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ARÁN

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Trabajo Original

Obesidad y síndrome metabólico

Trends in the association between smoking history and general/central obesity in Catalonia, Spain (1992-2003)

Tendencias en la asociación entre el historial tabáquico y la obesidad general/central en Cataluña, España (1992-2003)

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Abstract

Objectives: To examine trends in the relationship between smoking history and both general and central fatness in adults from a Mediterranean setting.

Materials and methods: The ENCAT 1992-1993 and 2002-2003 surveys were used; samples consisted of 482 men, 589 women from 1992-1993, and 515 men, 613 women from 2002-2003, aged 25-60 years. Measured anthropometry and self-reported data on smoking habits, diet, lifestyle and SES were collected. General fatness was defined as WHO's BMI overweight and obesity, and central fatness was defined as WHO's Increased-Risk-for-metabolic-complications Waist Circumference (IR WC) and Substantially-Increased-Risk WC (SIR WC). Simple logistic regression was used to estimate multivariate-adjusted associations between general/central fatness and smoking history.

Results: By 2002-2003, most associations observed in 1992-1993 had been strongly attenuated: only male current-heavy-smoking remained associated with IR/SIR WC (three-fold) and female current-moderate-smokers were 0.57 times less likely to have an IR/SIR WC ($p < 0.10$).

Conclusions: Although causality cannot be established, results suggest a positive association between heavy smoking and central fatness among men, but no association between former smoking and general/central fatness; findings strengthen arguments for promoting smoking cessation to reduce smoking –and obesity– associated morbidity and mortality.

Key words:

Obesity. Tobacco smoking. Body mass index. Waist circumference. Nutrition surveys.

Resumen

Objetivos: examinar las tendencias en la relación entre el historial tabáquico y el exceso de peso general y central, en adultos de una región mediterránea.

Materiales y métodos: se utilizaron las encuestas ENCAT 1992-1993 y 2002-2003. Tamaño muestral: 482 hombres, 589 mujeres de 1992-1993, y 515 hombres, 613 mujeres de 2002-2003, de edades comprendidas entre 25-60 años. Se recogieron medidas antropométricas y datos autoinformados sobre hábito tabáquico, dieta, estilo de vida y estado socioeconómico (ESE). El exceso de peso general se definió como sobrepeso y obesidad según IMC (clasificación OMS), y el central como el "Riesgo Aumentado de enfermedad metabólica según el Perímetro de la Cintura" (RA PC) y el "Riesgo Aumentado Sustancialmente de enfermedad metabólica según el Perímetro de la Cintura" (RAS PC) (clasificación OMS). Se utilizó la regresión logística simple para estimar asociaciones multivariantes ajustadas entre exceso de peso e historial tabáquico.

Resultados: en 2002-2003, la mayoría de las asociaciones observadas en la primera encuesta se vieron considerablemente atenuadas: únicamente en varones fumadores actuales de más de 20 cigarrillos/día se mantuvo la asociación con RA/RAS PC (siendo el triple que en 2002-2003) y las mujeres fumadoras moderadas resultaron tener 0,57 veces menos probabilidades de tener un RA/RAS PC ($p < 0,10$).

Conclusiones: a pesar de no poder establecer una causalidad, los resultados sugieren una asociación positiva entre fumar más de 20 cigarrillos/día y el exceso de peso central entre los hombres, pero ninguna asociación entre el extabaquismo y el exceso de peso general/central; estos hallazgos refuerzan los argumentos para promover el abandono del tabaco y poder así reducir la morbimortalidad asociada al tabaquismo y la obesidad.

Palabras clave:

Obesidad. Hábito de fumar. Índice de masa corporal. Circunferencia de la cintura. Encuestas nutricionales.

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Conflict of interests: All authors declare that: a) the funder Body (Generalitat of Catalonia) had no direct say in the survey methods or outcome beyond providing funding for materials and personnel, and had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript; and b) they have no conflicts of interest to declare.

Disclaimer: The views expressed in the submitted article are the authors' own and not an official position of the funding Body of the surveys.

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INTRODUCTION

In developed countries, the most important modifiable factors recognised as responsible for excess mortality and morbidity at the population level are tobacco smoking and obesity (1). Smoking cessation has been associated with increased risk of weight gain (2). In addition, it has been suggested that current smoking –particularly of high intensity– may increase insulin resistance and may thus be associated with central fat accumulation (3,4), which could increase the risk of diabetes and metabolic syndrome and, hence, the risk of cardiovascular disease (5,6). Thus in addition to more direct pathways, smoking may also contribute to morbidity and mortality indirectly through an influence on obesity, particularly as numerous studies suggest that central fatness is a more important determinant of disease risk than is generalized obesity (7). Individuals with elevated waist circumference (WC), a marker of abdominal fat accumulation, appear to have higher risks of developing diabetes (8), hypertension (9) and CVD (10) than those with elevated BMI alone.

Although the literature on the obesity-smoking relationship is accumulating (4,5,11-13), a greater pool of evidence is needed, especially on the central obesity-smoking relationship, with some very recent studies in Asian populations among which the prevalence of central obesity is greater than that of Caucasians (4,13). In particular, it is crucial to explore both the emerging evidence that central fatness and current heavy smoking may co-occur, and of the attenuation over the longer term of the weight status-smoking cessation relationship. Moreover, when possible, it is important to assess whether and how the rising prevalence of obesity in the general population may influence relationships observed between smoking and body weight.

The aim of this paper is to contribute to the understanding of these issues by examining the relationships between past and current tobacco use and both BMI and WC in a Mediterranean area with high smoking (14) and obesity rates (15).

OBJECTIVES

- To examine trends in the association between smoking and both general/central fatness after adjusting for possible confounders.
- To understand how these relationships change with temporal trends in the prevalence of both obesity and smoking.

METHODS

ETHICS STATEMENT AND INFORMED CONSENT

Before starting the fieldwork, the two Evaluations of the Nutritional Status of the Catalan Population (surveys ENCAT 1992-1993 and ENCAT 2002-2003) were ethically approved by the Catalan Department of Health. The two surveys were coordinated by the Fundación para la Investigación Nutricional (FIN) (Nutritional Research Foundation) of the University of Barcelona (formerly the Centre de Reserca en Nutrició Comunitària - CRENC, Community Nutrition Research Centre).

Written informed consent was obtained from all participants before joining the ENCAT surveys. All data were recorded manually *i.e.* pen-and-paper. The data were made anonymous when recorded electronically i.e. the respondents' contact details were not entered into the survey database. Instead, the FIN assigned ID numbers to each respondent and used these assigned ID numbers in the analysis process.

CONDUCTION OF THE SURVEYS

The Evaluation of the Nutritional Status of the Catalan Population (ENCAT) is a regional survey carried out by the Department of Health of the Catalan Government and co-ordinated by the FIN (formerly the CRENC). So far, two surveys have been conducted: the ENCAT 1992-1993 and the ENCAT 2002-2003. Samples of both surveys were stratified according to household size and randomized into subgroups, with Catalan municipalities being the primary sample units and individuals within these municipalities comprising the final sample units. Samples were selected by considering the proportion of the number of inhabitants and the specific weight of each municipality in the sample and were obtained from the census registers of the selected municipalities. ENCAT's random sample population consisted of civilian non-institutionalized individuals aged 6 to 75, living in 82 Catalan municipalities of different sizes (ENCAT 1992-1993 with an n = 2,757 and ENCAT 2002-2003 with an n = 2,160). The response rate for the first survey was 68.9% and for the second 66.0%. Further details on sampling have been described elsewhere (16).

Recruitment of each of the selected sample populations was carried out using the IDESCAT census (17). Selected individuals who were going to be interviewed received an information letter from the Department of Health announcing the study and asking for their collaboration. When fieldwork started, the interviewer visited the home of the person selected and requested his/her participation; if the person could not be contacted (at least three attempts at different times in the day), the person was replaced with a substitute of the same age group and sex.

STUDY SAMPLE POPULATION

Data used in the current paper consisted of 1,242 individuals from the ENCAT 1992-1993 and of 1,223 individuals from the ENCAT 2002-2003 -all aged 25-60 years. However, analysis included all subjects aged 25-60 years with available data on anthropometric measures and smoking history, i.e. from ENCAT 1992-1993, a total of 1,071 subjects, 482 men (45 % of the sample) and 589 women (55%), and from ENCAT 2002-2003, a total of 1,128 subjects, 515 men (45.7%) and 613 women (54.3%). Mean age, the gender distribution, and level of education

did not differ between the analysis sample and the full sample aged 25-60 years ($p > 0.05$ for all three variables) in either of the surveys.

DATA COLLECTION

All data were collected by trained dietician-interviewers using standardized questionnaires and anthropometric measurements (weight, height and waist circumference) during a home interview. Food data was coded according to the Spanish Food Composition Tables of CESNID (16). Further details on the methods and instruments used have been described elsewhere (16).

VARIABLES

Table I includes all variables and covariates considered for analysis and their descriptions.

Multivariate-adjusted associations between smoking history are reported for overweight and obesity combined (hereafter "overweight/obesity"), as findings were generally similar for overweight and obesity when examined separately using multinomial logistic models, and the sample size for exploring obesity separately was limited given that very few smokers were obese (data not shown). Similarly, "increased-risk" and "substantially-increased-risk" of metabolic complications according to WC (hereafter "IR WC" and "SIR WC", respectively) were combined in the multivariate models (hereafter IR/SIR WC), as findings were similar when these variables were examined separately (not shown).

STATISTICAL ANALYSIS

All analyses were performed with Intercooled Stata 8.0 for Windows (STATA Corporation, 98/95/NT. Texas, USA; 2002).

Multivariate-adjusted associations between smoking history variables and each obesity outcome (both for BMI and WC) were estimated using simple logistic regression. Separate models were fit for each survey, and for men and women; age-adjusted and multivariate adjusted results are presented. Models analysed odds of "overweight/obesity", and "IR/SIR WC" among stratified current smokers (light, moderate and heavy) and former smokers *vs.* never smokers (the referent group). No data on smoking intensity was available for former smokers.

Variables included as confounders in the final multivariate models were: age, education level, occupation level, physical activity level at work, alcohol (ethanol) consumption, energy intake and fruit and vegetable consumption. Confounder selected included all variables that changed odds ratios of interest by > 10% in at least some models. Within the analysis sample, sensitivity analyses were also carried out to assess whether missing values for covariates were influential, confirming that excluding subjects with missing values did not influence the main associations of interest (not shown). Final models excluded subjects with missing values for all covariates included. Results are presented as odds ratios (ORs) and 95% confidence intervals (CIs). Mantel-Haenzel test for trend was used to determine whether there was a dose-dependent relationship between smoking history/intensity and BMI and between smoking history/intensity and WC ($p < 0.05$ as significance level). All prevalence estimates and ORs were weighted using the Catalan census population of 1991 and 2001 (25) respectively, accounting for the population gender and age group distribution.

RESULTS

SHIFTS IN THE PREVALENCE OF GENERAL AND CENTRAL OBESITY BY SMOKING HISTORY GROUP

Figures 1 and 2 show prevalence rates of general and central obesity by smoking history. In 1992-1993, among men, former smokers had the highest prevalence of overweight, obesity, and both IR and SIR WC. By 2002-2003, however, substantial increases among never and current smokers led to levels of general and central obesity similar to those in former smokers. More specifically, in 2002-2003, while former smokers had the highest prevalence of overweight (57.2%) and SIR WC (28.2%), never smokers had the highest rates of obesity (19.3%) and current smokers had the highest level of IR WC (30.7%).

In contrast to men, among women, in 1992-1993 the prevalence of overweight, obesity, IR WC and SIR WC was highest among never smokers. As among men, however, in 2002-2003 disparities in prevalence rates across smoking groups were substantially diminished as a consequence of increased levels in both former and current smokers, as well as lower levels in never smokers.

ASSOCIATIONS BETWEEN SMOKING HISTORY AND GENERAL AND CENTRAL OBESITY: 1992-1993

Age- and multivariate-adjusted associations between smoking history and overweight/obesity and IR/SIR WC are presented in table II. In 1992-1993, the multivariate-adjusted analysis showed that male moderate and heavy smokers were 0.40 and 0.63 times less likely to be overweight/obese than never smokers, although the association was only significant ($p < 0.05$) for moderate smokers. Neither former smoking nor current-light smoking was associated with general obesity among men. For central fatness, however, both male former and current-heavy smoking were associated with a more than two-fold increased odds of IR/SIR WC compared to never smoking ($p < 0.05$).

In contrast to the null association among men, women who were current-light smokers were significantly less likely to be overweight/obese than never smokers (OR 0.42, CI 0.22-0.81).

[Nutr Hosp 2017;34(1):102-110]

Table I. Variables considered in the analysis

Variables	Definition (categories)	Additional information
BMI[a]	Weight (kg)/height2 (metres) Categories: WHO's standard cut-off points were used to define general: a) obesity (BMI ≥ 30 kg/m^2), b) overweight (BMI 25-< 30 kg/m^2), c) normal weight (BMI 18.5-< 25 kg/m^2); and d) underweight (BMI < 18.5 kg/m^2) (18) Underweight individuals (0.2% of men and 1.9% of women in 1992-1993 and 0.4% of men and 2.3% of women in 2002-2003) were combined with normal weight, since separating these two groups had no meaningful effect on results (not shown)	Used as an indicator of general excess in total body fat independent of height
WC[a]	Categories: WHO's sex-specific WC cut-off points were used for a) increased-risk of metabolic complications (WC > 94 cm in men, WC > 80 cm in women) (hereafter "IR WC"); and b) substantially-increased-risk (WC > 102 cm in men, 88 cm in women) (hereafter "SIR WC") (19)	Provided an index of abdominal fatness, which has more recently been included in efforts to classify obesity, as the distribution of body fat has been found to be important and carrying it around the abdomen has been found to be especially unhealthy (20)
Smoking history[b] and smoking intensity[b]	Smoking history categories: "never smoker", "former smoker" (had quit at the time of the interview but had smoked in the past for at least 6 months or longer) and "current smoker" (includes both daily and occasional smokers consuming < 1 cigarette/day) Smoking intensity categories: "light" (1-10 cig/d), "moderate" (11-20 cig/d) and "heavy" (> 20 cig/day)	Information on tobacco smoking was collected by self-report. Individuals smoking > 20 cigarettes/day were considered as heavy smokers because this corresponds to the quantity of cigarettes contained in a standard pack in Western countries and other studies have also used this cut-off (21)
Sex[c]	Categories: "male" and "female"	
Age[c]	Categories: "20-40 years" and "41-60 years" *(i.e.* using the median age)	
Physical activity (PA) at work[c]	Categories: "sedentary", "light and moderate activity" and "active and very active", based on each subject's current employment, where sedentary occupations included those where most time is seated, light and moderate included standing occupations, and active or very active included manual occupations	Provided by questions adapted from the WHO physical activity "Countrywide Integrated Non-communicable Diseases Intervention" questionnaire (22) used in the ENCAT 1992-1993 and ENCAT 2002-2003 surveys
Occupation social class[c]	Categories based on the subject's occupation as: "low" (including farm labourer and fishermen, manual unskilled and skilled workers, craftsmen/skilled industry workers, amenities and machinery guards), "medium" (including foremen, rest of administrative staff, commercial and technical staff, service sector, army, medium-level technicians, business owners without employees, agriculture skilled professional, support technician, administrative staff, writers and artists), "high" (including high-level technicians, self-employed professionals –dentists, lawyers etc.–, business owners with employees, directors/managers), and "other" (including the unemployed, housewives and the non-classifiable)	The definition of Garcia-Alvarez et al. (15) was used, although slightly modified
Education level of the subject[c] and Education level of the family´s head member[c] (ELS and ELH)	Categories: as defined in García-Álvarez et al. (15)	
Ethanol consumption[c]	Categories: "level 1" (0-9.99 g/day –men and women–), "level 2" (men: 10.00-29.99 g/day, women: 10.00-19.99 g/day), "level 3" (men: > 30.00 g/day, women: > 20.00 g/day)	1 standard unit of alcoholic beverage in Spain is equivalent to 10 g of ethanol (23)
Energy intake[c]	Categories defined as "tertiles of intake (kcal/day)"	Obtained from the 24-hour recalls
Fruit and vegetable consumption[c]	Defined according to recommendations (24) as "low" (< 170 g/day), "moderate" (170-400 g/day)", "high" (> 400 g/day).	Obtained from the 24-hour recalls

[a]*Outcome variable;* [b]*Explanatory variable;* [c]*Covariate.*

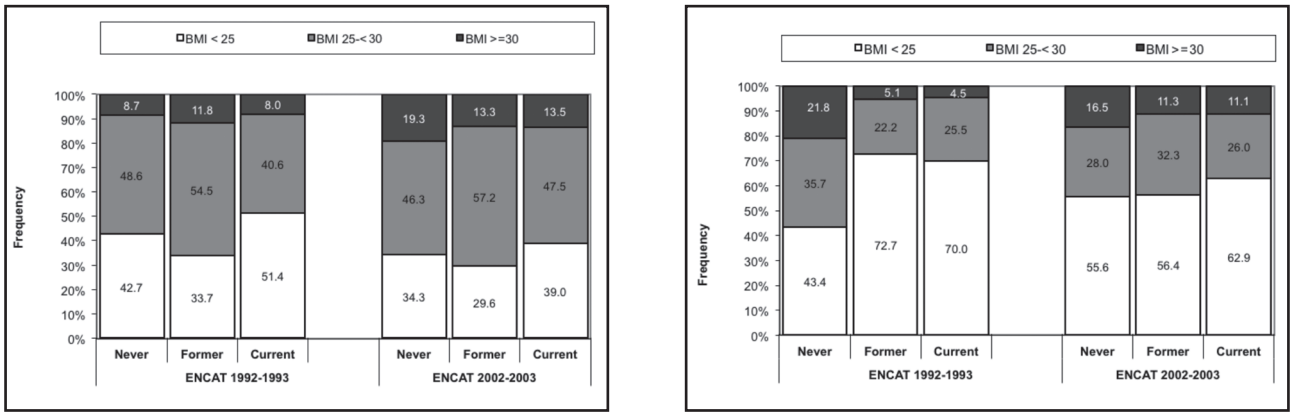

Figure 1.

Prevalence of BMI categories in male (left) and female (right) never smokers, former smokers and current smokers, by Survey (ENCAT 1992-1993 and 2002-2003).

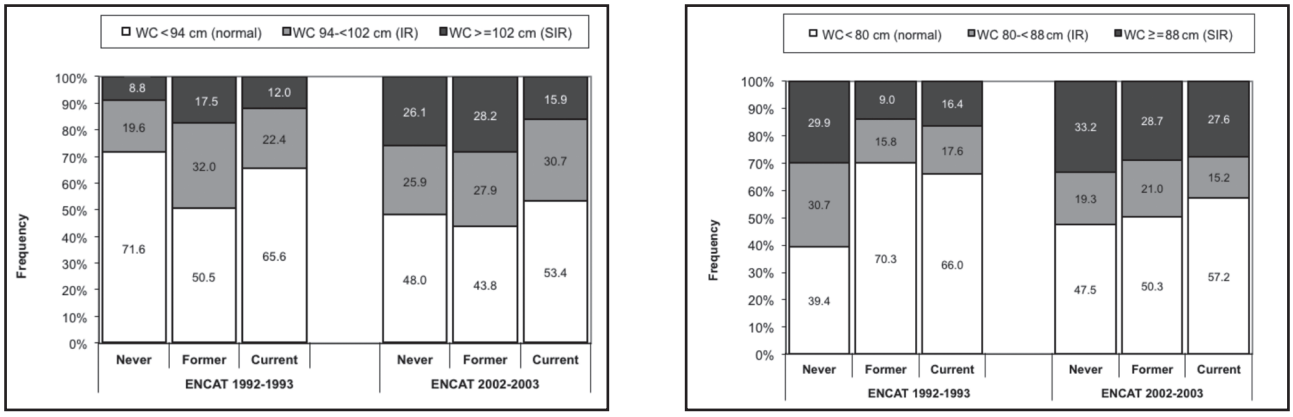

Figure 2.

Prevalence of WC categories in male (left) and female (right) never smokers, former smokers and current smokers, by Survey (ENCAT 1992-1993 and 2002-2003).

For central fatness, both former and current-light smokers had lesser odds of an IR/SIR WC than never smokers, with associations significant at the 10 and 5% level respectively, again contrary to the positive association between central fatness and former smoking observed in men.

Results of the Mantel-Haenszel test for trend (Table II) show a significant trend ($p = 0.007$) only in male BMI overweight/obesity-smoking OR; in females however, OR for both BMI overweight/obesity-smoking and IR/SIR WC-smoking show a significant trend ($p = 0.000$ and $p = 0.006$, respectively).

ASSOCIATIONS BETWEEN SMOKING HISTORY AND GENERAL AND CENTRAL OBESITY: 2002-2003

In 2002-2003, when the prevalence rates of general and central obesity were notably higher, particularly in men, a rather different situation emerged, with most associations strongly attenuated compared to those observed in 1992-1993. Thus among men, current moderate and heavy smoking were no longer associated with general overweight/obesity, and former smoking was no longer associated with IR/SIR WC. However, current heavy smoking remained associated with IR/SIR WC, although the magnitude of the association was nearly two-fold rather than three-fold.

Associations were similarly attenuated towards the null among women in 2002-2003. Current light smoking was no longer associated with reduced odds of overweight/obesity or with reduced odds of IR/SIR WC, and former smoking was no longer associated with reduced odds of IR/SIR WC. However, current moderate smokers were 0.57 times less likely to have an IR/SIR WC as compared to never smokers, although the association was very weak ($p < 0.10$).

Results of the Mantel-Haenszel test (Table II) show a significant trend in female BMI overweight/obesity-smoking OR and IR/SIR WC-smoking OR ($p = 0.046$ and $p = 0.025$ respectively), but not in any of the male OR.

Table II. Associations between smoking history and overweight/obesity and increased-risk/substantially-increased-risk WC (IR/SIR WC)

Smoking history	Overweight/obesity (BMI ≥ 25 kg/m²)				IR/SIR WC (WC > 94 cm in men, WC > 80 cm in women)			
	ENCAT 1992-1993		*ENCAT 2002-2003*		*ENCAT 1992-1993*		*ENCAT 2002-2003*	
	n	*OR (95% CI)*	*n*	*OR (95% CI)*	*n*	*OR (95% CI)*	*n*	*OR (95% CI)*
Age-adjusted associations								
Men	469		508		468		507	
Never (ref)	74	1.0	121	1.0	37	1.0	95	1.0
Former	68	1.23 (0.67-2.25)	88	0.98 (0.58-1.65)	50	2.03* (1.08-3.81)	70	0.94 (0.57-1.56)
Current light (≤10 cig/day)	48	1.23 (0.65-2.31)	40	0.72 (0.39-1.32)	22	0.94 (0.47-1.89)	29	0.67 (0.36-1.24)
Current moderate (11-20 cig/day)	46	0.47* (0.26-0.83)	46	0.81 (0.45-1.46)	34	1.13 (0.60-2.10)	31	0.67 (0.38-1.17)
Current heavy (> 20 cig/day)	24	0.61 (0.30-1.21)	31	1.22 (0.56-2.66)	24	2.51* (1.22-5.14)	29	1.82‡ (0.87-3.83)
Women	579		611		574		610	
Never (ref)	187	1.0	151	1.0	195	1.0	174	1.0
Former	20	0.51* (0.27-0.98)	58	1.02 (0.65-1.61)	22	0.48* (0.25-0.91)	66	0.94 (0.59-1.48)
Current light (≤ 10 cig/day)	24	0.48* (0.26-0.89)	34	1.01 (0.60-1.69)	23	0.42* (0.22-0.78)	41	0.95 (0.57-1.56)
Current moderate (11-20 cig/day)	24	0.85 (0.42-1.75)	21	0.65 (0.35-1.22)	30	1.06 (0.54-2.12)	23	0.53* (0.29-0.97)
Current heavy (> 20 cig/day)	8	1.09 (0.40-2.99)	6	1.13* (2.18-4.33)	6	0.84 (0.29-2.46)	7	1.09 (0.26-4.60)
Multivariate-adjusted associations								
Men	443		503		442		502	
Never (ref)		1.0		1.0		1.0		1.0
Former		1.33 (0.69-2.54)[a]		0.97 (0.57-1.67)[c]		2.37* (1.19-4.69)[b]		1.01 (0.61-1.68)d
Current light (≤ 10 cig/day)		1.00 (0.52-1.93)[a]		0.73 (0.39-1.36)[c]		0.93 (0.46-1.92)[b]		0.71 (0.37-1.35)[d]
Current moderate (11-20 cig/day)		0.40* (0.22-0.75)[a]		0.75 (0.41-1.36)[c]		1.12 (0.59-2.22)[b]		0.58 (0.32-1.04)[d]
Current heavy (> 20 cig/day)		0.63 (0.31-1.29)[a]		1.11 (0.50-2.51)[c]		2.73* (1.21-6.16)[b]		1.98‡ (0.91-4.31)[d]
MH# test for trend		0.007		0.481		0.904		0.986
Women	528		591		523		590	
Never (ref)		1.0		1.0		1.0		1.0
Former		0.71 (0.37-1.38)[a]		1.27 (0.78-2.05)[c]		0.56‡ (0.29-1.09)[b]		1.14 (0.71-1.83)[d]
Current light (≤ 10cig/day)		0.42* (0.22-0.81)[a]		1.20 (0.67-2.13)[c]		0.39* (0.20-0.77)[b]		1.15 (0.68-1.93)[d]
Current moderate (11-20 cig/day)		0.76 (0.36-1.60)[a]		0.71 (0.37-1.36)[c]		1.00 (0.49-2.05)[b]		0.57‡ (0.30-1.09)[d]
Current heavy (> 20 cig/day)		1.29 (0.46-3.59)[a]		1.46 (0.43-5.04)[c]		0.83 (0.29-2.44)[b]		1.35 (0.36-5.10)[d]
MH# test for trend		0.000		0.046		0.006		0.025

OR: odds ratio; CI: confidence interval; BMI: body mass index; overweight: BMI 25 -< 30 kg/m²; obesity; BMI ≥ 30 kg/m²; overweight/obesity: overweight plus obese subjects; WC: waist circumference; IRWC/SIR WC: subjects with IR WC plus subjects with SIR WC; IR WC: increased-risk of metabolic complications (i.e. WC > 94 cm for men, WC > 80 cm for women); SIR WC: substantially-increased-risk (i.e. *WC > 102 cm for men, WC > 88 cm for women).
**p < 0.05; ‡p < 0.10. #MH: Mantel-Haenszel. [a]Adjusted for age, energy intake, physical activity level at work, ELS and SES-occupation. [b]Adjusted for age, energy intake, ELS and fruit and vegetable consumption. [c]Adjusted for age, energy intake, ELH, ELS, SES-occupation, fruit and vegetable consumption and ethanol consumption. [d]Adjusted for age, energy intake, ELS, SES-occupation and ethanol consumption.*

DISCUSSION

The analysis of these two samples of adults from the region of Catalonia yielded very different results and may illustrate the trends in tobacco use and its body weight implications in a Mediterranean setting.

Associations between current smoking intensity and general obesity, adjusted for confounders such as subject's age, energy intake, physical activity at work, education level and occupation, were initially strongly negative in men for moderate and heavy smoking, and in women for light smoking. By 2002-2003, null associations were observed, indicating that current smokers were no longer leaner than never smokers.

With some exceptions indicating no association (3), the majority of studies on this topic have found negative associations between current smoking –especially moderate and heavy smoking– and general obesity (2,4,13,26,27). No previous studies have looked at changes in associations coinciding with shifts in the prevalence of obesity and smoking over time. These shifts in results suggest that the increased overweight and obesity among current smokers diminish disparities in prevalence *vs.* never smokers.

Mechanisms for a possible causal relationship between current smoking and a lower BMI may include the increased metabolic rate induced by nicotine (3,5,11), the decreased metabolic efficiency or the decreased caloric absorption (reduction of appetite) (5,28) or the lower consumption of desserts –choosing to smoke after lunch instead- that some authors have observed among men (but not in women) (28); an increased total energy expenditure involving the stimulation of the sympathetic nervous system (11), although weaker among obese subjects (5,11) and also depending on physical activity and fitness degree (29).

In contrast, despite negative associations between smoking and general overweight/obesity, there were strong positive associations between current heavy smoking –but not moderate or light smoking– and central obesity in men. These associations were only slightly attenuated in 2002-2003: this was the most persistent association observed. Among women, moderate smokers and the small number of heavy smokers had similar levels of IR/SIR WC as did never smokers, although current light smoking was initially associated with reduced odds of IR/SIR WC; by 2002-2003, however, after multivariate adjustment, female light smokers had similar levels of IR/SIR WC to those of never smokers, and moderate smokers, unexpectedly, had lower levels ($p < 0.10$).

Our finding of a positive association for heavy smoking-WC in men is again in line with results reported by Kim et al. (13), Travier et al. (27), and Clair et al. (3), who found heavy smoking to be positively associated with elevated WC, though in the two latter studies this was observed in both sexes. Clair et al. however, did observe a positive association between moderate smoking and elevated WC in men. On the other hand, the negative association between moderate smoking and central obesity in women is in line with Travier et al. (27) findings, which observed a lower elevated WC in female current smokers of the average number of cigarettes, but did not observe this in men. A recent large cohort study in the Chinese adult population has also shown that tobacco smoking is an important risk factor for central obesity. However, the positive association of regular smoking with WC was observed especially in male normal-weight adults after adjustment for BMI (4). Again, changes in associations at different points in time have not been reported previously, but our results in men suggest that disparities between current smokers and never smokers are diminished as levels of central obesity rise among the never smokers.

A possible mechanism for a greater WC among smokers is, for instance, the higher fasting plasma cortisol concentrations seen in smokers as compared to non-smokers, which are strongly associated with visceral adipose tissue (VAT) (30), in turn strongly associated with WC (31); higher cortisol concentrations could be a consequence of the stimulation of sympathetic nervous system activity that is induced by smoking (32). In addition, sex hormones may be involved. In women, low concentrations of oestrogens and an excess of androgens such as testosterone –typically seen after menopause (33)– has been associated with VAT accumulation (34). In men, VAT increases when testosterone concentration decreases (35), and testosterone administration in middle-aged men reduces VAT by increasing lipolysis (36); in addition, smoking may reduce testosterone concentrations (35,36). However, in the case of heavy smokers, the mentioned increase in metabolism induced by nicotine might be outweighed by the metabolic effects of nicotine that favour abdominal fat accumulation and the smokers propensity for unhealthy lifestyle habits, thus causing a direct relationship for heavy smokers and WC as compared to light smokers (4,5).

In 1992-1993, age-adjusted associations between former smoking and general overweight/obesity were weakly positive in men but strongly negative in women as compared to never smokers; after multivariate adjustment for confounders such as subject's age, energy intake, physical activity at work, education level and occupation, both the positive and negative associations seen in men and women respectively were attenuated. However, it is important to note that associations with former smoking were strongly diminished over time, as the prevalence of obesity increased more among never and current smokers (Fig. 1). Our results are in line with those by John et al. (26), who found that former smokers did not reveal more overweight or obesity than never smokers, suggesting that a short-term increase in body weight after smoking cessation does not become critical in public health terms when never smokers are taken as the reference group. Other authors, however, have reported different results for male former smokers indicating that they weigh more than never smokers (12,27). Mechanisms for weight gain among male former smokers might include higher energy intake, decreased resting metabolic rate and physical activity and possibly changes in adipose tissue metabolism (37). Moreover, it has been suggested that more female than male quitters might develop decisions or psychological strategies that are strong enough to curb weight gain (26,38).

Associations between former smoking and central obesity: in 1992-1993 were strongly positive in men as compared to never smokers, persisting even more strongly positive after multivariate adjustment for age, energy intake, subject's education level

and fruit and vegetable consumption; these results have been found previously in men (39). In women, however, age-adjusted associations were strongly negative, persisting at a lower significance level (10%) after multivariate adjustment. These results for both men and women are in line with those of Travier et al. (27), although they analysed the association in former smokers of the average time since quitting. In contrast, Pisinger and Jorgensen (12) observed that female quitters had a higher increase in WC than men. Nevertheless, our results show that by 2002-2003, when levels of central obesity had increased especially in the never and current smokers (Fig. 2), no association between former smoking and central obesity was observed.

Moreover, it is important that results have been derived from multivariate-adjusted analyses with the intention to eliminate as much as possible the effect of confounders such as physical activity, energy intake or alcohol consumption on the relationship between smoking and general/central fatness. In this sense, Chiolero et al. (5) suggested that, heavy smokers tend to have greater body weight than light smokers or non-smokers because heavy smokers are more likely to adopt behaviours favouring weight gain *(e.g.* low physical activity, sedentary life style, unhealthy diet, and high alcohol intake) than are light smokers or non-smokers. It is noteworthy that we found very little disparity in age-adjusted *vs.* multivariate-adjusted results, and the list of variables included in the adjustment did not explain persistent positive associations between current heavy smoking and central obesity (in men).

The reasons for the observed gender disparities are unclear. Other studies that have considered the effects of confounding factors such as alcohol and food intake, physical activity, and education still showed similar findings between sexes (40,41). It has been argued that nicotine might have a stronger antiestrogenic effect in women (42) and that menopause increases BMI, measures of central adiposity and visceral fat (43). Heterogeneity in the results could be caused by differences in sample sizes, because smaller studies are less likely to detect modest effects, variation in reporting smoking variables and other important confounders, and age structure of the population (44). In our study, the very small number of female heavy smokers may be limiting the ability to examine associations between current heavy smoking and central obesity and compare them with those in men.

A very recent study tested the hypothesis that high tobacco consumption is causally associated with low body weight using a genetic variant in CHRNA3 (rs1051730) as proxy for high tobacco consumption. The authors concluded that high tobacco consumption causes lower body weight among current smokers; however, smoking does not seem to affect fat distribution causally. They stated that the lack of association between CHRNA3 genotype and body weight among former and never smokers favors smoking as the causal factor for the observed associations (45).

We recognise the following study limitations: the cross-sectional nature of the surveys, which does not allow us to establish any definitive temporal association between smoking and general/central adiposity; relying on self-reported measures of smoking habits; using surrogate markers for fat distribution; the missing data on anthropometry (outcomes) and smoking history (exposure) variables, although, no significant differences in terms of age, education and SES (occupation) were observed when the sample of individuals with missing data on outcome and exposure variables was compared with the sample that had all data; the smoking-WC associations not being adjusted for BMI, question that has been raised in a recent study (4). We cannot totally rule out the effect of confounding caused by factors that we have not considered.

Major strengths of the present study include that: it uses measured anthropometry; it is based on two general population samples of relatively large total size, which provide a rather good number of explanatory factors (potential confounders) and detailed information on current smoking intensity; but most importantly, it is based on two methodologically very similar samples that are 10-years apart, which allows comparison and trends identification.

We conclude that although causality cannot be established, results suggest a positive association between heavy smoking and central fatness among men, but no association between former smoking and general/central fatness; findings strengthen arguments for promoting smoking cessation to reduce the morbi-mortality associated with both smoking and obesity.

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