

Comparison of different overweight and obesity indexes in young adult Spanish workers

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Summary Background. Obesity is a major public health problem in both developed and underdeveloped countries due to its high prevalence and the complications it causes, such as type 2 diabetes, cardiovascular diseases, musculoskeletal and psychological disorders and avoidable lost life years.

Objectives. The aim of this study was to determine the prevalence of overweight and obesity in young Spanish adults using different scales.

Material and methods. Retrospective and cross-sectional study in 136,821 Spanish workers 18 to 34 years of age from different labour sectors. In this group, different scales related to overweight and obesity, such as BMI, waist-to-height ratio, and body fat estimators, such as CUNBAE, ECORE-BF, relative fat mass, Deuremberg formula and Palafolls formula, among others, were evaluated.

Results. 12.03% of women and 12.15% of men were obese according to BMI. The prevalence of obesity due to excess body fat with the gold standard CUN BAE scale was 28.09% in women and 27.11% in men. Most overweight and obesity scales using anthropometric parameters show a higher prevalence in men, while scales using body fat show a higher prevalence of obesity in women.

Conclusions. The prevalence of medium and high values of the different scales used to assess overweight and obesity can be considered high in the active population between 18 and 34 years of age, which implies secondary pathologies, loss of quality of life and premature death.

Key words: obesity, adipose tissue, body mass index.

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Background

Obesity has become a major public health problem in developed and many developing countries. In the last century, the WHO predicted it as the global epidemic of the 21st century, increasing from then until today to become a true pandemic [1].

Obesity has been widely associated with the appearance of different health conditions, such as diabetes, cardiovascular disease [2] and cancer, which present a continually increasing trend in relation to obesity, making the prevention of these pathologies a public health priority. Currently, the proportion of cancer that can be assigned to obesity, expressed as a fraction attributable to the population, is 11.9% in men and 13.1% in women [3] and is one of the most important causes of premature death. According to the World Health Organization, overweight and obesity are responsible for almost 3 million deaths and at least 35 million disability-adjusted life years worldwide [4]. Obesity can also lead to osteoarthritis and other chronic disabilities, as it increases mechanical stress on the cartilage of the knee joint and also increases the prevalence of osteoarthritis in non-weight bearing areas. A relationship between obesity and inflammation has been demonstrated, as fat tissue is the main

source of metabolically active cytokines, chemokines and mediators called adipokines. Adipokines, including adiponectin and leptin, regulate inflammatory immune responses in cartilage, which play a critical role in cartilage matrix degradation and bone resorption [5]. The increase in the prevalence of obesity, together with an aging population, especially in less developed countries, means that the burden of diseases due to obesity is expected to increase. For all these reasons, obesity is considered a major public health problem [6, 7].

A study published in *The Lancet Public Health* [8] analysed ten large cohort studies and estimated the extent to which body mass index (BMI), and particularly obesity, was associated with the number of years free of serious diseases. Setting normal weight as a reference, they reported a loss of disease-free years in men as 1.8 (95% CI: 1.3 to 4.9) for underweight, 1.1 (0.7 to 1.5) for overweight, 3.9 (2.9 to 4.9) for class I obesity and 8.5 (7.1 to 9.8) for class II–III obesity. In women, values were found to be 0.0 (-1.4 to 1.4) for underweight, 1.1 (0.6 to 1.5) for overweight, 2.7 (1.5 to 3.9) for class I obesity and 7.3 (6.1 to 8.6) for class II–III obesity.

Adulthood is defined as the age at which the human body reaches its maximum development and physical strength. It can be subdivided into three phases: early, middle and late adult-



hood, although there is no unanimous consensus on when each of these begins. For the purpose of this study, the workers included were considered to be either in early or young adulthood (between 18 and 34 years of age).

Objectives

The aim of this study was to determine the prevalence of overweight and obesity in young Spanish adults using different scales in order to be able to recommend prevention measures that could reduce obesity in this young population, and, consequently, the morbidity and mortality associated with it, as well as the social burden it entails and the years of life lost.

Material and methods

A retrospective and cross-sectional study was performed on 418,343 Spanish workers between 18 and 69 years of age during the period January 2018 to December 2019. Of these, 281,522 were excluded (281,217 for being over 34 years of age, 11 for not having the necessary parameters to calculate the overweight and obesity indexes, and 48 were not willing to participate), leaving 136,821 workers, of whom 59,608 were women and 77,213 were men (see Figure 1). Workers were selected from among those who attended their periodic occupational medical check-ups, who were from different Spanish geographical areas (Balearic Islands, Andalusia, Canary Islands, Valencian Community, Catalonia, Madrid, Castilla La Mancha, Castilla León, Basque Country) and those with different occupations, of which the most represented were hostelry, construction, commerce, health, public administration, transport, education, industry and cleaning.

The study population was obtained from the anonymised database of workers deposited in the repository of ADEMA-UIB (University of the Balearic Islands). This database comes from the occupational medical examinations carried out in the last 5 years in various occupational risk prevention services throughout the national territory (RD 688/2005 of 10 June and Law 31/95 on Occupational Risk Prevention). ADEMA's anonymisation system does not allow investigators to know the identity of the workers.

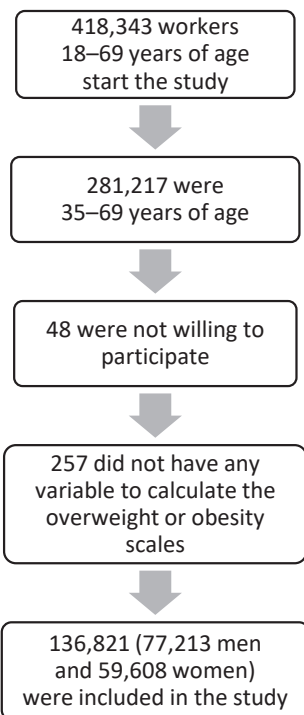


Figure 1. Participant flow chart

Inclusion criteria

- Between 18 and 34 years of age.
- Agreed to participate in the study and use their data for epidemiological purposes.

Anthropometric measurements were performed by the health personnel of the occupational health units after homogenising the measurement techniques. Weight (expressed in kilograms) and height (cm) were determined with a SECA 700 scale equipped with a SECA 220 telescopic height bar.

Waist circumference (cm) was measured with a SECA model 200 tape measure. The individual stood upright, feet together and upper limbs hanging on both sides of the body. The tape measure was then placed parallel to the ground at the height of the last floating rib.

The overweight and obesity indexes used include:

- Visceral adiposity index [9] (VAI):

$$\text{VAI} = \left(\frac{\text{WC}}{39.68 + (1.88 \times \text{BMI})} \right) \times \left(\frac{\text{TG}}{1.03} \right) \times \left(\frac{1.31}{\text{HDL}} \right)$$

$$\text{VAI} = \left(\frac{\text{WC}}{36.58 + (1.89 \times \text{BMI})} \right) \times \left(\frac{\text{TG}}{0.81} \right) \times \left(\frac{1.52}{\text{HDL}} \right)$$

- Body shape index (ABSI) [10]:

$$\text{ABSI} = \frac{\text{WC}}{\text{BMI}^{2/3} \times \text{height}^{1/2}}$$

- Normalised weight-adjusted index (NWA) [11]:

$$[(\text{weight}/10) - (10 \times \text{height}) + 10]$$

Weight is measured in kg and height in m.

- Conicity index [12]:

$$\frac{\text{waist circumference (in meters)}}{0.109} \times 1 / \sqrt{\frac{\text{weight (in kilogram)}}{\text{height (in meters)}}}$$

- Body mass index: weight (kg)/height² (metres). Obesity was considered as being over 30 kg/m².

- The waist-to-height ratio was higher when > 0.50 [13].
- Body surface index [14] (BSI):

$$\text{BSA} = w^{0.425} * h^{0.725} * 0.007184 \quad \text{BSI} = \frac{\text{WEIGHT}}{\sqrt{\text{BSA}}}$$

Calculated from the body surface area (BSA), where w represents weight in kg and h height in cm.

- Body Roundness Index [15] (BRI):

$$\text{BRI} = 364.2 - 365.5 \times \sqrt{1 - \left(\frac{\text{WC}/(2\pi)}{(0.5 \text{ height})^2} \right)}$$

The formulas used to estimate the percentage of body fat were the following:

- Relative fat mass [16]:

$$76 - (20 \times (\text{height}/\text{p waist}))$$

Height and waist circumference are expressed in metres.

- CUN BAE [17] (University of Navarra Body Adiposity Estimator Clinic):

$$-44.988 + (0.503 \times \text{age}) + (10.689 \times \text{gender}) + (3.172 \times \text{BMI}) - (0.026 \times \text{BMI}^2) + (0.181 \times \text{BMI} \times \text{sex}) - (0.02 \times \text{BMI} \times \text{age}) - (0.005 \times \text{BMI}^2 \times \text{gender}) + (0.00021 \times \text{BMI}^2 \times \text{age})$$

- **ECORE-BF (Equation Cordoba Estimator Body Fat) [18]:**
 $-97.102 + 0.123 (\text{age}) + 11.9 (\text{gender}) + 35.959 (\text{LnBMI})$
 In both the CUN BAE and ECORE-BF indexes, male is given a value of 0 and female 1, and cut-off points for obesity are 25% in men and 35% in women.
- **Palafolls formula [19]:**
 $\text{Men} = (\text{BMI}/\text{waist}) * 10 + \text{BMI}$
 $\text{Women} = (\text{BMI}/\text{waist}) * 10 + \text{BMI} + 10$.
- **Deuremberg formula [20]:**
 $1.2 \times (\text{BMI}) + 0.23 \times (\text{age}) - 10.8 \times (\text{gender}) - 5.4$
 Male = 0 Female = 1

An individual was considered a smoker if they had regularly consumed 1 or more cigarettes/day (or its equivalent in other types of consumption) during the last month or had quit smoking less than one year ago.

The type of work carried out by the participants was determined based on the 2011 National Classification of Occupations (CNO-11) and the Social Factors Group from the Spanish Society of Epidemiology [21]. Individuals were classified into two categories: white-collar workers, which included directors/managers, jobs requiring a university degree, sportsmen and artists, intermediate job categories and self-employed individuals without employees; and blue-collar workers, which included low-skilled workers.

Statistical analysis

Frequency was calculated for categorical variables and mean and standard deviation for quantitative variables. Bivariate anal-

ysis was performed using the Chi-square test (with a correction with Fisher’s exact test when conditions required it) and a Student’s *t*-Test for independent samples. Multivariate analysis was performed by binary logistic regression with the Wald method, with an Odds Ratio calculation and a Hosmer-Lemeshow goodness-of-fit test. The cut-off points were established by means of ROC curves determining sensitivity, specificity and Youden indices. The Pearson model was used to estimate the correlation between the different indexes. All statistical analysis was performed with the SPSS 27.0 program, and a *p*-value < 0.05 was considered statistically significant.

Ethical considerations

The study was approved by the Clinical Research Ethics Committee of the Illes Balears Health Area. All procedures were performed in accordance with the ethical standards of the institutional research committee and with the 2013 Declaration of Helsinki. All patients signed written informed consent documents before participating in the study.

Results

The mean values of the anthropometric variables were generally higher in men. In all cases, the differences observed between men and women were statistically significant. Almost 80% of the workers included were blue-collar and more than a third were smokers. All the data is included in Table 1.

The mean values of the different overweight and obesity indexes are higher in men, except for those that estimate body fat (CUN BAE, ECORE-BF, RFM, Palafolls formula, Deuremberg formula and body fat index), since it is well known that the percentage of normal body fat is higher in women. All the differences observed were statistically significant and are shown in Table 2.

Table 1. Socio-demographic, anthropometric, clinical and analytical characteristics of participants

	Women <i>n</i> = 59,608	Men <i>n</i> = 77,213	Total <i>n</i> = 136,821	
	Mean (SD)	Mean (SD)	Mean (SD)	<i>p</i>
Age (years)	27.8 (4.3)	27.6 (4.5)	27.7 (4.4)	< 0.0001
Height (cm)	163.0 (6.3)	176.0 (6.8)	170.4 (9.2)	< 0.0001
Weight (kg)	64.1 (14.2)	78.2 (14.7)	72.1 (16.1)	< 0.0001
Waist circumference (cm)	74.2 (10.4)	84.5 (11.3)	80.0 (10.6)	< 0.0001
	%	%	%	<i>p</i>
18–24 years	24.9	26.5	25.8	< 0.0001
25–29 years	34.9	33.4	34.0	
30–34 years	40.3	40.1	40.2	
White-collar	29.9	15.8	31.9	< 0.0001
Blue-collar	70.1	84.3	78.1	
Non-smokers	65.0	66.3	65.6	< 0.0001
Smokers	35.0	33.7	34.4	

Table 2. Mean values of overweight and obesity scales in young adults classified by gender

	Women <i>n</i> = 59,608	Men <i>n</i> = 77,213	Total <i>n</i> = 136,821	
	Mean (SD)	Mean (SD)	Mean (SD)	<i>p</i>
Waist-to-height ratio	0.46 (0.06)	0.48 (0.06)	0.47 (0.06)	< 0.0001
Body mass index	24.1 (5.1)	25.2 (4.3)	24.7 (4.7)	< 0.0001
CUN BAE scale	31.8 (7.2)	21.7 (6.7)	26.1 (8.6)	< 0.0001
ECORE-BF scale	32.0 (6.9)	21.8 (6.0)	26.3 (8.2)	< 0.0001
Relative fat mass	31.3 (5.39)	21.7 (5.1)	25.9 (7.1)	< 0.0001
Palafolls formula	37.4 (5.4)	28.19 (4.5)	32.2 (6.7)	< 0.0001

Table 2. Mean values of overweight and obesity scales in young adults classified by gender

	Women <i>n</i> = 59,608	Men <i>n</i> = 77,213	Total <i>n</i> = 136,821	
	Mean (SD)	Mean (SD)	Mean (SD)	<i>p</i>
Deuremberg formula	29.9 (6.2)	20.39 (5.5)	24.5 (7.5)	< 0.0001
Body fat index	27.0 (7.7)	21.59 (8.2)	24.0 (8.4)	< 0.0001
Normal weight-adjusted index	0.11 (1.36)	0.22 (1.4)	0.17 (1.36)	< 0.0001
Body roundness index	2.6 (1.2)	3.1 (1.1)	2.9 (1.2)	< 0.0001
Body shape index	0.070 (0.01)	0.075 (0.01)	0.073 (0.01)	< 0.0001
Visceral adiposity index	2.4 (1.4)	5.6 (4.8)	4.2 (4.0)	< 0.0001
Conicity index	1.09 (0.08)	1.17 (0.10)	1.13 (0.10)	< 0.0001
Body surface index	49.1 (8.2)	55.9 (7.9)	52.9 (8.7)	< 0.0001

Table 3. Area under the curve and cut-off points for body surface index and normalised weight-adjusted index classified by gender

	Women		Men	
	BSI	NWAI	BSI	NWAI
AUC (95% CI)	0.979 (0.978–0.980)	0.998 (0.997–0.998)	0.966 (0.965–0.968)	0.998 (0.998–0.999)
Cut-off	51.0	0.50	58.0	0.8
Sensitivity	91.7	98.5	90.8	94.7
Specificity	91.7	96.3	88.4	89.5
Youden index	0.834	0.948	0.792	0.842

Table 4. Prevalence of overweight and obesity in young adults according to the different indexes employed

	Women <i>n</i> = 59,608	Men <i>n</i> = 77,213	Total <i>n</i> = 136,821	
	% (95% CI)	% (95% CI)	% (95% CI)	<i>p</i>
Waist-to-height ratio > 0.50	17.2 (17.1–17.2)	32.4 (32.3–32.6)	25.8 (25.6–25.9)	< 0.0001
BMI overweight	20.3 (20.2–20.4)	32.6 (32.5–32.7)	27.2 (27.1–27.3)	< 0.0001
BMI obesity	12.0 (11.9–12.1)	12.2 (12.1–12.3)	12.1 (12.0–12.2)	
CUN BAE overweight	25.3 (25.1–25.4)	30.6 (30.5–30.7)	28.3 (28.2–28.4)	< 0.0001
CUN BAE obesity	28.1 (27.9–28.3)	27.1 (27.0–27.2)	27.5 (27.4–27.6)	
ECORE-BF overweight	27.1 (27.0–27.2)	34.3 (34.2–34.5)	31.2 (31.1–31.3)	< 0.0001
ECORE-BF obesity	28.1 (28.0–28.2)	26.6 (26.4–26.7)	27.2 (27.1–27.3)	
RFM obesity	27.7 (27.6–27.8)	34.3 (34.3–34.5)	31.2 (31.1–31.3)	< 0.0001
Palafolls overweight	37.4 (37.3–37.5)	22.6 (22.5–22.7)	29.0 (28.8–29.1)	< 0.0001
Palafolls obesity	61.0 (60.5–61.5)	76.6 (75.5–77.7)	69.8 (68.6–71.1)	
IMG Deuremberg overweight	41.4 (41.3–41.6)	31.1 (31.0–31.2)	35.6 (35.4–35.8)	< 0.0001
IMG Deuremberg obesity	39.2 (39.1–39.3)	16.6 (16.5–16.7)	26.5 (26.4–26.6)	
Body roundness index high	12.1 (12.0–12.2)	29.0 (28.9–29.1)	21.6 (21.5–21.7)	< 0.0001
Body shape index high	7.5 (7.4–7.6)	48.8 (48.7–48.9)	30.8 (30.6–31.0)	< 0.0001
Visceral adiposity index high	38.6 (38.5–38.8)	86.5 (85.4–87.7)	65.7 (64.8–66.6)	< 0.0001
Conicity index high	42.4 (42.3–42.5)	12.6 (12.5–12.8)	29.4 (29.2–29.6)	< 0.0001
Normal weight-adjusted index high	30.3 (30.2–30.4)	27.5 (27.4–27.6)	28.7 (28.5–28.9)	< 0.0001
Body surface index high	31.8 (31.7–31.9)	33.2 (33.1–33.3)	32.6 (36.3–36.9)	< 0.0001

ROC curves were used to establish cut-off points for BSI and NWAI that had not been established by the authors. The CUN BAE obesity gold standard is used to establish the above cut-off points (see Table 3).

Overweight and obesity were, in general, more prevalent in men, whereas the Deuremberg formula and the Conicity index were higher in women. All the differences observed show statistical significance (Table 4).

Discussion

Obesity is defined as a chronic disease characterised by an increase in fat mass and/or abnormal distribution of it and, con-

sequently, by an increase in weight, which produces changes at the metabolic and endocrine level, with increased morbidity and mortality and shorter life expectancy. The formula commonly used in clinical practice and in epidemiological studies is the body mass index (BMI), considering a person with a BMI equal to or greater than 30 kg/m² as obese [22]. However, BMI underestimates the prevalence of obesity by 50% compared to direct fat measurement techniques. Their relationship with adiposity is influenced by age, gender and race [22].

In this study, we aimed to determine the prevalence of overweight and obesity with different scales, and 20.30% of women were found to be overweight and 12.03% obese. In men, these figures rose to 32.58% overweight and 12.15% obese, according to BMI.

Previous studies have assessed overweight and obesity in different groups of people under 35 years of age. In terms of the Spanish population, data from the 2017 National Health Survey [23] showed somewhat lower obesity figures than ours, since obesity was found in 8.4% of males and 7.9% in females in the 18–24 age group, while in the 25–34 age group, the prevalence was 11.11% in males and 10.6% in females. Furthermore, the ENPE [24] study analysed anthropometric measurements in 809 Spaniards (394 men and 415 women) between 25–34 years of age. Interestingly, they reported higher values than ours regarding waist circumference (88.7 cm in men and 79.9 cm in women compared to the 84.5 cm and 74.2 cm, respectively, seen in our study), waist/height (0.51 in men and 0.49 in women, while we found 0.48 in men and 0.46 in women) and BMI (25.8 in men and 24.5 in women compared to 25.2 and 24.1 obtained in this study). Moreover, the prevalence of obesity was much higher than ours (22.8% in males and 20.5% in females), while our study indicates 12.2% and 12.0%, respectively.

In other countries, the incidence of obesity and overweight detected in this age group is lower. A study of 620 Mexican university students [25] showed a lower prevalence of overweight and obesity than that obtained by us, with 28.4% overweight and 11.1% obesity in men and 19.0% and 10.6% in women, respectively.

Another study carried out on 306 Colombian university students [26] presented overweight figures lower than ours (41.48% in men and 16.67% in women), with no differences between overweight and obesity. Lower figures were found in Brazilian university students of both genders [27], where 21.3% were overweight and 5.1% were obese. A possible explanation for these lower figures could be related to the educational level of the people included in these studies (university students), while in our study, 78.08% of the participants belonged to lower social classes.

The 2006 National Household Survey carried out in Peru [28] showed that in the age group of 20 to 29 years (7,633 men and 4,265 women), 30.9% of the men were overweight and 8.7% were obese, both lower than in our study. However, in women, the prevalence of overweight and obesity was higher than that reported in this study (30.8% of women were overweight and 10.9% obese).

Comparing a systematic analysis carried out worldwide in 2014, in which the BMI was used, with our work. In comparing our results with the three divisions of the European population performed in the study, our results were lower than in the three cases [29]. Central Europe, East Europe and Eastern Europe have higher percentages for both obesity and overweight. The same is seen if we compare our results with those obtained in Spain (62.3% overweight and 20.2% obesity for men, 46.5% overweight and 20.9% obesity for women) [29]. This could be explained by the fact that in our study the age range only went up to 34 years, while in this systematic review we made the comparison with a population older than 20 years with no upper age limit. If we also consider that overweight and obesity, in developed countries, have a higher prevalence in 55-year-old men and 60-year-old women, not having studied the age group over 34 years could explain these differences [29]. The most used formula to evaluate overweight and obesity is BMI; however, when calculated by the relationship between weight and height, it does not evaluate other dimensions, such as lean mass or muscle mass, so people who perform physical exercise can be classified as overweight due to a higher percentage of muscle mass. Similarly, people with normal weight can accumulate excess body fat due to a lack of muscle or sarcopenia, which makes it necessary to perform additional measurements, such as waist circumference and body fat proportion [22].

When determining obesity using different formulas (Table 4), with anyone of them the percentage of obese that we obtain in both sexes is more than double that obtained with the BMI. This is consistent with other publications in which the estimated

prevalence of obesity through the percentage of body fat is 2 to 6 times greater than those obtained by BMI [22], where BMI presents a good specificity but a low sensitivity to determine the excess of fat.

The largest differences in obesity values in both men and women are found between BMI and the Palafolls formula (12% versus 61% in women and 12.2% versus 76.6% in men).

We did not find any studies assessing predictive indexes of body fat (CUN BAE, ECORE-BF, RFM, Palafolls formula or Deuremberg Formula) or other indicators related to overweight and obesity in young adults utilising the scales we used (BRI, ABSI, NWA, VAI, body surface index, Conicity index) in this age group, so we cannot make a comparison with our results.

The first step to address a risk factor is to identify the pathophysiological problem, and not diagnosing obesity in people with excess adiposity creates a loss of opportunity to act on changing lifestyle habits in those with this factor risk profile [30].

This constitutes a very important element to achieve stopping the increase in obesity before 2025. Established by the member states of the World Health Organization in 2013, as an essential target to increase the health of the population in relation to non-communicable diseases [31]. Young adults are in a period of transition from adolescence to adulthood, and therefore have greater autonomy in decision making, which makes them a vulnerable group for the acquisition of unhealthy lifestyles that can lead to overweight and obesity [32]. In addition, this population is one that least frequents primary care consultations, so it is very difficult to establish a diagnosis of obesity in them.

The transfer of such information from medical consultations to primary care physicians can help with this disease and facilitate prevention and treatment.

Strengths and limitations of the study

Importantly, our study used a large sample size (more than 136,000 people), making it the largest population-based study in this age group to assess overweight and obesity in the world to date. Also noteworthy is the large number of overweight and obesity scales analysed, some of which have never been used in this age group.

As limitations, it should be noted that our data is based on the Spanish population, so this cannot be extrapolated to other countries. When dealing with the working population, it excludes groups of unemployed people and students. In addition, only those patients who have attended company medical check-ups are included. Furthermore, for two of the indices used, the BSI and the NWA, cut-off points were calculated based on the CUN BAE. The CUN BAE was chosen because it is the gold standard for body fat prediction scales, and the values of the Youden index of the BSI and the NWA obtained were also very high. Finally, as it is a cross-sectional study, it does not allow for establishing causal relationships between the assessed factors.

Conclusions

The prevalence of overweight and obesity assessed with the different scales used can be considered high in the working population between 18 and 34 years of age in Spain.

Overweight and obesity constitute pathologies with great socio-sanitary repercussions and which affect quality of life, avoidable lost life years in the population and a significant expense for society and the health system. Therefore, the detection of this problem in company examinations and its subsequent communication to primary care services can constitute an important element in the prevention of overweight, obesity and all the secondary pathologies and consequences derived from them.

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