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Influence of Physical Activity, Mediterranean Diet, Smoking, and Different Sociodemographic Variables on the Prevalence of Diabesity

ABSTRACT

Background: Diabesity is a pathological entity that encompasses the presence of obesity and type 2 diabetes in the same individual and, as occurs with both entities, its prevalence is increasing in industrialized countries. The objective of this study is to determine the influence of healthy habits and sociodemographic variables on the occurrence of diabesity.

Methods: Descriptive, cross-sectional study in 1457 Spanish workers in which the influence of healthy habits such as physical exercise determined with the International. Physical Activity Questionnaire (IPAQ), adherence to the Mediterranean diet, and tobacco consumption were assessed, as well as sociodemographic variables such as age, sex, and social class on the prevalence of diabesity.

Results: The prevalence of diabesity determined with seven scales increased as the level of physical activity decreased and adherence to the Mediterranean diet decreased. In the multivariate analysis, the variables that most influenced the appearance of diabesity were, in order, age over 50 years, male sex, and low or moderate physical activity. High adherence to the Mediterranean diet also had an inverse influence on diabesity, although the results obtained were not always significant; while tobacco consumption, Mediterranean diet, and social class II-III had no influence on almost any scale.

Conclusions: Age is the risk factor that most increases the risk of diabesity, followed by the male sex. (Clin Diabetol 2022, 11; 2: 90–96)

Keywords: obesity, diabetes mellitus, diabesity, physical activity, Mediterranean diet

Introduction

Obesity is nowadays considered a major public health problem in the western world and is growing exponentially to the point of pandemic proportions [1]. Many publications relate excess weight, especially obesity, to the increase in several chronic pathologies, among which cardiovascular diseases [2], different types of cancer [3–4], osteoarticular [5], and respiratory diseases [6] stand out. It is therefore considered an important risk factor for general morbidity.

Obesity is defined as a chronic process characterized by a significant increase in fat mass [7] and consequently an increase in body weight. In epidemiological studies, the methods most commonly used to establish the diagnosis are anthropometric, according to which a person is considered obese when his or her body mass index is equal to or exceeds 30 kg/m^2.

Several publications have established the increased risk of suffering type 2 diabetes mellitus in people who

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are overweight and particularly obese, among other factors, due to greater insulin resistance. Individuals with a greater accumulation of fat in the abdominal waist, central obesity, present a higher risk of insulin resistance.

Our study focuses on diabesity, a new concept that brings together two serious pathologies, obesity and type 2 [8–10] diabetes. In most cases, obesity appears prior to diabetes and is often responsible for the onset of diabetes, to such an extent that it is considered the most important cause of the increase in the prevalence of type 2 diabetes worldwide. Although body mass index (BMI) is the most commonly used variable in epidemiological studies to evaluate overweight and obesity — as it is a mathematical ratio between the mass and the height of the individual — it does not evaluate other dimensions such as lean mass or muscle mass, so people who exercise regularly can be classified as overweight due to their higher percentage of muscle mass. Similarly, individuals with normal weight and low muscle mass may have excess body fat. This makes it necessary to use other obesity assessment measures such as waist circumference and body fat measurement.

In the approach and prevention of obesity and type 2 diabetes, interventions aimed at modifying lifestyles are fundamental [11]. The aim of this study was to assess the influence of physical activity assessed with the International. Physical Activity Questionnaire (IPAQ), the Mediterranean diet, tobacco consumption, age, sex, and social class on the appearance of diabesity (diabetes + obesity).

Methods

A retrospective, cross-sectional study was conducted on 1584 Spanish workers during the period January 2017 and December 2017. A total of 127 were excluded (69 not accepting to participate and 58 not having the required age) leaving 1457 workers who were included in the study, 718 of whom were women (mean age 43.30 years) and 739 men (mean age 46.02 years). The workers were selected from among those attending periodic occupational medical examinations.

Inclusion criteria:

— aged between 18 and 67 years;

— being an active worker;

— belonging to one of the companies collaborating in the study;

— agreeing to participate in the study.

The anthropometric measurements of height and weight, clinical and analytical, were performed by the health personnel of the different occupational health units participating in the study after the measurement techniques had been homogenized.

Parameters related to diabesity included in the assessment:

— A height and weight-measuring scale: model SECA 700 with 200 kg capacity with an added SECA 220 telescopic measuring rod with 60–200 cm range was used to measure weight and height.

— Abdominal waist and hip circumference were measured with a SECA 20 tape measure. The person stood upright, feet together and trunk erect, abdomen relaxed, and upper limbs hanging on both sides of the body. The tape measure was placed parallel to the ground at the level of the last floating rib (waist) and horizontal to the hip (hips). Blood pressure was measured in the supine position with a calibrated OMRON M3 automatic sphygmomanometer after 10 minutes of rest. Three determinations were made at one-minute intervals and the mean value of the three was obtained. Blood tests were obtained by peripheral venipuncture after a 12-hour fasting period. Samples were sent to the reference laboratories and processed within 48–72 hours. Automated enzymatic methods were used for blood glucose, total cholesterol, and triglycerides. Values are expressed in mg/dL. High-density lipoprotein (HDL) was determined by precipitation with dextran sulfate Cl2Mg, and values are expressed in mg/dL. Low-density lipoprotein (LDL) was calculated using the Friedewald formula (provided that triglycerides were less than 400 mg/dl). Values are expressed in mg/dL. Friedewald formula: LDL = total cholesterol – HDL – triglycerides/5.

Blood glucose figures were classified according to the recommendations of the American Diabetes Association [12]. Patients with a previous diagnosis, those with a blood glucose figure greater than or equal to 126 mg/dL, those with an HbA1c ≥ 6.5%, or who were taking hypoglycemic treatment were classified as diabetic. Body mass index is calculated by dividing weight by height in meters squared. Obesity is considered to be 30 kg/m^2 or more.

Five formulas were used to estimate the percentage of body fat:

1. Clínica Universidad de Navarra Body Adiposity Estimator (CUN BAE) [13]:
   $-44.988 + (0.503 \times \text{age}) + (10.689 \times \text{sex}) + (3.172 \times \text{BMI}) - (0.026 \times \text{BMI}^2) + (0.181 \times \text{BMI} \times \text{sex}) - (0.02 \times \text{BMI} \times \text{age}) - (0.005 \times \text{BMI}^2 \times \text{sex}) + (0.00021 \times \text{BMI}^2 \times \text{age})$

Where male equals 0 and female equals 1. The CUN BAE cut-off points for obesity are from 25% in men and 35% in women.

2. Equation Córdoba for Estimation of Body Fat (ECORE-BF) [14]

   $-97.102 + 0.123$ (age) $+ 11.9$ (sex) $+ 35.959$ (LBMI)

   Where male equals 0 and female equals 1. The cut-off points are the same as CUNBAE.
3. Palafolls formula [15]

   Women = ([BMI/AC] $\times$10) + BMI + 10; Men = ([BMI/AC] $\times$10) + BMI

   The authors propose the same cut-off points as CUN BAE.
4. Deuremberg fat mass index [16]

   Fat mass % = 1.2 (BMI) + 0.23 $\times$ (Age in years) – 10.8 $\times$ (sex) – 5.4

   Where female equals 0 and male equals 1. Obesity is considered as from 25% in men and 32% in women.
5. Relative fat mass [17] is calculated with the following formula where height and waist circumference are expressed in meters.

   Women: 76 – (20 $\times$ (height/waist)); Men: 64 – (20 $\times$ (height/waist))

   The cut-off points for obesity are the same as in the Deuremberg scale.

Body fat was determined by bioelectrical impedance measurement using a Tanita BC-420MA monitor. The Gallagher criteria [18] were used to classify this percentage.

A smoker was defined as a person who had regularly consumed at least 1 cigarette/day (or the equivalent in other types of consumption) in the previous month or had quit smoking less than a year before.

Social class was determined from the 2011 National Classification of Occupations (CNO-11) and based on the proposal made by the social determinants group of the Spanish Society of Epidemiology [19]. We opted for classification in three categories: Class I. Directors/managers, university professionals, athletes, and artists. Class II. Intermediate occupations and self-employed workers without employees. Class III. Unskilled workers.

Diet was assessed by means of the "Mediterranean diet adherence questionnaire" [20] used in the Predimed study, which includes 14 questions rated with 0 or 1 point each. Scores below 9 are considered low adherence and above 9, good adherence.

Physical activity was determined by means of the IPAQ [21], a 7-question self-administered questionnaire that assesses the physical activity performed in daily life in the previous week.

Statistical analysis

A descriptive analysis of the categorical variables was performed, by calculating the frequency and distribution of responses for each one. For quantitative variables, the mean and standard deviation were calculated, while for qualitative variables, the percentage was calculated. The bivariate association analysis was performed using the Chi-square test (with correction using Fisher's exact statistic when conditions required it) and Student's t-test for independent samples. For the multivariate analysis, binary logistic regression was used with the Wald method, with the calculation of the odds ratio and the Hosmer-Lemeshow goodness-of-fit test. Statistical analysis was performed with the SPSS 27.0 program, with an accepted statistical significance level of 0.05.

Ethical considerations and aspects

The study was approved by the Clinical Research Ethics Committee of the Balearic Islands Health Area no. IB 4383/20. 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

Table 1 shows the values of the anthropometric, clinical, analytical, sociodemographic, and healthy habit variables of the population studied. It can be observed that the values were worse among men, except for total cholesterol and tobacco consumption.

The prevalence of diabesity with the different scales decreased as the level of physical exercise increased; this situation was seen in both men and women. (Tab. 2).

The prevalence of diabesity with the different scales was lower in the group with high adherence to the Mediterranean diet in men and women, although the differences observed were not always statistically significant (Tab. 3).

In the multivariate analysis by means of binary logistic regression, the covariates established were male, aged 50 years or above, smoker, low or moderate physical activity, low adherence to the Mediterranean diet, and social class II–III.

Sex and age were the only variables to display an influence on all the diabesity scales analyzed. Age showed the greatest influence with odds ratios ranging from 1.91 (95% CI 1.51–2.42) for body fat with bioimpedance and 5.30 (95% CI 2.71–10.37) for the Deuremberg formula. All results are presented in Table 4.

Discussion

The results of our study show that the prevalence of diabesity with all the models analyzed and in both sexes is lower in people who exercise regularly, mainly

Table 1. Characteristics of the population

	Women (n = 718) mean (SD)	Men (n = 739) mean (SD)	Total (n = 1457) mean (SD)	P
Age [years]	43.30 (8.44)	46.02 (8.50)	44.68 (8.57)	< 0.0001
Height [kg]	66.29 (12.29)	82.24 (13.81)	74.38 (15.32)	< 0.0001
Weight [m]	1.62 (0.06)	1.73 (0.07)	1.68 (0.09)	< 0.0001
BMI [kg/m²]	25.36 (4.61)	27.40 (4.13)	26.39 (4.49)	< 0.0001
Waist [cm]	89.44 (16.36)	97.00 (10.65)	93.27 (14.27)	< 0.0001
Relative fat mass [%]	38.56 (7.34)	28.51 (4.98)	33.46 (8.02)	< 0.0001
CUN BAE [%]	35.91 (6.20)	27.23 (5.69)	31.51 (7.36)	< 0.0001
ECORE-BF [%]	35.85 (6.46)	27.21 (5.56)	31.47 (7.41)	< 0.0001
Palafolls formula [%]	38.22 (4.73)	30.22 (4.28)	34.16 (6.03)	< 0.0001
Deuremberg formula [%]	34.99 (6.28)	27.26 (5.75)	31.07 (7.15)	< 0.0001
Body fat impedance [%]	34.34 (9.91)	29.97 (8.17)	32.12 (9.33)	< 0.0001
Hip [cm]	105.78 (13.22)	108.77 (10.27)	107.29 (11.91)	< 0.0001
Systolic blood pressure [mmHg]	121.31 (17.05)	133.76 (18.11)	127.62 (18.66)	< 0.0001
Diastolic blood pressure [mmHg]	75.03 (10.58)	80.63 (11.43)	77.87 (11.36)	< 0.0001
Cholesterol [mg/dL]	186.02 (31.14)	183.37 (31.72)	184.67 (31.46)	0.108
HDL [mg/dL]	60.18 (13.55)	49.83 (12.16)	54.93 (13.86)	< 0.0001
LDL [mg/dL]	107.88 (28.16)	108.94 (29.15)	108.42 (28.66)	0.483
Triglycerides [mg/dL]	86.57 (43.59)	119.55 (87.42)	103.30 (71.28)	< 0.0001
Glycemia [mg/dL]	92.16 (16.31)	98.68 (19.54)	95.47 (18.30)	< 0.0001
	%	%	%	P
< 35 years	16.71	10.42	13.52	< 0.0001
35–49 years	57.80	51.01	54.36	
≥ 50 years	25.49	38.57	32.12	
Social class I	18.94	8.80	13.80	< 0.0001
Social class II	63.65	82.67	73.30	
Social class III	17.41	8.53	12.90	
No tobacco	71.87	72.94	72.41	< 0.0001
Yes tobacco	28.13	27.06	27.59	
MET low	23.68	19.08	21.35	< 0.0001
MET moderate	48.05	36.4	42.14	
MET high	28.27	44.52	36.51	
Adherence to Mediterranean diet low	36.49	48.17	42.42	< 0.0001
Adherence to Mediterranean diet high	63.51	51.83	57.58	

The χ test was used to determine the difference between the prevalence. The T-Student test was used to determine the difference between the means
BMI — body mass index; CUN BAE – Clinica Universitaria de Navarra Body Adiposity Estimator; ECORE-BF — Equation Córdoba for Estimation of Body Fat; HDL — high-density lipoprotein; LDL — low-density lipoprotein; MET — metabolic equivalent for task; SD — standard deviation

intensely. The same trend is found in people with high adherence to the Mediterranean diet. The factors that most increase the risk of presenting diabesity are male sex and age over 50 years, according to the results of the multivariate analysis; while tobacco consumption and social class show no influence.

We have found no studies that assess the influence of physical exercise, diet, smoking, or sociodemographic variables on the prevalence of diabesity, so a direct comparison cannot be established with our results. However, we have seen studies that assess the influence of the aforementioned variables on obesity and type 2 diabetes, and it is these studies that we use to make a comparison with our results.

As in our study, where a higher prevalence of diabesity is observed in men, data from various Spanish population surveys in people over 16 years of age also found this association [22].

Some authors discovered a relationship between racial and ethnic aspects and the increase in the prevalence of type 2 diabetes and obesity, possibly due to different dietary habits, levels of physical activity, and

Table 2. Prevalence of diabesity with different obesity scales according to physical activity by sex

	Women				Men			
	MET low n = 170	MET moderate n = 345	MET high n = 203		MET low n = 141	MET moderate n = 269	MET high n = 329	
Diabesity	%	%	%	P	%	%	%	P
Body mass index	2.35	0.87	0.00	< 0.0001	3.55	2.97	2.43	< 0.0001
Relative fat mass	4.71	1.45	0.49	< 0.0001	7.09	5.20	3.04	< 0.0001
Deuremberg formula	4.71	1.45	0.49	< 0.0001	7.09	6.32	2.74	< 0.0001
Palafolls formula	4.71	1.45	0.49	< 0.0001	7.09	6.69	3.34	< 0.0001
CUN BAE	4.71	1.45	0.49	< 0.0001	6.38	6.32	2.74	< 0.0001
ECORE-BF	4.71	1.45	0.49	< 0.0001	6.38	6.32	2.74	< 0.0001
Body fat impedance	36.47	1.45	28.57	< 0.0001	56.03	51.67	41.95	< 0.0001

The chi-square test was used to determine the difference between the prevalence
CUN BAE — Clinica Universitaria de Navarra Body adiposity Estimator; ECORE-BF — Equation Córdoba for Estimation of Body Fat; MET — metabolic equivalent for task

Table 3. Prevalence of diabesity with different obesity scales according to healthy food by sex

	Women			Men		
	Adherence to Mediterranean diet low n = 262	Adherence to Mediterranean diet high n = 456		Adherence to Mediterranean diet low n = 356	Adherence to Mediterranean diet high n = 383	
Diabesity	%	%	P	%	%	P
Body mass index	0.76	0.70	< 0.0001	2.81	2.67	ns
Relative fat mass	1.91	1.77	< 0.0001	5.06	4.18	< 0.0001
Deuremberg formula	1.53	ns	< 0.0001	5.06	4.70	< 0.0001
Palafolls formula	1.53	ns	< 0.0001	5.62	4.96	< 0.0001
CUN BAE	1.53	ns	< 0.0001	4.78	4.70	ns
ECORE-BF	1.53	ns	< 0.0001	4.78	4.70	ns
Body fat impedance	38.93	31.14	< 0.0001	56.46	40.47	< 0.0001

The chi-square test was used to determine the difference between the prevalence
CUN BAE — Clinica Universitaria de Navarra Body adiposity Estimator; ECORE-BF — Equation Córdoba for Estimation of Body Fat

sleep cycles caused by different lifestyles [23]. These aspects were not assessed in the present study.

Most of the risk factors for obesity and type 2 diabetes are related to unhealthy lifestyle habits, including diet and physical exercise, and it is, therefore, important to act preventively on these unhealthy habits from a very early age [24]. Public health interventions should focus primarily on diabesity and unhealthy lifestyles, acting preferentially on sedentary lifestyles, the dietary system, and socioeconomic factors in general in order to be more effective [25].

Our work found an inverse relationship between a high level of physical activity and the presence of type 2 diabetes and obesity; this effect of exercise was found in practically all the studies analyzed [26–28]. We discovered a similar effect to that of physical exercise with the Mediterranean diet and the prevalence of diabetes and obesity, and our results are supported by those obtained by other authors [29–30].

The strengths of this study include the large sample size (over 1400 people); the inclusion of the social class variable, which is little used by other authors; and the variety of scales used to determine diabesity, specifically seven.

The most important contribution of our study is the assessment of the influence of physical exercise, diet, social class, and smoking on the prevalence of diabesity. Although there are other publications that evaluate the influence of these variables on obesity and diabetes mellitus, we are not aware of any study to date that evaluates both together (diabesity).

A fundamental limitation of the study is the fact that, since it deals with the working population, it does

Table 4. Binary logistic regression

	Men	Age ≥ 50 years	Smokers	MET low-moderate	Adherence to Mediterranean diet low	Adherence to Mediterranean diet high
Diabesity	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)
Body mass index	2.47 (1.02– 6.00)	5.29 (2.20– 12.75)	ns	ns	ns	ns
Relative fat mass	2.07 (1.08– 3.98)	4.80 (2.48– 9.28)	ns	ns	ns	ns
Deuremberg formula	2.49 (1.28– 4.85)	5.30 (2.71– 10.37)	ns	2.57 (1.22– 5.40)	ns	ns
Palafolls formula	2.64 (1.36– 5.10)	5.24 (2.74– 10.03)	ns	2.17 (1.08– 4.35)	ns	ns
CUN BAE	2.43 (1.25– 4.75)	5.14 (2.62– 10.08)	ns	2.55 (1.21– 5.37)	ns	ns
ECORE-BF	2.49 (1.28– 4.81)	5.15 (2.60– 10.11)	ns	2.50 (1.22– 5.40)	ns	ns
Body fat bioimpedance	1.58 (1.26– 1.99)	1.91 (1.51– 2.42)	0.77 (0.60– 0.99)	1.57 (1.23– 2.00)	1.59 (1.27– 1.99)	4.40 (2.88– 6.73)

In all cases $p < 0.001$
CI — confidence interval; CUN BAE — Clinica Universitaria de Navarra Body adiposity Estimator; ECORE-BF — Equation Córdoba for Estimation of Body Fat; MET — metabolic equivalent for task; ns — non-significance; OR — odds ratio

not include people who are unemployed, retired, or either under 18 or over 67 years of age, so the results cannot be extrapolated to the general population as they are not representative of it.

Conclusions

The factors that produce a greater increase in the risk of diabesity are advanced age, male sex, and a sedentary lifestyle. High adherence to the Mediterranean diet has an inverse influence on diabesity, although the results obtained are not always significant, whereas tobacco consumption and belonging to the least favored social classes do not seem to have an influence.

Conflict of interest

None declared.

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