPVC-ESDL180417).

2.2. Health screening measurements

The examiners were experts in measuring anthropometric indices and body composition parameters using bioelectrical impedance (BIA). During the measurements, participants stood barefoot, wore minimal clothing along with strictly standardized conditions as set by the manufacture and previous research. BIA was performed with a multi-frequency segmented body mass composition analyzer (TANITA MC-780 S MA). The analysis of all body mass composition components took approximately 20s and also measure body mass with a precision of 0.1 kg. In the present research, the percent of fat was considered the gold standard as such measurement comes directly from BIA. Age, sex, and height without a decimal number were considered into the analyzer. Height was measured with the subject standing using a portable stadiometer (SECA, 213) accurate to within 1 mm. Waist and hip circumference were measured with a inextensible tape measure [28]. Waist circumference (WC) was measured midway between the lowest rib and the pelvis in position of expiration and hip circumference (HC) was measured at the widest circumference of the hip.

The different anthropometric measures were calculated: body mass index (BMI = weight in kg divided by the square of height in meters) [29] waist-hip ratio (WHR=WC in cm divided by HC in cm) [30], waist-height ratio (WHtR =WC in cm divided by height in cm) [31], body adiposity index (BAI = HC in cm/{[height in m]$^{1.5}$-18}) [15] and conicity index (CI=WC in m/[0.109 X $\sqrt{}$ {Bodyweight in kg/Height in m}]) where 0.109 is a constant that results from the conversion of units of volume and mass into units of length [32].

2.3. Statistical analysis

In this study, descriptive statistics were used to obtain the metrics of central tendency, deviation, and percentages. The descriptive analysis was carried out globally and the sample was separated by gender and country. Continuous variables were tested for normality using the Kolmogorov–Smirnov test. The relationship between the different anthropometrics indices was examined using Pearson's correlation analysis, based on Taylor correlation levels [33] - weak correlation ($r \leq 0.35$), moderate correlation ($0.35 < r \leq 0.68$) and strong correlation ($0.68 < r \geq 1.0$). To predict continuous outcomes, linear regression analysis (method: enter) were performed to investigate the association between physical activity level (dependent variable) and independent variables (anthropometric indices, body composition and age). All statistical analyses were performed using SPSS version 25 (SPSS Inc., Chicago, IL, USA). P value was set at <0.05.

3. Results

The basic characteristics of the study population, divided into country of residence, are shown in Table 1. 608 participants were analyzed four times over two years, resulting in a total of 2210 complete evaluations, with women being in the majority in all countries (74.2%). The mean age of the study population was 68.05 ± 5.43 years, with Spain being the country with longest lived participants (70.45 ± 6.30 years). Spain is also the country where the study group do more physical exercise per week on average (5.27 ± 1.91 days per week) than participants from other countries, who average only 2.81–3.85 days per week. A high percentage of the total sample (74.2%) reported a lower educational level (non-university). Spain has the highest percentage (97.2%) of non-university students while Hungary has the highest percentage of people who have studied for a Masters or a PhD (19.3%).

Regarding the anthropometric variables, Spain's participants have the smallest Height (155.17 ± 6.62 cm) while Slovenia's have the greatest (164.87 ± 7.85 cm). In turn, Slovenia's subjects have higher Weight (78.37 ± 14.50 kg) than other countries, while Italy's have the lowest (70.62 ± 13.23 kg).

As regards Fat (%), WC (cm) and HC (cm), Bulgaria presents the highest percentages and data (37.84%), (97.30 ± 11.55 cm) and (113.12 ± 10.39 cm) respectively, whereas Italy is the country with the lowest Fat % (29.62%) and WC (90.93 ± 12.42 cm). Bulgaria's participants also present the highest BMI (30.38 ± 5.13kg/m2) and Italy's the lowest (26.56 ± 4.14kg/m2). The mean BMI (kg/m^2) of the total sample is 28.21 ± 4.48 kg/m^2. With respect to the anthropometric indices of WHR, WHtR, BAI and CI we should indicate that Spain presents the highest data (0.99 ± 0.72), (0.62 ± 0.09), (31.67%) and (1.30 ± 0.15) respectively, while Italy has the lowest data of WHtR (0.56 ± 0.07), BAI (25.88%) and CI (1.27 ± 0.11). However, for WHR, Bulgaria is the country with the lowest metrics in this data group. (0.86 ± 0.07).

The Pearson's correlation coefficients between the various anthropometric measures, disaggregated by gender, are shown in Table 2. All the anthropometric measures correlated significantly with each other, with men having the lowest correlation coefficients, except in the case of BMI (kg/m2) with WHR, WHtR, BAI and CI.

When analyzing the total sample, we observed that the Fat % parameter has a moderate correlation with the BMI parameter ($r = 0.612$; $p < 0.001$), WHtR ($r = 0.521$; $p < 0.001$), BAI ($r = 0.556$; $p < 0.001$), presenting a significantly weak correlation with WHR ($r = -0.156$; $p < 0.001$) and CI ($r = 0.144$; $p < 0.001$). If we stratify the analysis according to the sex of the participants, the results show that the Fat % parameter for men (Fig. 1) has a moderate correlation with the BMI parameter ($r = 0.617$; $p < 0.001$), WHtR ($r = 0.526$; $p < 0.001$) and BAI ($r = 0.497$; $p < 0.001$), presenting a significant and weak correlation with the parameters WHR ($r = -0.084$; $p < 0.001$) and CI ($r = 0.272$; $p < 0.001$). The results for women show that while the Fat % parameter (Fig. 1) presents a strong correlation with the BMI parameter ($r = 0.734$; $p < 0.001$), and a moderate correlation with the WHtR ($r = 0.647$; $p < 0.001$) and BAI ($r = 0.613$; $p < 0.001$) parameters, it presents a significantly weak correlation with the WHR ($r = -0.174$; $p < 0.001$) and CI ($r = 0.354$; $p < 0.001$) parameters, however.

The results also identified other significant relationships: The WHtR parameter showed a significant and strong correlation with BAI ($r = 0.981$; $p < 0.001$) and also with CI ($r = 0.744$; $p < 0.001$).

Table 1
Characteristics of study subjects.

	Total n = 2210	Spain n = 436	Portugal n = 315	Slovenia n = 401	Bulgaria n = 299	Hungary n = 350	Italy n = 409
	Mean ± SD/%	Mean ± SD/%	Mean ± SD/%	Mean ± SD/%	Mean ± SD/%	Mean ± SD/%	Mean ± SD/%
Age (years)	68.05 ± 5.43	70.45 ± 6.32	68.85 ± 5.36	68.11 ± 6.75	69.23 ± 4.48	67.09 ± 4.59	66.38 ± 4.65
Days/week do you physical exercise?	3.44 ± 1.78	5.27 ± 1.91	3.85 ± 1.69	3.69 ± 1.85	2.81 ± 1.79	2.95 ± 1.31	2.98 ± 1.33
Gender (female)	74.2 %	76.5 %	52.7 %	81.1 %	88.2 %	76.7 %	74.4 %
Educacional level							
No university	79.5 %	97.2 %	80.3 %	81.7 %	83.1 %	54.6 %	83.6 %
Degree/Bacherol	15.9 %	2.8 %	18.2 %	15.6 %	12.1 %	26.1 %	15.4 %
Master/PhD.	4.6 %	0.0 %	1.5 %	2.8 %	4.8 %	19.3 %	0.9 %
Anthropometric indices							
Height	160.97 ± 8.55	155.17 ± 6.62	161.67 ± 9.38	164.87 ± 7.85	159.42 ± 7.15	163.40 ± 7.76	162.81 ± 8.64
Weight (kg)	72.96 ± 12.92	71.22 ± 11.85	71.96 ± 12.03	78.37 ± 14.50	75.85 ± 11.39	74.50 ± 14.23	70.62 ± 13.23
Fat %	33.18 ± 8.14	33.21 ± 6.87	31.11 ± 8.47	32.15 ± 8.89	37.84 ± 6.63	36.49 ± 7.12	29.62 ± 7.64
BMI (kg/m^2)	28.21 ± 4.48	29.43 ± 3.79	27.51 ± 3.89	28.73 ± 4.58	30.38 ± 5.13	27.71 ± 3.90	26.56 ± 4.14
WC (cm)	94.25 ± 12.34	96.07 ± 13.13	93.51 ± 11.78	96.80 ± 11.79	97.30 ± 11.55	94.33 ± 11.68	90.93 ± 12.42
HC (cm)	106.01 ± 17.34	104.21 ± 12.08	102.31 ± 7.69	106.78 ± 10.62	113.12 ± 10.39	106.64 ± 9.94	103.92 ± 28.03
WHR	0.92 ± 0.31	0.99 ± 0.72	0.98 ± 0.14	0.91 ± 0.09	0.86 ± 0.07	0.89 ± 0.08	0.89 ± 0.12
WHtR	0.59 ± 0.08	0.62 ± 0.09	0.58 ± 0.07	0.59 ± 0.07	0.61 ± 0.08	0.58 ± 0.07	0.56 ± 0.07
BAI (%)	28.28 ± 6.75	31.67 ± 7.51	27.64 ± 6.30	27.72 ± 5.64	30.53 ± 6.77	27.26 ± 5.81	25.88 ± 6.00
CI	1.29 ± 0.11	1.30 ± 0.15	1.29 ± 0.11	1.29 ± 0.09	1.30 ± 0.10	1.29 ± 0.11	1.27 ± 0.11

Abbreviations: BAI, body adiposity index; BMI, body max index; CI, conicity index; Fat%, body fat percentage; HC, hip circumference; WC, waist circumference; WHtR, waist to height ratio; WHR, the waist to hip ratio.

Table 2
Pearson Correlation Coefficient between different anthropometric indices and Physical Activity level.

		Fat %	BMI (kg/m^2)	WHR	WHtR	BAI (%)	CI	PA Level (Days/week)
Overall (n = 2221)								
Fat %	Pearson Coefficient (r)	-	0.612**	−0.156**	0.521**	0.556**	0.144**	−0.179**
	Sig.	-	0.001	0.001	0.001	0.001	0.001	0.001
BMI (kg/m2)	Pearson Coefficient (r)	0.612**	-	0.171*	0.789**	0.770**	0.295**	−0.093*
	Sig.	0.001	-	0.001	0.001	0.001	0.001	0.013
WHR	Pearson Coefficient (r)	−0.156**	0.171**	-	0.512**	0.359**	0.606**	0.067
	Sig.	0.001	0.001	-	0.001	0.001	0.001	0.072
WHtR	Correlation coefficient (r)	0.521**	0.789**	0.426**	-	0.981**	0.744**	−0.083*
	Sig.	0.001	0.001	0.001	-	0.001	0.001	0.026
BAI (%)	Correlation coefficient (r)	0.556**	0.770	0.359**	0.981**	-	0.673**	−0.082*
	Sig.	0.001	0.001	0.001	0.001	-	0.001	0–029
CI	Correlation coefficient (r)	0.144**	0.295**	0.606**	0.744**	0.673**	-	−0.034*
	Sig.	0.001	0.001	0.001	0.001	0.001	-	0.370
PA Level (Days/week)	Correlation coefficient (r)	−0.179**	−0.093*	−0.067*	−0.083*	−0.082*	−0.034*	-
	Sig.	0.001	0.013	0.042	0.026	0–029	0.370	-
Male (n = 578)								
Fat %	Pearson Coefficient (r)	-	0.617**	0.084*	0.526**	0.497**	0.272**	−0.189*
	Sig.	-	0.001	0.033	0.001	0.001	0.001	0.012
BMI (kg/m^2)	Pearson Coefficient (r)	0.617**	-	0.298**	0.815**	0.786**	0.358**	−0,035
	Sig.	0.001	-	0.001	0.001	0.001	0.001	0.646
WHR	Pearson Coefficient (r)	0.084*	0.298**	-	0.487**	0.467**	0.493**	−0.020
	Sig.	0.033	0.001	-	0.001	0.001	0.001	0.791
WHtR	Pearson Coefficient (r)	0.526**	0.815**	0.487**	-	0.985**	0.770**	−0.046
	Sig.	0.001	0.001	0.001	-	0.001	0.001	0.541
BAI (%)	Pearson Coefficient (r)	0.497**	0.786**	0.467**	0.985**	-	0.727**	−0.027
	Sig.	0.001	0.001	0.001	0.001	-	0.001	0.722
CI	Pearson Coefficient (r)	0.272**	0.358**	0.493**	0.770**	0.727**	-	−0.070
	Sig.	0.001	0.001	0.001	0.001	0.001	-	−0.352
PA Level (Days/week)	Pearson Coefficient (r)	−0.189*	−0,035	−0.020	−0.046	−0.027	−0.070	-
	Sig.	0.012	0.646	0.791	0.541	0.722	−0.352	-
Female (n = 1643)								
Fat %	Pearson Coefficient (r)	-	0.734**	0.174**	0.647**	0.613**	0.354**	−0.153**
	Sig.	-	0.001	0.001	0.001	0.001	0.001	0.001
BMI (kg/m^2)	Pearson Coefficient (r)	0.734**	-	0.214**	0.784**	0.768**	0.313**	−0.101*
	Sig.	0.001	-	0.001	0.001	0.001	0.001	0.020
WHR	Pearson Coefficient (r)	.174**	0.214**	-	0.524**	0.514**	0.635**	0.033
	Sig.	0.001	0.001	-	0.001	0.001	0.001	0.453
WHtR	Pearson Coefficient (r)	0.647**	0.784**	0.524**	-	0.989**	0.774**	−0.084*
	Sig.	0.001	0.001	0.001	-	0.001	0.001	0.044
BAI (%)	Pearson Coefficient (r)	0.613**	0.768**	0.514**	0.989**	-	0.736**	−0.075*
	Sig.	0.001	0.001	0.001	0.001	-	0.001	0.044
CI	Pearson Coefficient (r)	0.354**	0.313**	0.635**	0.774**	0.736**	-	−0.043
	Sig.	0.001	0.001	0.001	0.001	0.001	-	0.318
PA Level (Days/week)	Pearson Coefficient (r)	−0.153**	−0.101*	0.033	−0.084*	−0.075*	−0.043	-
	Sig.	0.001	0.020	0.453	0.044	0.044	0.318	-

Abbreviations: BAI, body adiposity index; BMI, body max index; CI, conicity index; Fat%, body fat percentage; PA, Physical Activity; WHtR, waist to height ratio; WHR, the waist to hip ratio.

Similarly, BMI also has a significant and strong correlation with BAI ($r = 0.770$; $p < 0.001$). Both the parameters of WHtR and BMI (kg/m2) present a significant and strong correlation with each other ($r = 0.789$; $p < 0.001$). When considering the analysis by gender, both men and women present significant and strong correlations of the WHtR parameter with the BAI parameters (Male: $r = 0.985$; $p < 0.001$; Female: $r = 0.989$; $p < 0.001$) and IQ (Male: $r = 0.770$; $p < 0.001$; Female: $r = 0.774$; $p < 0.001$). The same behavior was observed in BMI, showing a significant and strong correlation with BAI (Male: $r = 0.786$; $p < 0.001$; Female: $r = 0.768$; $p < 0.001$) and WHtR (Male: $r = 0.815$; $p < 0.001$; Female: $r = 0.768$; $p < 0.001$).

Table 3 shows a linear regression analysis predicting the level of physical activity of active older adults. The results show that high values in the variables: age, Fat %, BMI and WHtR negatively influence physical activity levels, while the rest of the variables analysed influence positively. The calculation equation would be: Physical activity level = 6.209 - 0.018*age (years) - 0.038*Fat(%) - 0.222*(BMI) + 1.402*(WHR) - 14.9880*(WHtR) + 0.171*BAI (%). This equation represents 47% of the sample analysed.

4. Discussion

Aging is the main risk factor in the development of CVD, the pathologies of which are related to excessive fat accumulation [18]. Early detection, as well as the identification of groups at risk, is essential to reduce the incidence of CVD and related health consequences. Therefore, establishing the most accurate anthropometric indices in old age, and their degree of association with CVD, will allow us to detect with greater accuracy the possible development of this illness, and reduce its incidence.

In the present study, more than 2200 evaluations were carried out on a study group of 608 elderly European people (Spain, Bulgaria, Hungary, Portugal and Italy), and the results have reported BMI, BAI and WHtR as the being the most accurate anthropometric measures in this group, both for men and women, which concurs with the data presented by other studies [34,35].

The major finding of this research is the significant correlation of the anthropometric indicators with the fat percentage parameter (Fat %; Gold Standard), in which men presented a Fat % [36] and lower correlation coefficient with respect to women, and where the

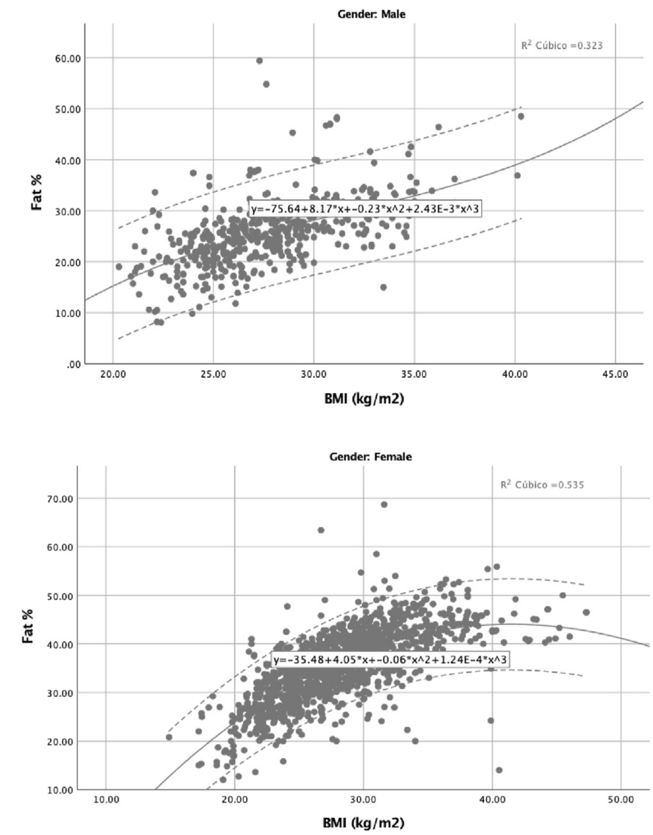

Fig. 1. Analysis of the relationship between % Fat and BMI according to gender.

BMI, BAI, WHtR and WHR were the parameters with the highest degree of correlation [37].

The studies by Van Hubbar [38] and Kuczmarski [39] ratify the results obtained in the present study, indicating that the calculation of BMI is considered more accurate than just a weight measurement in the estimation of total body fat. Another study suggests that a lack of differentiation between fat and non-fat weight may lead to the misinterpretation of high BMI values, and thus individuals being wrongly considered to be overweight or at risk of obesity [40]. Despite these considerations, in the present study BMI shows the highest degree of correlation with Fat %, so it should be taken as the best anthropometric index for the identification of CVD risk factors in old age. In fact, the detailed analysis of the association between BMI and Fat % has shown that although they are moderately correlated in the overall sample, this correlation is stronger in women and only moderate in men. Kuk [18] conducted a review on the changes and distribution of fat % in older adults, indicating that the peak fat % is between 64 and 70 years old, experiencing a redistribution of body fat towards the abdominal region and visceral during aging. These changes cannot be detected with simple anthropometric measurements alone, and the influence of gender, race/ethnicity, and physical activity patterns on these changes is unclear. Another study carried out by Ramires-Vélez [41] in non-active elderly has revealed how the waist-height ratio (WtHR) seems to be a good discriminator to detect the risk of CVD. The results of our study are characterized by being obtained in a sample of active older people, a difference from the studies by Kuk [18] and Ramires-Vélez [41], coinciding in the age interval in which older adults reach peak body fat. The results obtained in our study in relation to the best indicator of CVD risk based on sex, reflect how the BMI and WHtR have obtained the best results; these results may be due to physical activity patterns as indicated by Kuk [18].

García [41] also demonstrates in his study how this parameter is an effective predictor of CVD risk factors, data which follows on from that of other studies, such as that by González-Ruiz [42] in which the research indicates that the BAI can be a useful tool for predicting Fat % in adults. Both Garcia and Gonzalez-Ruiz's results agree with those presented in this study. In addition, other studies of individuals from different countries have validated and used this index as an anthropometric assessment parameter both in the obese population [43] and in individuals without CVD [44,45]. In the present study the results reflect a moderate correlation between Fat % and BAI for both sexes.

The study carried out by Gharakhanlou [35] lists results similar to those presented here, with WHtR being considered the best anthropometric indicator for predicting CVD risk in men aged 15–74 years, results that agree with those obtained in the present study, in which WHtR is found to be the third best anthropometric measure in this group for both men and women. In general, it is suggested that anthropometric measures which incorporate waist measurement and body shape, as the WHtR does, would have a greater ability to predict obesity-related risk factors [14,46]. Similarly, the study by Koch [47], determines that the WHtR anthropometric index is a more accurate predictor of overall mortality than BMI and WHR. Considering the total sample of this study, it can be seen that Fat % has a moderate correlation with the WHtR parameter for both men and women. However, according to the results of our study BMI is the best anthropometric index, followed by BAI and WHtR.

Finally, with reference to CI and considering the total sample of the study, we can observe that this anthropometric index has the lowest correlation with Fat %, although it maintains the same behavior as the other indexes, in that women have a higher correlation coefficient between Fat % and CI than men.

Previous studies have revealed the influence of the practice of physical activity on anthropometric indices in different groups [48–50], however few of them have been analysed focused on studying this influence in active older adults [51], despite the fact that these indices are a reference to the physical state of people [52].

Table 3
Linear regression analysis to predict the Physical Activity Level.

	Parameter	B	Desv. Error	t	Sig.
Predicted Physical Activity Level	Constant	6.209	1.594	3.895	0.001
	Age (years)	−0.018	0.013	1.420	0.046
	Fat %	−0.038	0.011	−3.496	0.001
	BMI (kg/m^2)	−0.222	0.073	1.522	0.042
	WHR	1.402	0.732	1.915	0.043
	WHtR	−14.988	9.409	−1.593	0.042
	BAI	0.171	0.080	2.145	0.032
	CI	−0.451	1.762	−0.282	0.778

Our results have shown that high levels of physical activity (days/week) contribute to reducing % Fat in active older adults. These same results were shown by Chen et al. [48] after carrying out a study on the association of anthropometric indices and the physical condition of the adult population, in which they concluded that % FAT is a marker that may indicate the decrease in physical activity due to central obesity. We should also highlight that IQ is the only index that is not associated with physical activity levels.

Among the limitations of the study, its cross-sectional nature should be highlighted, which prevents an understanding of the development, and changes to, the anthropometric indices throughout old age. As the study involved participants from five different countries, it would also have been interesting to know something about the dietary patterns followed in each, so as to identify possible adverse effects of diet on the anthropometric indices. The low percentage of men who participated in the study should also be highlighted as a weak point. Finally, not having an objective marker of the level of muscle mass in active older adults has prevented us from analyzing the association with physical activity levels and knowing the influence of this parameter on the different indices analysed. As strengths, however, the high number of evaluations carried out on the sample should be stressed, which has resulted in stable data; also, the age homogeneity of the sample regardless of which country they come from. As a final conclusion, it has been shown that the best anthropometric index to use with physically active older adults of both sexes is the BMI. Therefore, based on the results obtained in this study, its use is recommended as an indicator of cardiovascular risk.

Finding statement

None.

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Author contributions

Conceived the study and analyzed the data: JMCC; analyzed the data: PB; completed data collection: BS; Completed data collection: ALR; Review and editing: ALR; all authors have read and approved the final version manuscript.

Data availability statement

http://www.olympics4all.eu/(accessed on 15 october 2022).

Declaration of competing interest

The authors do not have conflicts of interest to declare.

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References

[1] Alvarado-García AM, Salazar-Maya ÁM. Análisis del concepto de envejecimiento. Gerokomos 2014;25(2):57–62.
[2] Lehr U. Psicología de la senectud [Old age Psychology. Herder: Barcelona; 1980.
[3] Laforest J. Introducción a la Gerontología. Herder: Barcelona: España; 1991.
[4] Gómez J, Curcio C. Valoración integral del anciano sano. Manizales: Artes Gráficas Tizan; 2002. p. 500.
[5] Roth GA, Mensah GA, Jonhson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990-2019:update from the GBD 2019 study. J Am Coll Cardiol 2020;76(25):2982. -2021, https://10.1016/j.jacc.2020.11.010. Pubmed PMID:33309175; Pubmed Central PMCID: PMC7755038.
[6] Ahn Y, Cho S, Sohn M. Adiposity of Korean school-age children measured by national and international growth charts. Res Nurs Health 2013;36(1):16–25. https://doi.org/10.1002/nur.21510. Epub 2012/09/19 PubMed PMID: 22996416.
[7] Gatica P, Vargas R, Jirón O, Herrera M, Duarte C, Gómez R, et al. Cambios en la adiposidad corporal de adolescentes escolares (1997-2007). Nutr Clínica Dietética Hosp 2013;33(3):23–9. https://doi: 10.12873/333bodyfat.
[8] Boutari C, Mantzoros CS. A 2022 update on the epidemiology of obesity and a call to action: as its twin COVID-19 pandemic appears to be receding, the obesity and dysmetabolism pandemic continues to rage on. Metabolism 2022: 155217. https://doi:10.1016/j.metabol.2022.155217. Epub 2022/05/15 PubMed PMID: 35584732 ; PubMed Central PMCID: PMC9107388.
[9] Cornier MA, Despres JP, Davis N, Grossniklaus DA, Klein S, Lamarche B, et al. Assessing adiposity: a scientific statement from the American Heart Association. Circulation 2011;124(18):1996–2019. https://doi:10.1161/CIR.0b013e318233bc6a. Epub 2011/09/26 PubMed PMID: 21947291.
[10] Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC Publ Health 2009;9:88. https://doi:10.1186/1471-2458-9-88. PubMed PMID: 19320986; PubMed Central PMCID: PMC2667420.
[11] Oviedo G, Morón A, Solano L. Indicadores antropométricos de obesidad y su relación con la enfermedad isquémica coronaria. Nutr Hosp 2006;21(6): 694–8.
[12] Chan RS, Woo J. Prevention of overweight and obesity: how effective is the current public health approach. Int J Environ Res Publ Health 2010;7(3): 765–83. https://10.3390/ijerph7030765. Epub 2010/02/26 PubMed PMID: 20617002; PubMed Central PMCID: PMC2872299.
[13] Rodríguez C, Gavilan S, Goita V, Luzuriaga J, Costa M, Jorge A. ¿Índice cintura/cadera en la valoración de riesgo cardiovascular y metabólico en pacientes internados? Universidad Nacional del Nordeste, Comunicaciones científicas y tecnológicas; 2003. citado 19 de enero 2023].
[14] Lee CM, Huxley RR, Wildman RP, Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol 2008;61(7):646. –53, https://doi:10.1016/j.jclinepi.2007.08.012. Epub 2008/03/21 PubMed PMID: 18359190.
[15] Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG, et al. A better index of body adiposity. Obesity 2011;19(5): 1083–9. https://doi:10.1038/oby.2011.38. PubMed PMID: 21372804; PubMed Central PMCID: PMC3275633.
[16] World Health Organization. Physical status: the use and interpretation of anthropometry. Geneva: World Health Organization; 1995.
[17] Jackson AS, Stanforth PR, Gagnon J, Rankinen T, Leon AS, Rao DC, et al. The effect of sex, age and race on estimating percentage body fat from body mass index: the Heritage Family Study. Int J Obes Relat Metab Disord 2002;26(6): 789–96. https://doi:10.1038/sj.ijo.0802006. Pubmed PMID: 12037649.
[18] Kuk JL, Saunders TJ, Davidson LE, Ross R. Age-related changes in total and regional fat distribution. Ageing Res Rev 2009;8(4):339–48. https://doi.org/10.1016/j.arr.2009.06.001. Pubmed PMID: 19576300.
[19] Nyamdorj R, Qiao Q, Lam TH, Tuomilehto J, Ho SY, Pitkaniemi J, et al. BMI compared with central obesity indicators in relation to diabetes and hypertension in Asians. Obesity 2008;16(7):1622–35. https://doi:10.1038/oby.2008.73. Epub 2008/04/10 Pubmed PMID: 18421260.
[20] InterAct C, Langenberg C, Sharp SJ, Schulze MB, Rolandsson O, Overved K, et al. Long-term risk of incident type 2 diabetes and measures of overall and regional obesity: the EPIC-InterAct casecohort study. PLoS Med 2012;9(6):e1001230. https://doi:10.1371/journal.pmed.1001230. PMID: 22679397. Epub 2012/05/5 PubMed PMID: 22679397; PubMed Central PMCID: PMC3367997.
[21] Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev 2010;23(2):247–69. https://doi:10.1017/S0954422410000144. Epub 2010/09/7 PubMed PMID: 20819243.
[22] Ashwell M, Cole TJ, Dixon AK. Ratio of waist circumference to height is strong predictor of intraabdominal fat. BMJ 1996;313(7056):559–60. https://doi:10.1136/bmj.313.7056.559d. PubMed PMID: 8790002; PubMed Central PMCID: PMC2351911.
[23] Pilar A, Marin A, Pino F, Barja S, Aglony M, Navarrete C, et al. Índice cintura estatura y agregación de componentes cardiometabólicos en niños y adolescentes de Santiago. Rev Med Chile 2010;138(11):1378–85. https://doi.org/10.4067/S0034-98872010001200006.
[24] Rodríguez M, Cabrera A, Aguirre A, Dominguez S, Brito B, Almeida D, et al. The waist to height ratio as an index of cardiovascular risk and diabetes. Med Clin 2010;134(9):386–91. https://doi:10.1016/j.medcli.2009.09.047. Epub 2010/02/6 PubMed PMID: 20138315.

[25] Ramírez-Vélez R, Pérez-Sousa MÁ, Izquierdo M, Cano-Gutierrez CA, González-Jiménez E, Schmidt-RioValle J, et al. Validation of surrogate anthropometric indices in older adults: what is the best indicator of high cardiometabolic risk factor clustering? Nutrients 2019 Jul 24;11(8):1701. https://doi.org/10.3390/nu11081701. PMID: 31344803; PMCID: PMC6723899.
[26] Ko GT, Chan JC, Woo J, Lau E, Yeung VT, Chow CC, et al. Simple anthropometric indexes and cardiovascular risk factors in Chinese. Int J Obes Relat Metab Disord 1997;21(11):995–1001. https://doi:10.1038/sj.ijo.0800508. PubMed PMID: 9368822.
[27] Dalton M, Cameron A, Zimmet P, Shaw JE, Jolley D, Dunstan DW, et al. Waist circumference, waist-hip ratio and body mass index and their correlation with cardiovascular disease risk factors in Australian adults. J Intern Med 2003;254(6):555–63. https://10.1111/j.1365-2796.2003.01229.x. PubMed PMID: 14641796.
[28] Roubenoff R, Baumgartner RN, Harris TB, Dallal GE, Hannan MT, Economos CD, et al. Application of bioelectrical impedance analysis to elderly populations. J Gerontol A Biol Sci Med Sci 1997;52(3):M129–36. https://doi:10.1093/gerona/52a.3.m129. PubMed PMID: 9158553.
[29] Roubenoff R, Dallal GE, Wilson PW. Predicting body fatness: the body mass index vs estimation by bioelectrical impedance. Am J Publ Health 1995;85(5):726–8. https://doi:10.2105/ajph.85.5.726. PubMed PMID: 7733439; PubMed Central PMCID: PMC1615438.
[30] World Health Organization. Waist circumference and waist-hip ratio. Report of a WHO expert consultation. Geneva: WHO; 2008.
[31] Hsieh SD, Yoshinaga H. Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. Int J Obes Relat Metab Disord 1995;19:585–9. PubMed PMID: 7489031.
[32] Lira Santos A, Araújo Tavares de Sá CM, Calado Brito D, Lourenço Batista C, Kétteryn Maior Evangelista da Costa M, Araújo Gomes de Lima KB, et al. Accuracy parameters as indicators of anthropometric adiposity visceral scheduled for two-dimensional equation. Nutr Hosp 2015;32(5):2046–53. https://doi:10.3305/nh.2015.32.5.9685. PubMed PMID: 26545659.
[33] Taylor R. Interpretation of the correlation coefficient: a basic review. J Diagn Med Sonogr 1990;6(1):35–9.
[34] Schneider HJ, Friedrich N, Klotsche J, Pieper L, Nauck M, John U, et al. The predictive value of different measures of obesity for incident cardiovascular events and mortality. J Clin Endocrinol Metab 2010;95(4):1777–85. https://doi:10.1210/jc.2009-1584. Epub 2010/02/3 PubMed PMID: 20130075.
[35] Gharakhanlou R, Farzad B, Agha-Alinejad H, Steffen LM, Mahdi B. Anthropometric measures as predictors of cardiovascular disease risk factors in the urban population of Iran. Arq Bras Cardiol 2012;98(2):126–35. https://doi:10.1590/s0066-782x2012005000007. Epub 2012/01/9 PubMed PMID: 22231916.
[36] Cardalda IM, Pereira K, Rodríguez AL, Carral JMC. Relación entre índices antropométricos y la obesidad en personas mayores de 60 años. Estudios Europeo IN COMMON SPORT. Rev Andal Med Deport 2021;14(2):87–92. https://doi.org/10.33155/j.ramd.2020.08.001.
[37] Canaan-Rezende FA, Queiroz-Ribeiro A, Eloiza-Priore S, Franceschinni SDCC. Diferencias antropométricas relacionadas con géneros y edad en los ancianos. Nutr Hosp 2015;32(2):757–64. https://doi:10.3305/nh.2015.32.2.8641. PubMed PMID: 26268108.
[38] Van Hubbard S. Defining overweigth and obesity: what are the issues? Am J Clin Nutr 2000;72(5):1067–8. https://doi:10.1093/ajcn/72.5.1067. PubMed PMID: 11063427.
[39] Kuczmarski RJ, Flegal KM. Criteria for definition of overweight in transition: background and recommendations for the United States. Am J Clin Nutr 2000;72(5):1074–81. https://doi:10.1093/ajcn/72.5.1074. PubMed PMID: 11063431.
[40] Price GM, Uauy R, Breeze E, Bulpitt J, Fletcher AE. Weight, shape, and mortality risk in older persons:elevated waist-hip ratio, not high body mass indez is associated with a greater risk of death-. Am J Clin Nutr 2006;84(2):449–60. https://doi:10.1093/ajcn/84.1.449. PubMed PMID: 16895897.
[41] García AI, Niño-Silva LA, González-Ruíz K, Ramírez-Vélez R. Utilidad del índice de adiposidad corporal como indicador de obesidad y predictor de riesgo cardiovascular en adultos de Bogotá, Colombia. Endocrinol Nutr 2015;62(3):130–7. https://doi:10.1016/j.endonu.2014.11.007. Epub 2015/01/9 PubMed PMID: 25583657.
[42] González-Ruíz K, Correa-Bautista JE, Ramírez-Vélez R. Evaluación del índice de adiposidad corporal en la predicción del porcentaje de grasa en adultos de Bogotá, Colombia. Nutr Hosp 2015;32(1):55–60. https://doi:10.3305/nh.2015.32.1.9087. PubMed PMID: 26262696.
[43] Geliebter A, Atalayer D, Flancbaum L, Gibson CD. Comparison of body adiposity index (Bai) and BMI with estimations of % body fat in clinically severe obese women. Obesity 2013;21(3):493–8. https://doi:10.1002/oby.20264. PubMed PMID: 23592658; PubMed Central PMCID: PMC3470730.
[44] Bennasar-Veny M, Lopez-Gonzalez AA, Tauler P, Cespedes ML, Vicente-Herrero T, Yanez A, et al. Body adiposity index and cardiovascular health risk factors in caucasians: a comparison with the body mass index and others. PLoS One 2013;8:e63999. https://doi:10.1371/journal.pone.0063999. PubMed PMID: 23734182; PubMed Central PMCID: PMC3667028.
[45] López AA, Cespedes ML, Vicente T, Tomas M, Bennasar-Veny M, Tauler P, et al. Body adiposity index utilization in a Spanish mediterranean population: comparison with the body mass index. PLoS One 2012;7(4):e35281. https://doi:10.1371/journal.pone.0035281. Epub 2012/04/9 Pubmed PMID: 22496915; PubMed Central PMCID: PMC3322155.
[46] Maffeis C, Banzato C, Talamini G. Waist-to-Height ratio, a useful index to identify high metabolic risk in overweight children. J Pediatr 2008;152(2):207–13. https://doi:10.1016/j.jpeds.2007.09.021. Epub 2007/11/19 Pubmed PMID: 18206690.
[47] Koch E, Díaz C, Romero T, Kirschbaum A, Manriquez L, Paredes M, et al. Razón cintura-estatura como predictor de mortalidad en población chilena: un estuido de 8 años de seguimiento en la cohorte del poryecto San Francisco. Rev Chil Cardiol 2007;26(4):145–50.
[48] Chen PH, Chen W, Wang CW, Yang HF, Huang WT, Huang HC, et al. Association of physical fitness performance tests and anthropometric indices in Taiwanese adults. Front Physiol 2020;11:583692. https://doi.org/10.3389/fphys.2020.583692.
[49] Mathisen TF, Rosenvinge JH, Friborg O, Pettersen G, Stensrud T, Hansen BH, et al. Body composition and physical fitness in women with bulimia nervosa or binge-eating disorder. Int J Eat Disord 2018;51(4):331–42.
[50] Zaqout M, Vyncke K, Moreno LA, De Miguel-Etayo P, Lauria F, Molnar D, et al. Determinant factors of physical fitness in European children. Int J Publ Health 2016;61:573–82. https://doi.org/10.1007/s00038-016-0811-2.
[51] Chang KV, Hung CY, Li CM, Lin YH, Wang TG, Tsai KS, et al. Reduced flexibility associated with metabolic syndrome in community-dwelling elders. PLoS One 2015 2015;10:e0117167. https://doi.org/10.1371/journal.pone.0117167.
[52] Staub K, Floris J, Koepke N, Trapp A, Nacht A, Scharli Maurer S, et al. Associations between anthropometric indices, blood pressure and physical fitness performance in young Swiss men: a cross-sectional study. BMJ Open 2018;8:e018664. https://doi.org/10.1136/bmjopen-2017-018664.