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Corporal body adiposity (BAI) and abdominal volume (AVI) indices: Relationship with obesity scales in the working population

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Abstract

Objective: Obesity is a growing pandemic and body mass index (BMI) is insufficient to assess the risk of complications. Other estimates of adiposity are used.

Materials and methods: Cross-sectional study in 193,462 workers. BMI, CUN-BAE (Clínica Universitaria de Navarra Body adiposity Estimator), Cordoba Equation (ECORE-BF), Relative Fat Mass (RFM), Metabolic Score for Visceral Fat (METS-VF) and Palafolls formula. Their correlation with body adiposity index (BAI) and abdominal volume (AVI) was estimated. SPSS 27.0 was used, considering statistical significance p<0.05.

Results: With all scales AVI and BAI are higher in obesity. AVI is higher in men, except with METS-VF. BAI in women has higher values in all scales. The highest values of AVI and BAI are with METS-VF, the lowest with PALAFOLLS. There is a good correlation of BMI with AVI and BAI and with the RFM and METS-VF scales and a very good correlation with Palafolls, ECORE-BF and CUN BAE. AVI and BAI show good correlation with Palafolls, ECORE-BF and CUN BAE and very good correlation with RFM and METS-VF.

Conclusions: AVI and BAI show differences in their values according to sex. With METS-VF, both indexes are higher in men and women. AVI and BAI show good correlation with BMI and RFM. With METS-VF very good correlation with AVI. With the rest of the scales BAI and AVI show moderate or good correlation. The simplicity of these formulas and of both indexes makes them recommendable in clinical practice.

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Introduction

The current obesity epidemic poses a public health issue, as it heightens the risk of chronic diseases in an aging population. The body mass index (BMI) and the overall amount of body and visceral fat, referred to as adiposity, have a direct relationship with the risk of cardiovascular and metabolic complications (1).

However, the way in which fat is distributed throughout the body, as well as the function of adipose tissue, has a significant impact on factors such as insulin resistance and its subsequent complications, more so than the total amount of fat itself (1).

The dysfunction of fatty tissue is due to its altered ability to expand, an increase in the size of fat cells, changes in fat metabolism, and inflammatory phenomena. The oxygenation of fatty tissue can be crucial in its pathogenesis, and analyzing the metabolism of individuals with obesity is fundamental to identify those at higher risk and implement more effective preventive and therapeutic strategies (1). Therefore, characterizing the metabolic profile of individuals with obesity is essential for early risk detection and prompt intervention in resulting cardiometabolic complications.

While the relationship between adiposity indices and the onset of complications is not clear, especially in at-risk groups, it is asserted that greater variability in adiposity indices is associated with increased cardiovascular and metabolic complications, regardless of traditional risk factors and baseline adiposity levels (2).

The objective of this study was to determine the correlation in a working population between the average values of the BAI and AVI with obesity and adiposity, establishing differences between men and women and using various methods: BMI, CUN-BAE (Clinica Universitaria de Navarra Body Adiposity Estimator), Cordoba Equation (ECORE-BF), RFM, Metabolic Score for Visceral Fat (METS-VF), and Palafolls formula.

Materials and methods

A study was conducted on 193,462 employees (116,407 men and 77,055 women) from nine regions of Spain (Balearic Islands, Andalusia, Canary Islands, Valencian Community, Catalonia, Madrid, Castilla-La Mancha, Castilla y León, and Basque Country) belonging to various professional sectors: hospitality, construction, commerce, health, public administration, transportation, education, industry, and cleaning.

The study was carried out during health exams performed at the Occupational Risk Prevention Services (SPRL) of the participating companies from January 2019 to September 2021.

Eligibility criteria

Inclusion criteria was being aged between 18 and 67, not being on medical leave or on leave from the company for any other reason, and voluntarily agreeing to participate in the study. Medical staff record clinical and family history data during health exams, in accordance with the Organic Law on Personal Data Protection and Guarantee of Digital Rights 2018 (LOPD) (3).

Table 1: Comparison of methods for estimating obesity and associated risk

	Weight	Size	BMI	Age	Sex	Waist circumference
BMI	Yes	Yes	Yes	No	No	No
CUN-BAE	Yes	Yes	Yes	Yes	Yes	No
ECORE-BF	Yes	Yes	Yes	Yes	Yes	No
RFM	No	Yes	No	No	No	Yes
PALAFOLLS	Yes	Yes	Yes	No	No	Yes
METS-VF	Yes	Yes	Yes	Yes	Yes	Yes

Body Mass Index (BMI) -Quetelet index (BMI=weight (kg)/height^2 (meters). It is classified according to WHO-2023 recommendations. CUN-BAE (Clínica Universitaria de Navarra Body adiposy Estimator), Córdoba Equation (ECORE-BF), Relative Fat Mass (RFM), Metabolic Score for Visceral Fat (METS-VF), Palafolls equation, WC-waist circumference, ICA waist/height index.

Collected variables

BMI - Quetelet Index (BMI = weight (kg) / height^2 (meters)). It classifies (according to WHO-2023) as: normal weight <25; overweight >25-<30; obesity grade 1 >30-<40; obesity grade 2 >40 (4).

AVI: Uses the formula proposed by Guerrero-Romero et al: AVI = [2 x (waist-cm)^2 + 0.7 (waist-hip-cm)^2] / 1,000 (5).

BAI: Uses the formula proposed by Bergman RN et al: BAI = (hip circumference) / (height) (1.5) – 18) (6).

The various methods used have specific evaluations adjusted to their equations: Palafolls formula (7), RFM (8), Córdoba Equation (ECORE-BF) (9), CUN-BAE (Clinic University of Navarra Body Adiposity Estimator) (10), Metabolic Score for Visceral Fat (METS-VF) (11).

The comparison of parameters used for the calculation in each method is shown in **Table 1**.

Statistical analysis

A descriptive analysis of the categorical variables was carried out, calculating the frequency and distribution of each variable. For quantitative variables, the mean and standard deviation were calculated. The Kolmogorov-Smirnov test was applied to assess the normality of the sample. For the statistical study, a univariate analysis was performed using the t-student and the chi-square. The statistical analysis was carried out with the SPSS 27.0 program, with an accepted statistical significance level of 0.05. The correlation between the different scales was obtained using Pearson's coefficient.

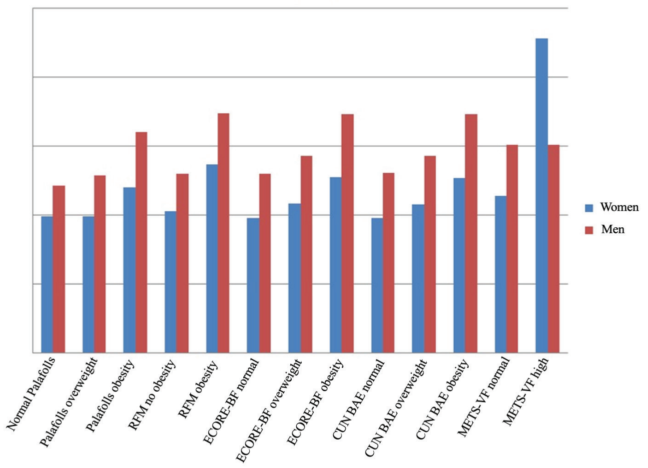
Ethical committee approval

The study was approved by the Clinical Research Ethics Committee of the Health Area of the Balearic Islands (IB 4383/20).

Results

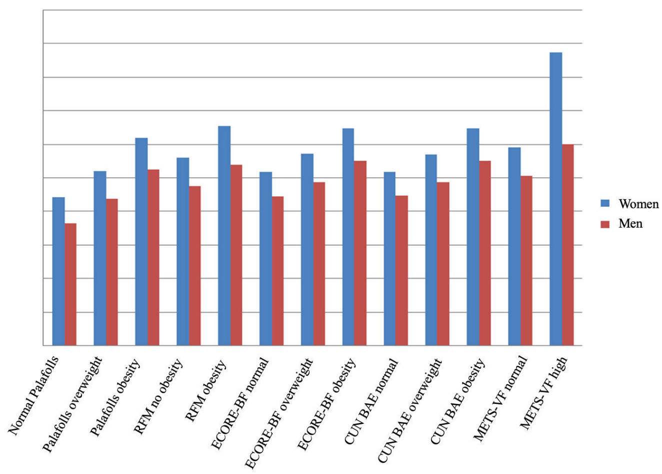
Descriptive cross-sectional study in a working population of 193,462 people (116,407 men and 77,055 women), with an average age of 39 years for women and 39.8 years for men. Most of both genders have basic educational levels and belong to social class III. The BMI is within overweight parameters, slightly higher among men (26.8) than in women (25.2). The levels of blood pressure, basal glucose, cholesterol and its fractions, and triglycerides are within normal limits, being higher in men. Women engage in more physical activity and have a higher adherence to the Mediterranean diet. The majority of the population are non-smokers.

With all the scales analyzed, the average values of AVI and BAI are higher when all the scales are within obesity parameters. The average AVI values are higher



* CUN-BAE (Clínica Universitaria de Navarra Body adiposy Estimator), Córdoba Equation (ECORE-BF), Relative Fat Mass (RFM), Metabolic Score for Visceral Fat (METS-VF), Palafolls equation.

Figure 1: AVI index; comparison of mean values for women vs. men according to overweight and obesity scales



* CUN-BAE (Clínica Universitaria de Navarra Body adiposy Estimator), Córdoba Equation (ECORE-BF), Relative Fat Mass (RFM), Metabolic Score for Visceral Fat (METS-VF), Palafolls equation.

Figure 2: BAI index; comparison of mean values for women vs. men according to overweight and obesity scales

Table 2: Mean values of AVI and BAI according to overweight and obesity scales

Scales	Women		AVI		BAI	
		n	Mean (sd)		Mean (sd)	p-value
PALAFOLLS	Normal Palafolls	544	9.91 (1.79)	<0.0001	22.17 (2.50)	<0.0001
	Palafolls overweight	20120	9.93 (1.57)		26.05 (3.54)	
	Palafolls obesity	56391	12.04 (2.43)		30.97 (4.69)	
RFM	RFM no obesity	50113	10.28 (1.29)	<0.0001	27.96 (4.01)	<0.0001
	RFM obesity	26942	13.71 (2.45)		32.73 (5.03)	
ECORE BF	ECORE-BF normal	19868	9.84 (1.52)	<0.0001	25.88 (3.58)	<0.0001
	ECORE-BF overweight	22421	10.88 (1.51)		28.63 (3.69)	
	ECORE-BF obesity	34766	12.79 (2.59)		32.41 (4.66)	
CUN BAE	CUN BAE normal	18836	9.84 (1.53)	<0.0001	25.83 (3.58)	<0.0001
	CUN BAE overweight	21905	10.81 (1.52)		28.46 (3.71)	
	CUN BAE obesity	36314	12.73 (2.57)		32.30 (4.65)	
BMI	BMI underweight	1944	9.38 (1.42)	<0.0001	23.21 (2.88)	<0.0001
	Normal weight BMI	42025	10.46 (1.57)		27.64 (3.86)	
	BMI overweight	21393	11.98 (1.75)		30.52 (3.21)	
	BMI obesity	11693	14.55 (3.07)		36.19 (4.70)	
METS-VF	METS-VF normal	76663	11.42 (2.26)	<0.0001	29.55 (4.84)	<0.0001
	METS-VF high	392	22.83 (4.25)		43.64 (5.53)	
Scales	Men		AVI		BAI	
		n	Mean (sd)		Mean (sd)	p-value
PALAFOLLS	Normal Palafolls	312	12.18 (1.38)	<0.0001	18.24 (2.06)	<0.0001
	Palafolls overweight	12848	12.92 (1.66)		21.84 (2.63)	
	Palafolls obesity	103247	16.06 (3.27)		26.18 (3.70)	
RFM	RFM no obesity	45191	13.01 (1.37)	<0.0001	23.73 (3.21)	<0.0001
	RFM obesity	71216	17.42 (2.98)		26.92 (3.72)	
ECORE BF	ECORE-BF normal	19328	13.02 (1.63)	<0.0001	22.26 (2.87)	<0.0001
	ECORE-BF overweight	35667	14.30 (2.16)		24.39 (2.87)	
	ECORE-BF obesity	61412	17.37 (3.27)		27.51 (3.59)	
CUN BAE	CUN BAE normal	20804	13.07 (1.64)	<0.0001	22.37 (2.89)	<0.0001
	CUN BAE overweight	34047	14.32 (2.17)		24.41 (2.87)	
	CUN BAE obesity	61556	17.37 (3.28)		27.51 (3.59)	
BMI	BMI underweight	680	12.10 (1.45)	<0.0001	19.49 (2.66)	<0.0001
	Normal weight BMI	40979	13.28 (1.67)		23.24 (2.92)	
	BMI overweight	51999	16.21 (2.59)		25.92 (2.94)	
	BMI obesity	22749	19.03 (3.49)		29.73 (3.53)	
METS-VF	METS-VF normal	106116	15.11 (2.60)	<0.0001	25.26 (3.55)	<0.0001
	METS-VF high	10291	21.92 (3.17)		30.05 (4.17)	

BMI=body mass index--Quetelet index (BMI=weight (kg)/height^2 (meters). It is classified according to WHO-2023 recommendations; CUN-BAE (Clínica Universitaria de Navarra Body adiposy Estimator), Córdoba Equation (ECORE-BF), Relative Fat Mass (RFM), Metabolic Score for Visceral Fat (METS-VF), Palafolls equation. WC-waist circumference, ICA waist/height index, AVI= Abdominal volume index, BAI= Body adiposity index.

Table 3: Pearson correlation coefficient between BAI and AVI with BMI and Overweight and Obesity Scales

	BMI	AVI	BAI	Palafolls	RFM	ECORE-BF	CUN BAE	METS-VF
Women								
BMI	1	.696 **	.720 **	.999 **	.675 **	.973 **	.965 **	.704 **
AVI		1	.487 **	.661 **	.866 **	.663 **	.656 **	,800 **
BAI			1	.723 **	.583 **	.712 **	.705 **	.608 **
Palafolls				1	.645 **	.973 **	.966 **	.680 **
RFM					1	.681 **	.677 **	.966 **
ECORE-BF						1	.998 **	.754 **
CUN BAE							1	.756 **
METS-VF								1
Men								
	BMI	AVI	BAI	Palafolls	RFM	ECORE-BF	CUN BAE	METS-VF
BMI	1	.665 **	.679 **	.999 **	.682 **	.969 **	.971 **	.727 **
AVI		1	.404 **	.626 **	.897 **	.641 **	.644 **	.811 **
BAI			1	.682 **	.533 **	.673 **	.673 **	.572 **
Palafolls				1	.649 **	.968 **	.971 **	.703 **
RFM					1	.689 **	.689 **	.943 **
ECORE-BF						1	.998 **	.797 **
CUN BAE							1	.794 **
METS-VF								1

Assessment of the Kappa Index (Strength of agreement): < 0.20 Poor; 0.21 – 0.40 Weak; 0.41 – 0.60 Moderate; 0.61 – 0.80 Good; 0.81 – 1.00 Very good.

BMI=body mass index--Quetelet index (BMI= weight (kg)/height^2 (meters). It is classified according to WHO-2023 recommendations; CUN-BAE (Clínica Universitaria de Navarra Body adiposy Estimator), Córdoba Equation (ECORE-BF), Relative Fat Mass (RFM), Metabolic Score for Visceral Fat (METS-VF), Palafolls equation. WC-waist circumference, ICA waist/height index, AVI= Abdominal volume index, BAI= Body adiposity index.

in men, except for METS-VF where they are higher in women (**Figure 1**). With BAI, women have higher average values on all scales (**Figure 2**).

Both in men and women, the highest average values of AVI and BAI correspond to the METS-VF scale, and the lowest to the PALAFOLLS scale (**Table 2**).

The Pearson correlation coefficient shows a good correlation of BMI in both men and women with: Palafolls, ECORE-BF, and CUN BAE (>0.9) and good with RFM and METS-VF (between 0.61 – 0.80). For AVI, in both men and women, there is a good correlation with RFM and METS-VF (>0.8) and good for Palafolls, ECORE-BF, and CUN BAE (>0.6). For BAI, there is a good correlation in both men and women with Palafolls, ECORE-BF, and CUN BAE (>0.6) and moderate for RFM and METS-VF (<0.6 and >0.4) (**Table 3**).

Discussion

The global population exhibits variations in exposure to health-related risks, which influence health outcomes, associated costs, and resultant mortality. Comparative evaluation studies conducted regularly reveal the trends and evolution of these risks. The most recent publication, from 2019, assesses

84 behavioral, environmental, occupational, and metabolic risk groups for 195 countries and territories, and provides a valuable tool for synthesizing evidence on risks and risk-outcome associations. Among these groups, it is the behavioral (lifestyle-related: tobacco, alcohol, dietary habits, drug use, low physical activity) and the metabolic (obesity –BMI–, high blood sugar levels) risks that show the least control. The rise in BMI and, consequently, obesity is the third leading cause of disability and mortality in both sexes, and this has remained the case for the last decade (12).

In the workplace, prevention is prioritized, which stems from the knowledge provided by epidemiological studies. In our work, we conduct a cross-sectional study establishing the correlation between obesity-adiposity with various methods, which facilitates early intervention to prevent damage related to cardiovascular diseases (CVD) and their socioeconomic and health consequences.

In 2020, 119,858 people died in Spain from CVD, which remain the leading cause of death at 24.3%. The main risk factors include high blood pressure, dyslipidemia, diabetes, smoking, and obesity (13). Globally, the BMI has significantly increased among adults in recent decades, and there is a continuous association between BMI and mortality. Both BMI and waist circumference are similar measures, strongly and continuously associated with atherosclerotic cardiovascular disease and type 2 diabetes mellitus. Therefore, obesity should be considered a chronic disease that requires a personalized, comprehensive, and sustained approach over time (14).

While abdominal adiposity is associated with an altered cardiometabolic risk profile, the specific contribution of the distribution of abdominal adipose tissue is not yet fully understood. Computed tomography is a well-established and accurate method for measuring the distribution of abdominal adipose tissue but is hardly accessible in the workplace setting. Therefore, in this work, indirect and validated methods have been used such as the Palafolls formula, RFM, ECORE-BF, CUN-BAE (Clínica Universidad de Navarra-Body Adiposity Estimator), and METS-VF.

BMI combines visceral and body mass and, therefore, may lead to biased estimations in correlations, and it is recommended to use complementary formulas.

In our study, RFM demonstrates good agreement with BMI. In studies by other authors and using previously validated formulas such as RFM, an improved measure of adiposity can be obtained. However, in some aspects, BMI correlates somewhat better with adiposity traits (15).

In our study, ECORE-BF exhibits very high concordance with BMI, aligning with findings from previous studies which highlight it as a simple and precise equation for estimating body fat percentage, remaining robust regardless of the population characteristics (16).

In our study, the CUN-BAE demonstrates a very high concordance with BMI. However, previous studies by other authors consider that CUN-BAE may overfit the correlation and recommend the use of simpler models (17). On the other hand, other studies have observed that the concordance decreases in individuals over 50 years of age, suggesting that this different criterion for obesity may have clinical applications. Nevertheless, more gold standard studies are needed to evaluate the CUN-BAE in older adults (18).

In our study, the MET-VF exhibits good concordance with BMI, which is consistent with previous research. This scoring system has been successful in predicting an increase in visceral adipose tissue as detected by dual-energy X-ray absorptiometry (DEXA), demonstrating good sensitivity and reasonable specificity for predicting high adiposity in the adult population. MET-VF is recommended when resources for more expensive methods, such as DEXA, are unavailable (19).

Additionally, in our work, the Palafolls formula shows very good concordance with BMI. Our results are consistent with previous studies comparing this formula to CUN-BAE, revealing no significant statistical differences in outcomes for both formulas designed for the Spanish population. This makes it advisable for the approximate calculation of the percentage of body fat composition and for its use in primary care settings (7).

The prevalence of complications associated with obesity and the distribution of body and visceral fat continues to rise, thereby underscoring the necessity of early detection to prevent potential adverse outcomes. Various anthropometric methods have been suggested to predict these complications, but there is no consensus on which is the best. In general, BMI and WC have demonstrated greater predictive ability than AVI and BAI. After stratification by gender, AVI showed higher capability in women, whereas BMI remained the superior index in men. Nonetheless, BMI and WC continued to be useful parameters.

In our study, AVI exhibited good correlation with the Palafolls formula, ECORE-BF, and CUN-BAE, and a very good correlation with RFM and METS-VF in both sexes. BAI showed moderate correlation with all formulas in both sexes.

The different formulas used in this study show variations among themselves: CUN-BAE and ECORE-BF do not include waist circumference in their formulas, and RFM is the only formulation that does not include BMI, which may explain the differences obtained in the correlations with AVI and BAI.

Despite decades of unequivocal evidence that waist circumference provides independent and additional information to Body Mass Index (BMI) for predicting morbidity and mortality risk, this measure is not routinely obtained in clinical practice. Nevertheless, it represents a significant enhancement for the preventive management of health. BMI alone is insufficient to accurately assess or manage the cardiometabolic risk associated with increased adiposity in adults. All formulations used in this study combine BMI and/or waist circumference, along with other parameters, and due to their simplicity, they are recommended for daily practice, since the assessment of visceral adipose tissue is limited in clinical settings due to the cost of more accurate and time-consuming methods such as dual-energy X-ray absorptiometry (DEXA) machines or magnetic resonance imaging (MRI) (20).

In this study, the abdominal volume index and the body adiposity index have shown good to very good correlation with all adiposity formulations and with BMI, which leads us to recommend them for their ease of use in the preventive practice in occupational health and primary care consultations. The choice of the most suitable method depends on the practice of each health professional.

Conclusions

The average values for the AVI are higher in men, while the BAI scores are higher in women. Using the METS-VF scale, the highest average values for BAI and AVI are obtained for both sexes. AVI and BAI show a good correlation with BMI. Both in men and women, RFM and METS-VF demonstrate a very good correlation with AVI. With the rest of the scales, BAI and AVI show moderate to good correlation, slightly better in women. The simplicity of these formulas and both indices makes them recommendable in clinical practice.

Conflict of interest

The authors report no conflict of interest.

Funding source

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Ethical approval

The study was approved by the Clinical Research Ethics Committee of the Health Area of the Balearic Islands (IB 4383/20).

Informed consent

Written informed consent was obtained from all individual participants and/or their gaurdians.

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No

Peer-review

Externally. Evaluated by independent reviewers working in at least two different institutions appointed by the field editor.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Contributions

Research concept and design: **LGS, AALG, MTVH**
Data analysis and interpretation: **LGS, JAG, AALG, MTVH**
Collection and/or assembly of data: **JAG, AALG, MTVH**
Writing the article: **LGS, JAG, MTVH**
Critical revision of the article: **LGS, JAG, AALG, MTVH**
Final approval of the article: **LGS, JAG, AALG, MTVH**

All authors read and approved the final version of the manuscript.

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