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ORIGINAL

Equation Córdoba body fat values according to sociodemographic variables and healthy habits in 386924 Spanish workers

Valores de ecuación Córdoba grasa corporal según variables sociodemográficas y hábitos saludables en 386.924 trabajadores españoles

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Abstract

Introduction and objective: Excess body fat is an important risk factor for multiple pathologies, especially cardiometabolic ones, and its genesis is multifactorial. There are many ways of determining excess body fat, either directly or indirectly by means of estimation scales, among which one very easy to calculate is the Cordoba fat estimator equation (ECORE-BF). The objective is to evaluate the effect on the ECORE-BF values of various sociodemographic variables and healthy habits.
Methodology: Descriptive and cross-sectional study in 386924 Spanish workers to determine the association between sociodemographic variables such as age, gender, social class and level of education and healthy habits such as physical activity, Mediterranean diet and tobacco consumption with ECORE-BF values.
Results: Higher mean values and higher prevalence of high ECORE-BF values were observed with increasing age, lower socioeconomic level, lower level of physical activity and lower adherence to the Mediterranean diet, and in smokers.
Conclusion:All the variables studied seem to influence the ECORE-BF values, being the profile of a male of advanced age, low socioeconomic level, sedentary, with low adherence to the Mediterranean diet and smoker.

Key words: Body fat, obesity, ECORE-BF, sociodemographic variables, physical activity, Mediterranean diet, smoking.

Resumen

Introducción y objetivo: El exceso de grasa corporal es un importante factor de riesgo para múltiples patologías, especialmente las cardiometabólicas y su génesis es multifactorial. Existen muchas formas de determinar el exceso de grasa corporal, ya sean directas o indirectas mediante escalas de estimación, dentro de ellas una de muy fácil cálculo es la ecuación Córdoba estimador de grasa (ECORE-BF). El objetivo es valorar el efecto sobre los valores de ECORE-BF de diversas variables sociodemográficas y hábitos saludables.
Metodología: Estudio descriptivo y transversal en 386924 trabajadores españoles en los que se determina la asociación que existe entre variables sociodemográficas como edad, género, clase social y nivel de estudios y hábitos saludables como actividad física, dieta mediterránea y consumo de tabaco con los valores de ECORE-BF.
Resultados: Se observan mayores valores medios y mayor prevalencia de valores altos de ECORE-BF a medida que aumenta la edad, cuando el nivel socioeconómico es más bajo, cuanto menor es el nivel de actividad física y menor es la adherencia a la dieta mediterránea y en los fumadores.
Conclusión: Todas las variables estudiadas parecen influir en los valores de ECORE-BF, siendo el perfil de mayor riesgo el de un varón de edad avanzada, nivel socioeconómico bajo, sedentario, con baja adherencia a la dieta mediterránea y fumador.

Palabras clave: Grasa corporal, obesidad, ECORE-BF, variables sociodemográficas, actividad física, dieta mediterránea, tabaco.

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Introduction

Body fat percentage is an important indicator for assessing the health and physical condition of the individual[1-4].

Calculation of the amount of body fat can be performed in various ways. Some methods do it directly and objectively, such as bone densitometry (DEXA)[5,6] which is considered the reference standard. This technique uses very low levels of radiation to assess body composition divided into three compartments: fat mass, bone mass and lean mass. Other objective techniques such as bioimpedancemetry[7-9] and plethysmography[10,11] are also available.

Indirect methods or estimators of body fat include the tape measure that measures the perimeters of the abdominal waist[12,13], hip[14], neck[15-17], or wrist[18], and other procedures that use formulas for their evaluation (Clínica Universitaria de Navarra Body adiposity estimator CUN BAE[19,20], Deuremberg[21] or relative fat mass RFM[22]). The latter group includes a recently described indicator, the Cordoba Body fat equation (ECORE-BF)[23], which is calculated on the basis of age, gender and body mass index (BMI).

Among the different factors that can affect body fat values, the most relevant are:

1. Genetics[24] and Hereditary Factors[25]: Genetic predisposition can influence the amount of fat a person stores. A family history of obesity[26] facilitates a greater tendency to accumulate fat.
2. Gender: The percentage of body fat varies between men and women[27]. Women tend to have a higher fat percentage due to hormonal differences[28,29] and the biological need to store fat for reproduction30. Whereas men, under the same conditions, have a higher proportion of muscle mass[31].
3. Age: As we age, it is common for our body fat percentage to increase[32].This is a consequence of changes in metabolism, decreased physical activity, and, very importantly, sarcopenia[33,34], which produces a decrease in metabolic expenditure and facilitates the replacement of lean tissue by fatty tissue.
4. Eating habits and lifestyle[35-37]: A diet high in calories and low in physical activity increases the percentage of body fat. In contrast, a healthy diet and regular physical exercise decrease body fat and increase the proportion of lean tissue.
5. Fat distribution: The location of fat in the body is also relevant. Multiple studies have shown that subcutaneous fat[38-40] (under the skin) and visceral fat[41,42] (around internal organs) can affect health differently. Constituting a cardiovascular risk factor.

It is important to remember that body fat percentage is not the only indicator of health. Body composition, muscle mass and other risk factors should also be assessed to obtain a complete picture of health[43].

In humans, both too much and too little fat can affect health and athletic performance. Excess fat has been linked to increased risk of chronic disease, while a lack of fat can affect hormone production and muscle mass[44].

The aim of this study is to assess how different sociodemographic variables (age, gender, social class and level of education) and healthy habits (Mediterranean diet, physical activity and smoking) are associated with ECORE-BF values in a group of Spanish workers.

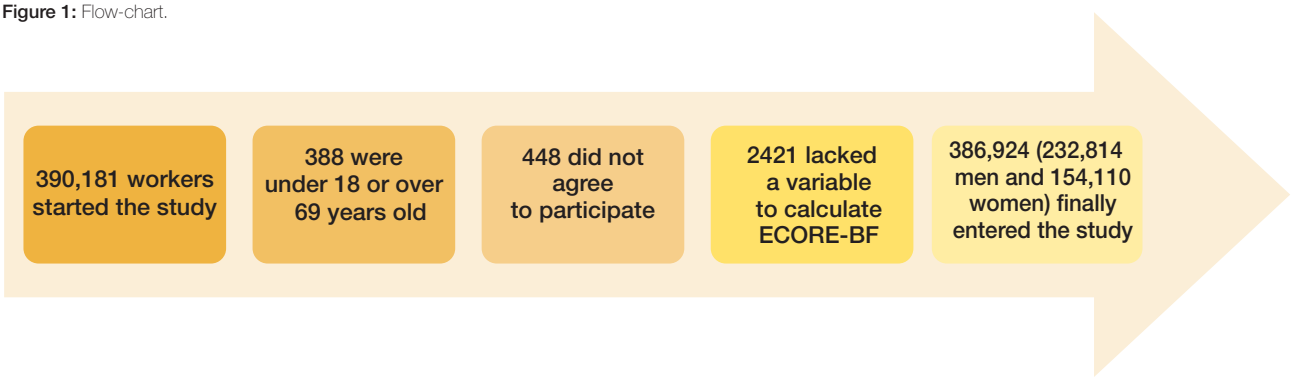
Methods

Utilising data from occupational medical tests conducted on 386,924 Spanish workers (232,814 men and 154,110 women) in the primary, secondary, and tertiary sectors between January 2019 and June 2020, a descriptive, cross-sectional analysis was conducted.

The following were the inclusion criteria:

- Aged eighteen to sixty-nine.
- Employed by one of the study's participating companies.
- Deciding to take part in the research.

Figure 1: Flow-chart.



Determination of variables

After standardising measuring techniques beforehand, the medical and nursing staff members of the study were in charge of performing clinical, analytical, and anthropometric (waist circumference, weight, and height) measures.

To calculate height and weight, a measuring scale based on the SECA 700 model was employed. An SECA model measuring tape was used to measure the subject's abdominal waist circumference when they were standing upright, with their lower limbs together, their trunk erect, and their abdomen relaxed. To obtain a precise measurement, the tape measure was placed parallel to the floor at the level of the last floating rib.

Using a calibrated automatic sphygmomanometer (OMRON M3), blood pressure was collected while the employee was seated and after at least a 10-minute rest interval.

Three measurements were made, separated by sixty seconds, and averaged. Following a minimum 12-hour fast, the different analytical values were ascertained. Total cholesterol, glycemia, and triglycerides were measured using automated enzyme techniques. Dextran sulfate-MgCl2 precipitation techniques were used to produce high-density lipoprotein (HDL) levels.

We used the Friedewald formula to indirectly calculate low-density lipoproteins (LDL). Each of these analytical parameters has a mg/dL expression.

Friedewald's equation: LDL equals triglycerides/5 - HDL + cholesterol.

Equation Cordoba for Estimation of Body Fat, or ECORE-BF45. The cut-off points for obesity are from 25% in men and 35% in women.

ECORE-BF = 97.102+0.123 (age) +11.9 (sex) +35.959 (LnBMI).

Man = 0 Woman = 1

As evidenced by a study published in Diabetes Care, our group's prior investigation established a very good concordance (0.998) between ECORE-BF and the gold standard body fat estimate, the Clínica Universitaria de Navarra body adiposity estimator (CUNBAE)[46].

There are two recognised genders: male and female.

The age is calculated by subtracting the date of birth from the date of the medical examination.

The level of education that is being considered is the highest of all those that were taken. The three official educational levels are primary, secondary, and university.

For the purpose of determining social class, the 2011 national classification of occupations (CNO-11) criteria of the Spanish Society of Epidemiology were utilised[47]. Three levels were established: - Social class I. This includes managers, artists, professional athletes, and professionals with university training. - Social class II. This includes intermediate-level professions and capable independent contractors. - Social class III. This holds true for unskilled workers as well.

If a person has smoked for at least one day in the preceding thirty days or if they haven't stopped for less than a year, we classify them as smokers.

The degree to which people adhere to the Mediterranean diet[48] is measured using a fourteen-item survey with a point system of 0 or 1. A nine indicates high adherence.

To ascertain an individual's degree of physical activity, the International Physical Activity Questionnaire (IPAQ)49 is utilised. This self-administered questionnaire is intended to determine the amount of physical activity completed throughout the previous seven days.

Statistical Analysis

The Student's t-test was employed to ascertain the mean and standard deviation for quantitative data.

The chi-square test was used to find prevalences for qualitative variables. ROC curves were used to calculate the cutoff points for cardiac ages as moderate and high. Multinomial logistic regression was used to carry out the multivariate analysis. We performed the statistical analysis using SPSS 29.0. $p<0.05$ was the recognised threshold for statistical significance.

Aspects of ethics

All other ethical principles governing research, including the 2013 Helsinki Declaration50, have been adhered to. Anonymity and privacy for participants have always been assured. The Balearic Islands Research Ethics Committee (CEI-IB), which granted consent under IB 483/20, approved the project. The identities of the participants are only known to the principal investigator because all of the data are coded. The Organic Law 3/2018, enacted on December 5, 2018, mandates that research subjects shall always have the right to see, amend, withdraw, and object to the utilisation of the collected data. Additionally, it protects digital rights.

Results

Table I presents the anthropometric, clinical, analytical, sociodemographic, and healthy habit data for the 386924 workers in the research. The average age of the participants was somewhat higher than 39. All other variables—apart from LDL cholesterol—have lower levels in the group of women. Of the participants,

women comprised 39.8% and males 60.2%. The average age of the population is between 30 and 49 years old. Most of them just have an elementary education and come from socioeconomic class III. 41% of men and 51.4% of women eat a Mediterranean diet, and 45.5% of men and 52.2% of women regularly exercise. 37% of males and 33% of women were smokers, respectively.

Table II shows how the ECORE-BF values increase with age. This increase is also observed as we descend in social class or educational level. It is observed that both physical activity and high adherence to the Mediterranean diet or not consuming tobacco will favor the appearance of lower ECORE-BF values. The mean values are higher in women, as occurs with all the scales that assess body fat. In all cases the differences observed are statistically significant.

Table I: Characteristics of the population.

	Men n=232.814	Women n=154.110	
	Mean (SD)	Mean (SD)	p-value
Age (years)	39.8 (10.3)	39.2 (10.2)	<0.001
Height (cm)	173.9 (7.0)	161.2 (6.6)	<0.001
Weight (kg)	81.1 (13.9)	65.3 (13.2)	<0.001
Waist circumference (cm)	87.7 (9.1)	73.9 (7.9)	<0.001
Hip circumference (cm)	100.0 (8.4)	97.2 (8.9)	<0.001
Systolic blood pressure (mmHg)	124.4 (15.1)	114.4 (14.8)	<0.001
Diastolic blood pressure (mmHg)	75.4 (10.6)	69.7 (10.3)	<0.001
Total cholesterol (mg/dl)	195.9 (38.9)	193.6 (36.4)	<0.001
HDL-c (mg/dl)	51.0 (7.0)	53.7 (7.6)	<0.001
LDL-c (mg/dl)	120.5 (37.6)	122.3 (37.0)	<0.001
Triglycerides (mg/dl)	123.8 (88.0)	88.1 (46.2)	<0.001
Glycaemia (mg/dl)	88.1 (12.9)	84.1 (11.5)	<0.001
	%	%	p-value
< 30 years	17.9	19.5	<0.001
30-39 years	33.1	33.3	
40-49 years	29.7	29.4	
50-59 years	16.3	15.3	
60-69 years	3.0	2.5	
Social class I	61.2	51.8	<0.001
Social class II	34.0	40.7	
Social class III	4.8	7.5	
University	5.3	7.2	<0.001
High school	17.4	33.2	
Elementary school	77.3	59.8	
Non physical activity	54.5	47.8	<0.001
Yes physical activity	45.5	52.2	
Non Mediterranean diet	59.0	48.6	<0.001
Yes Mediterranean diet	41.0	51.4	
Smokers	62.9	67.0	<0.001
Non smokers	37.1	33.0	

HDL-c High density lipoprotein cholesterol. LDL Low density lipoprotein cholesterol

Table II: Mean values of ECORE-BF according sociodemographic variables and healthy habits by gender.

	Men			Women		
ECORE-BF	n	Mean (SD)	p-value	n	Mean (SD)	p-value
< 30 years	41742	21.3 (5.7)	<0.001	29978	31.3 (6.6)	<0.001
30-39 years	76960	24.6 (5.3)		51392	33.5 (6.6)	
40-49 years	69068	27.0 (5.2)		45296	36.4 (6.4)	
50-59 years	38028	28.9 (5.2)		23516	39.1 (6.1)	
60-69 years	7016	30.4 (4.8)		3928	41.1 (5.7)	
Social class I	12262	25.4 (5.5)	<0.001	10744	32.9 (6.2)	<0.001
Social class II	40650	25.7 (5.8)		51230	33.4 (6.4)	
Social class III	179902	26.1 (6.2)		92136	36.1 (7.2)	
University	11094	25.4 (5.4)	<0.001	11610	32.9 (6.3)	<0.001
High school	79226	25.6 (5.7)		62690	33.8 (6.6)	
Elementary school	142494	25.9 (6.1)		79810	36.2 (7.2)	
Non physical activity	126808	29.0 (5.1)	<0.001	73684	39.6 (6.5)	<0.001
Yes physical activity	106006	21.5 (3.8)		80426	30.7 (4.1)	
Non Mediterranean diet	137464	28.4 (5.4)	<0.001	74828	39.2 (6.8)	<0.001
Yes Mediterranean diet	95350	21.5 (3.9)		79282	31.0 (4.2)	
Smokers	86334	26.2 (5.7)	<0.001	50810	33.9 (6.8)	<0.001
Non smokers	146480	24.6 (6.1)		103300	35.5 (7.0)	

ECORE-BF Equation Córdoba estimator body fat SD Standard deviation

Table III, which assesses the prevalence of obesity with the ECORE-BF scale, shows the same tendency already described for the mean values, that is, higher prevalence at older ages, in persons with a low socioeconomic level, sedentary, with low adherence to the Mediterranean diet and smokers. In this case the prevalences are higher in men. The differences observed in all cases show statistical significance.

The multinomial logistic regression analysis, shown in **Table IV**, shows that all the sociodemographic variables and healthy habits analyzed influence the appearance of obesity using the ECORE-BF scale. The most influential variables were physical activity, Mediterranean diet, gender and age. In all cases the differences observed show statistically significant differences.

Table III: Prevalence of high values of ECORE-BF according sociodemographic variables and healthy habits by gender.

	Men			Women		
ECORE-BF obesity	**n**	**%**	**p-value**	**n**	**%**	**p-value**
< 30 years	41742	22.5	<0.001	29978	24.1	<0.001
30-39 years	76960	43.5		51392	34.7	
40-49 years	69068	63.8		45296	53.1	
50-59 years	38028	78.2		23516	72.5	
60-69 years	7016	87.5		3928	86.4	
Social class I	12262	51.6	<0.001	10744	31.2	<0.001
Social class II	40650	52.6		51230	34.3	
Social class III	179902	53.0		92136	52.8	
University	11094	52.3	<0.001	11610	31.1	<0.001
High school	79226	52.9		62690	37.5	
Elementary school	142494	53.3		79810	53.0	
Non physical activity	126808	80.7	<0.001	73684	77.1	<0.001
Yes physical activity	106006	19.3		80426	15.8	
Non Mediterranean diet	137464	76.2	<0.001	74828	72.9	<0.001
Yes Mediterranean diet	95350	19.0		79282	18.9	
Smokers	86334	46.2	<0.001	50810	38.8	<0.001
Non smokers	146480	56.6		103300	48.2	

ECORE-BF Equation Córdoba estimator body fat

Table IV: Multinomial logistic regression.

ECORE-BF obesity	OR (95% CI)	p-value
Female	1	
Male	2.48 (2.22-32.74)	<0.001
< 30 years	1	
30-39 years	1.19 (1.15-1.23)	<0.001
40-49 years	1.48 (1.40-1.57)	<0.001
50-59 years	1.99 (1.80-2.19)	<0.001
60-69 years	2.70 (2.39-3.02)	<0.001
Social class I	1	
Social class II	1.18 (1.13-1.23)	0.611
Social class III	1.98 (1.70-2.27)	<0.001
University	1	
High school	1.19 (1.13-1.26)	0.001
Elementary school	2.08 (1.90-2.27)	<0.001
Non physical activity	1	
Yes physical activity	6.33 (5.75-6.92)	<0.001
Non Mediterranean diet	1	
Yes Mediterranean diet	2.87 (2.56-3.08)	<0.001
Smokers	1	
Non smokers	1.18 (1.14-1.23)	<0.001

ECORE-BF Equation Córdoba estimator body fat

Discussion

The distribution of body fat is influenced by age. Individuals tend to experience an increase in total body fat and changes in the distribution of this fat, resulting in a greater accumulation of fat in the abdomen, which is known as central obesity[50]. This is due to hormonal changes, a decrease in metabolic rate and a reduction in muscle mass, which can result in a higher proportion of fat compared to lean mass.

Different studies have found that abdominal fat was related to an increased risk of type 2[51] diabetes[52], and heart disease[53,54], especially in older men. Therefore, controlling body fat in old age is essential to improve health and prevent chronic diseases.

The distribution of body fat is influenced by gender[55]. Thus, the proportion of body fat in women is higher than

in men[56], mainly influenced by hormonal differences. Female body fat accumulates especially in the hips, thighs and breasts, while men tend to accumulate more fat in the abdomen.

Multiple studies associate this variation in body fat distribution with negative health effects. The accumulation of abdominal fat in men has been associated with an increased risk of type 2 diabetes and cardiovascular disease[57]. Whereas in women, fat accumulation in the thighs and hips may be related to a lower risk of metabolic diseases[58].

Social class and educational level are also linked to weight. Epidemiological studies link people with low income and lower educational level with a higher probability of developing obesity and overweight compared to people of higher socioeconomic levels[59,60].

This disparity may be influenced by several factors, including limited access to healthy foods due to economic constraints, less access to physical exercise facilities, and higher levels of stress, which can lead to unhealthy eating patterns and weight gain.

Diet plays a key role in body composition. The Mediterranean diet is well known for its health benefits, including the reduction of body fat. It includes a high intake of fruits, vegetables, legumes, whole grains, fish and olive oil, along with a moderate intake of red wine and dairy products, and a low intake of red meat and processed foods.

Several studies have described that following a Mediterranean diet is associated with fewer cases of obesity, less abdominal fat and less risk of cardiovascular and metabolic diseases[61,62].

To maintain a healthy body composition and control body fat levels, regular physical exercise is essential. Physical activity can change the distribution of fat, especially visceral fat, which is associated with an increased risk of chronic disease, as well as help to consume calories and maintain a healthy body weight[63].

It has been shown that both aerobic exercise63 and strength training[64] can improve overall body composition and reduce the amount of fat in the body. Aerobic exercise, such as running, swimming or cycling, helps to consume calories and improve cardiovascular health, while strength exercise, such as weight lifting, increases muscle mass and basal metabolism, resulting in increased fat consumption by resting muscle tissue.

Body fat levels are also affected by smoking[65], although the effects vary according to the individual and other lifestyle factors. Many studies have shown that smokers tend to have a higher proportion of visceral fat[66] even at normal body weight, despite the fact that smoking can suppress appetite and lead to slight short-term weight loss due to stimulation of metabolism.

Smoking is also associated with an increased risk of cardiovascular[67] and respiratory[68] diseases, as well as several types of cancer[69], demonstrating the importance of adopting healthy lifestyle habits, such as smoking cessation, to maintain good long-term health.

We may point to the sample size's enormous size—more than 386,000 people—and the range of sociodemographic and healthy habit analyses as positives. The primary drawback is that our results cannot be applied to the broader community because the study was conducted among working adults (18-69 years old).

Conclusion

A variety of factors, such as age, gender, social class, educational level, diet, exercise, and smoking, influence body composition and fat levels. Understanding how these factors interact can help create effective methods to promote healthy body composition and prevent chronic diseases in the population. A healthy lifestyle that includes a balanced diet, regular exercise and abstaining from smoking may be crucial.

Conflict of interest

The authors declare that they have no competing interests.

References

1. Reverte-Salisa L, Siddig S, Hildebrand S, Yao X, Zurkovic J, Jaeckstein MY, et al. EPAC1 enhances brown fat growth and beige adipogenesis. Nat Cell Biol. 2024 Jan;26(1):113-123. doi: 10.1038/s41556-023-01311-9.

2. Vints WAJ, Kušleikienė S, Sheoran S, Valatkevičienė K, Gleiznienė R, Himmelreich U, et al. Body fat and components of sarcopenia relate to inflammation, brain volume, and neurometabolism in older adults. Neurobiol Aging. 2023 Jul;127:1-11. doi: 10.1016/j.neurobiolaging.2023.02.011.

3. Sakers A, De Siqueira MK, Seale P, Villanueva CJ. Adipose-tissue plasticity in health and disease. Cell. 2022 Feb 3;185(3):419-446. doi: 10.1016/j.cell.2021.12.016.

4. Frank AP, de Souza Santos R, Palmer BF, Clegg DJ. Determinants of body fat distribution in humans may provide insight about obesity-related health risks. J Lipid Res. 2019 Oct;60(10):1710-1719. doi: 10.1194/jlr.R086975.

5. Silveira EA, Barbosa LS, Noll M, Pinheiro HA, de Oliveira C. Body fat percentage prediction in older adults: Agreement between anthropometric equations and DXA. Clin Nutr. 2021 Apr;40(4):2091-2099. doi: 10.1016/j.clnu.2020.09.032.

6. Tan C, Chan KE, Ng CH, Tseng M, Syn N, Tang ASP, et al. DEXA Scan Body Fat Mass Distribution in Obese and Non-Obese Individuals and Risk of NAFLD-Analysis of 10,865 Individuals. J Clin Med. 2022 Oct 21;11(20):6205. doi: 10.3390/jcm11206205.

7. Silveira EA, Barbosa LS, Rodrigues APS, Noll M, De Oliveira C. Body fat percentage assessment by skinfold equation, bioimpedance and densitometry in older adults. Arch Public Health. 2020 Jul 18;78:65. doi: 10.1186/s13690-020-00449-4.

8. Long V, Short M, Smith S, Sénéchal M, Bouchard DR. Testing Bioimpedance to Estimate Body Fat Percentage across Different Hip and Waist Circumferences. J Sports Med (Hindawi Publ Corp). 2019 Jun 11;2019:7624253. doi: 10.1155/2019/7624253.

9. Dimitrijevic M, Paunovic V, Zivkovic V, Bolevich S, Jakovljevic V. Body Fat Evaluation in Male Athletes from Combat Sports by Comparing Anthropometric, Bioimpedance, and Dual-Energy X-Ray Absorptiometry Measurements. Biomed Res Int. 2022 Sep 5;2022:3456958. doi: 10.1155/2022/3456958.

10. Devrim-Lanpir A, Badem EA, Işık H, Çakar AN, Kabak B, Akınoğlu B, et al. Which Body Density Equations Calculate Body Fat Percentage Better in Olympic Wrestlers?-Comparison Study with Air Displacement Plethysmography. Life (Basel). 2021 Jul 17;11(7):707. doi: 10.3390/life11070707.

11. Wagner DR, Castañeda F, Bohman B, Sterr W. Comparison of a 2D iPad application and 3D body scanner to air displacement plethysmography for measurement of body fat percentage. J Hum Nutr Diet. 2019 Dec;32(6):781-788. doi: 10.1111/jhn.12687.

12. Arif M, Gaur DK, Gemini N, Iqbal ZA, Alghadir AH. Correlation of Percentage Body Fat, Waist Circumference and Waist-to-Hip Ratio with Abdominal Muscle Strength. Healthcare (Basel). 2022 Dec 7;10(12):2467. doi: 10.3390/healthcare10122467.

13. Nuñez-Leyva RE, Lozano-López TE, Calizaya-Milla YE, Calizaya-Milla SE, Saintila J. Excess Weight and Body Fat Percentage Associated with Waist Circumference as a Cardiometabolic Risk Factor in University Students. Scientifica (Cairo). 2022 Jan 5;2022:1310030. doi: 10.1155/2022/1310030.

14. Wang R, Wang Q. A Differential Study into Body Fat in Healthy and Hypertensive Populations Using Multiple Indexes. Diabetes Metab Syndr Obes. 2021 Jan 20;14:279-284. doi: 10.2147/DMSO.S267366.

15. Padilha CM, Pescuma JMS, Rodrigues ALCC, Bianchi LLT, de Almeida MS, Machado TAO, et al. Neck circumference as a marker of body adiposity in young to middle-aged adults. Nutrition. 2022 Jan;93:111496. doi: 10.1016/j.nut.2021.111496.

16. Filgueiras MS, Albuquerque FM, Castro APP, Rocha NP, Milagres LC, Novaes JF. Neck circumference cutoff points to identify excess android fat. J Pediatr (Rio J). 2020 May-Jun;96(3):356-363. doi: 10.1016/j.jped.2018.11.009.

17. Carvalho WRC, França AKTDC, Santos AMD, Padilha LL, Bogea EG. Appropriate neck circumference and waist-to-height ratio cut-off points as predictors of obesity and cardiovascular risk in adolescents. Rev Saude Publica. 2023 Apr 14;57:24. doi: 10.11606/s1518-8787.2023057004349.

18. Luordi C, Maddaloni E, Bizzarri C, Pedicelli S, Zampetti S, D'Onofrio L, et al. Wrist circumference is a biomarker of adipose tissue dysfunction and cardiovascular risk in children with obesity. J Endocrinol Invest. 2020 Jan;43(1):101-107. doi: 10.1007/s40618-019-01086-7.

19. López-González AA, Jover AM, Martínez CS, Artal PM, Bote SA, Jané BA, Ramírez-Manent JI. The CUN-BAE, Deurenberg Fat Mass, and visceral adiposity index as confident anthropometric indices for early detection of metabolic syndrome components in adults. Sci Rep. 2022 Sep 15;12(1):15486. doi: 10.1038/s41598-022-19343-w.

20. López-González AA, Tomás-Gil P, Coll Villalonga JL, Martí- Lliteras P, González San Miguel HM, Ramírez-Manent JI. Correlation between overweight and obesity scales and blood pressure values in 418.343 Spanish workers. Academic Journal of Health Sciences 2023;38(3):44-51 doi: 10.3306/AJHS.2023.38.03.44

21. Martínez-Almoyna Rifá E, Tomás-Gil P, Coll Villalonga JL, Ramírez-Manent JI, Martí-Lliteras P, López-González AA. Relationship between nonalcoholic fatty liver disease and liver fibrosis risk scales with overweight and obesity scales in 219,477 spanish workers. Academic Journal of Health Sciences 2023;38(4):92-100 doi: 10.3306/AJHS.2023.38.04.92

22. Kamińska MS, Lubkowska A, Panczyk M, Walaszek I, Grochans S, Grochans E, et al. Relationships of Body Mass Index, Relative Fat Mass Index, and Waist Circumference with Serum Concentrations of Parameters of Chronic Inflammation. Nutrients. 2023 Jun 18;15(12):2789. doi: 10.3390/nu15122789.

23. Molina-Luque R, Romero-Saldaña M, Álvarez-Fernández C, Bennasar-Veny M, Álvarez-López Á, Molina-Recio G. Equation Córdoba: A Simplified Method for Estimation of Body Fat (ECORE-BF). Int J Environ Res Public Health. 2019 Nov 15;16(22):4529. doi: 10.3390/ijerph16224529.

24. Zhuang Z, Yao M, Wong JYY, Liu Z, Huang T. Shared genetic etiology and causality between body fat percentage and cardiovascular diseases: a large-scale genome-wide cross-trait analysis. BMC Med. 2021 Apr 29;19(1):100. doi: 10.1186/s12916-021-01972-z.

25. Hu X, Wen J, Yu W, Yang L, Pan W, Xu K, et al. Associations of early-life exposure to famine with abdominal fat accumulation are independent of family history of diabetes and physical activity. Br J Nutr. 2021 Apr 28;125(8):943-950. doi: 10.1017/S0007114520003414.

26. Burridge K, Christensen SM, Golden A, Ingersoll AB, Tondt J, Bays HE. Obesity history, physical exam, laboratory, body composition, and energy expenditure: An Obesity Medicine Association (OMA) Clinical

Practice Statement (CPS) 2022. Obes Pillars. 2022 Jan 10;1:100007. doi: 10.1016/j.obpill.2021.100007.

27. Roshandel D, Lu T, Paterson AD, Dash S. Beyond apples and pears: sex-specific genetics of body fat percentage. Front Endocrinol (Lausanne). 2023 Oct 5;14:1274791. doi: 10.3389/fendo.2023.1274791.

28. Ko SH, Kim HS. Menopause-Associated Lipid Metabolic Disorders and Foods Beneficial for Postmenopausal Women. Nutrients. 2020 Jan 13;12(1):202. doi: 10.3390/nu12010202.

29. Moccia P, Belda-Montesinos R, Monllor-Tormos A, Chedraui P, Cano A. Body weight and fat mass across the menopausal transition: hormonal modulators. Gynecol Endocrinol. 2022 Feb;38(2):99-104. doi: 10.1080/09513590.2021.2004395.

30. Katzer K, Hill JL, McIver KB, Foster MT. Lipedema and the Potential Role of Estrogen in Excessive Adipose Tissue Accumulation. Int J Mol Sci. 2021 Oct 29;22(21):11720. doi: 10.3390/ijms222111720.

31. Saini S, Kaur Walia G, Pal Sachdeva M, Gupta V. Genomics of body fat distribution. J Genet. 2021;100:32.

32. Kassir R, Gimet P, Hupin D, Boutet C, Barthélémy JC, Roche F, et al. Brain alterations associated with overweight evaluated by body mass index or body fat index in an elderly population: the PROOF study. Front Endocrinol (Lausanne). 2023 May 26;14:1148068. doi: 10.3389/fendo.2023.1148068

33. Li CW, Yu K, Shyh-Chang N, Jiang Z, Liu T, Ma S, et al. Pathogenesis of sarcopenia and the relationship with fat mass: descriptive review. J Cachexia Sarcopenia Muscle. 2022 Apr;13(2):781-794. doi: 10.1002/jcsm.12901.

34. Merchant RA, Seetharaman S, Au L, Wong MWK, Wong BLL, Tan LF, et al. Relationship of Fat Mass Index and Fat Free Mass Index With Body Mass Index and Association With Function, Cognition and Sarcopenia in Pre-Frail Older Adults. Front Endocrinol (Lausanne). 2021 Dec 24;12:765415. doi: 10.3389/fendo.2021.765415.

35. Harrison S, Couture P, Lamarche B. Diet Quality, Saturated Fat and Metabolic Syndrome. Nutrients. 2020 Oct 22;12(11):3232. doi: 10.3390/nu12113232.

36. Muscella A, Stefàno E, Lunetti P, Capobianco L, Marsigliante S. The Regulation of Fat Metabolism During Aerobic Exercise. Biomolecules. 2020 Dec 21;10(12):1699. doi: 10.3390/biom10121699.

37. Waters DL, Aguirre L, Gurney B, Sinacore DR, Fowler K, Gregori G, et al. Effect of Aerobic or Resistance Exercise, or Both, on Intermuscular and Visceral Fat and Physical and Metabolic Function in Older Adults With Obesity While Dieting. J Gerontol A Biol Sci Med Sci. 2022 Jan 7;77(1):131-139. doi: 10.1093/gerona/glab111.

38. Di Iorgi N, Mittelman SD, Gilsanz V. Differential effect of marrow adiposity and visceral and subcutaneous fat on cardiovascular risk in young, healthy adults. Int J Obes (Lond). 2008 Dec;32(12):1854-60. doi: 10.1038/ijo.2008.170.

39. Sardinha LB, Teixeira PJ, Guedes DP, Going SB, Lohman TG. Subcutaneous central fat is associated with cardiovascular risk factors in men independently of total fatness and fitness. Metabolism. 2000 Nov;49(11):1379-85. doi: 10.1053/meta.2000.17716.

40. Kwon S, Han AL. The Correlation between the Ratio of Visceral Fat Area to Subcutaneous Fat Area on Computed Tomography and Lipid Accumulation Product as Indexes of Cardiovascular Risk. J Obes Metab Syndr. 2019 Sep;28(3):186-193. doi: 10.7570/jomes.2019.28.3.186.

41. Neeland IJ, Ross R, Després JP, Matsuzawa Y, Yamashita S, Shai I, et al. Visceral and ectopic fat, atherosclerosis, and cardiometabolic disease: a position statement. Lancet Diabetes Endocrinol. 2019 Sep;7(9):715-725. doi: 10.1016/S2213-8587(19)30084-1.

42. Cesaro A, De Michele G, Fimiani F, Acerbo V, Scherillo G, Signore G, et al. Visceral adipose tissue and residual cardiovascular risk: a pathological link and new therapeutic options. Front Cardiovasc Med. 2023 Jul 27;10:1187735. doi: 10.3389/fcvm.2023.1187735

43. Martínez-Rodríguez A, Rubio-Arias JA, García-De Frutos JM, Vicente-Martínez M, Gunnarsson TP. Effect of High-Intensity Interval Training and Intermittent Fasting on Body Composition and Physical Performance in Active Women. Int J Environ Res Public Health. 2021 Jun 14;18(12):6431. doi: 10.3390/ijerph18126431.

44. Paoli A, Cenci L, Pompei P, Sahin N, Bianco A, Neri M, et al. Effects of Two Months of Very Low Carbohydrate Ketogenic Diet on Body Composition, Muscle Strength, Muscle Area, and Blood Parameters in Competitive Natural Body Builders. Nutrients. 2021 Jan 26;13(2):374. doi: 10.3390/nu13020374.

45. Aguiló Juanola MC, López-González AA, Tomás-Gil P, Paublini H, Tárraga-López PJ, Ramírez-Manent JI. Influence of tobacco consumption on the values of different overweight and obesity scales in 418,343 spanish people. Academic Journal of Health Sciences 2023; 38 (6):111-7 doi: 10.3306/AJHS.2023.38.06.111

46. Molina-Luque R, Yañez AM, Bennasar-Veny M, Romero-Saldaña M, Molina-Recio G, López-González ÁA. A Comparison of Equation Córdoba for Estimation of Body Fat (ECORE-BF) with Other Prediction Equations. Int J Environ Res Public Health. 2020 Oct 29;17(21):7940. doi: 10.3390/ijerph17217940.

47. Domingo-Salvany A, Bacigalupe A, Carrasco JM, Espelt A, Ferrando J, Borrell C, et al. Propuestas de clase social neoweberiana y neomarxista a partir de la Clasificación Nacional de Ocupaciones 2011 [Proposals for social class classification based on the Spanish National Classification of Occupations 2011 using neo-Weberian and neo-Marxist approaches]. Gac Sanit. 2013 May-Jun;27(3):263-72. Spanish. doi: 10.1016/j.gaceta.2012.12.009.

48. Riutord Sbert P, Riutord Fe B, Riutord Fe N, Arroyo Bote S, López González AA, Ramírez Manent JI. Relationship between healthy habits and sociodemographic variables in the values of different atherogenic indices. Academic Journal of Health Sciences 2022;37(2):22-7 doi: 10.3306/AJHS.2022.37.02.22

49. Laja García AI, Samaniego Vaesken ML, Partearroyo T, Varela Moreiras G. Validated questionnaire to assess the hydration status in a healthy adult Spanish population: a cross sectional study. Nutr Hosp. 2019 Aug 26;36(4):875-883. English. doi: 10.20960/nh.02533.

50. Bosello O, Vanzo A. Obesity paradox and aging. Eat Weight Disord. 2021 Feb;26(1):27-35. doi: 10.1007/s40519-019-00815-4.

51. Wan H, Wang Y, Xiang Q, Fang S, Chen Y, Chen C, et al. Associations between abdominal obesity indices and diabetic complications: Chinese visceral adiposity index and neck circumference. Cardiovasc Diabetol. 2020 Jul 31;19(1):118. doi: 10.1186/s12933-020-01095-4.

52. Garg UK, Mathur N, Sahlot R, Tiwari P, Sharma B, Saxena A, et al.. Abdominal fat depots and their association with insulin resistance in patients with type 2 diabetes. PLoS One. 2023 Dec 8;18(12):e0295492. doi: 10.1371/journal.pone.0295492.

53. Powell-Wiley TM, Poirier P, Burke LE, Després JP, Gordon-Larsen P, Lavie CJ, et al. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation. 2021 May 25;143(21):e984-e1010. doi: 10.1161/CIR.0000000000000973.

54. Koenen M, Hill MA, Cohen P, Sowers JR. Obesity, Adipose Tissue and Vascular Dysfunction. Circ Res. 2021 Apr 2;128(7):951-968. doi: 10.1161/CIRCRESAHA.121.318093.

55. Karnes JH, Arora A, Feng J, Steiner HE, Sulieman L, Boerwinkle E, et al. Racial, ethnic, and gender differences in obesity and body fat distribution: An All of Us Research Program demonstration project. PLoS One. 2021 Aug 6;16(8):e0255583. doi: 10.1371/journal.pone.0255583.

56. Loh NY, Wang W, Noordam R, Christodoulides C. Obesity, Fat Distribution and Risk of Cancer in Women and Men: A Mendelian Randomisation Study. Nutrients. 2022 Dec 9;14(24):5259. doi: 10.3390/nu14245259.

57. Kang PS, Neeland IJ. Body Fat Distribution, Diabetes Mellitus, and Cardiovascular Disease: an Update. Curr Cardiol Rep. 2023 Nov;25(11):1555-1564. doi: 10.1007/s11886-023-01969-5.

58. Goodpaster BH, Bergman BC, Brennan AM, Sparks LM. Intermuscular adipose tissue in metabolic disease. Nat Rev Endocrinol. 2023 May;19(5):285-298. doi: 10.1038/s41574-022-00784-2.

59. Manzanero RZ, López-González AA, Tomás-Gil P, Paublini H, Martínez-Jover A, Ramírez-Manent JI. Cardiometabolic risk assessment in 28300 spanish waiters. Academic Journal of Health Sciences 2023; 39 (2):16-24 doi: 10.3306/AJHS.2024.39.02.16

60. Mohebbi Ortuño V, Lagrava Burgoa R, Aramayo Quiroga A, Liceras Escalante C, Apaza Quevedo B. Results of a health intervention program in 1094 bolivian mining workers. Academic Journal of Health Sciences 2022;37(1):48-51 doi: 10.3306/AJHS.2022.37.01.48

61. Celada-Roldana C, López Díez J, Cerezuela MA, Rider F, Tárraga-Marcos A, Tárraga-López PJ, et al. Efectos cardiovasculares de una intervención educativa nutricional en pacientes diabéticos con mal control. Academic Journal of Health Sciences 2023; 38 (6):57-65 doi: 10.3306/AJHS.2023.38.06.57

62. Lassale C, Fitó M, Morales-Suárez-Varela M, Moya A, Gómez SF, Schröder H. Mediterranean diet and adiposity in children and adolescents: A systematic review. Obes Rev. 2022 Jan;23 Suppl 1:e13381. doi: 10.1111/obr.13381.

63. Kolnes KJ, Petersen MH, Lien-Iversen T, Højlund K, Jensen J. Effect of Exercise Training on Fat Loss-Energetic Perspectives and the Role of Improved Adipose Tissue Function and Body Fat Distribution. Front Physiol. 2021 Sep 24;12:737709. doi: 10.3389/fphys.2021.737709.

64. D'Onofrio G, Kirschner J, Prather H, Goldman D, Rozanski A. Musculoskeletal exercise: Its role in promoting health and longevity. Prog Cardiovasc Dis. 2023 Mar-Apr;77:25-36. doi: 10.1016/j.pcad.2023.02.006.

65. Graff-Iversen S, Hewitt S, Forsén L, Grøtvedt L, Ariansen I. Associations of tobacco smoking with body mass distribution; a population-based study of 65,875 men and women in midlife. BMC Public Health. 2019 Nov 1;19(1):1439. doi: 10.1186/s12889-019-7807-9.

66. Flor-Alemany M, Marín-Jiménez N, Nestares T, Borges-Cosic M, Aranda P, Aparicio VA. Mediterranean diet, tobacco consumption and body composition during perimenopause. The FLAMENCO project. Maturitas. 2020 Jul;137:30-36. doi: 10.1016/j.maturitas.2020.04.002.

67. Kondo T, Nakano Y, Adachi S, Murohara T. Effects of Tobacco Smoking on Cardiovascular Disease. Circ J. 2019 Sep 25;83(10):1980-1985. doi: 10.1253/circj.CJ-19-0323.

68. Znyk M, Jurewicz J, Kaleta D. Exposure to Heated Tobacco Products and Adverse Health Effects, a Systematic Review. Int J Environ Res Public Health. 2021 Jun 21;18(12):6651. doi: 10.3390/ijerph18126651.

69. Hecht SS, Hatsukami DK. Smokeless tobacco and cigarette smoking: chemical mechanisms and cancer prevention. Nat Rev Cancer. 2022 Mar;22(3):143-155. doi: 10.1038/s41568-021-00423-4.