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Relationship between body mass index, serum cholesterol, leisure-time physical activity, and diet in a Mediterranean Southern-Europe population

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The aim of the present study was to determine the relationship of BMI with other cardiovascular risk factors, leisure-time physical activity and diet. Participants were recruited in a cross-sectional population-based survey in a southern-Europe Mediterranean population (Spain); cardiovascular risk factors were measured, and leisure-time physical activity and diet intake were evaluated. Linear regression analysis adjusted for several confounders showed a significant, direct association of BMI and total cholesterol ($P < 0{\cdot}005$) and LDL-cholesterol ($P < 0{\cdot}006$), in men. HDL-cholesterol was inversely related to BMI in both sexes ($P < 0{\cdot}0001$). Higher BMI was more frequent in less-active men ($P < 0{\cdot}04$) but not in women. BMI increased significantly ($P < 0{\cdot}0001$) by 1·92 kg/m^2 with each 4·18 MJ consumed in men but not in women. Dietary intakes of carbohydrate ($P < 0{\cdot}03$), total fat ($P < 0{\cdot}03$) and saturated fatty acids ($P < 0{\cdot}02$) were directly associated with BMI in men but not in women, in whom protein intake was correlated ($P < 0{\cdot}001$) with BMI. Linear regression models including dietary components explained up to 10·6 and 21·1 % of BMI variability in men and women, respectively. Sex differences in the association of BMI with total cholesterol, and LDL-cholesterol, may account for the lower risk for CHD in women compared with men of similar BMI reported in the literature for the southern-Europe Mediterranean region. An increases of BMI may be more deleterious in populations in which it is accompanied by other risk factors such as a higher intake of total fat and, particularly, of saturated fatty acids, or lower leisure-time physical activity.

Body mass index: Nutrient intake: Coronary heart disease: Leisure-time physical activity

Excessive body weight is a major health problem in industrialised and developed countries where it could be considered epidemic (Seidell, 1995*a*; World Health Organization, 1998; National Institute of Diabetes and Digestive and Kidney Diseases, 2000) and a key determinant of health-care costs (Seidell, 1995*b*). Overweight and obesity have been related to increased morbidity and mortality rates due to diabetes mellitus, several forms of cancer, digestive diseases and CHD (Colditz *et al.* 1990; Manson *et al.* 1990; Pi-Sunyer, 1993; Deslypere, 1995; Jung, 1997; Caroll, 1998; National Institute of Diabetes and Digestive and Kidney Diseases, 2000). Furthermore, they are believed to be an independent risk factor for cardiovascular disease (Pi-Sunyer, 1993; Jung, 1997). Part of the increased risk of CHD conferred by an increased body weight is explained by the effects on blood pressure, glucose tolerance, and plasma lipid metabolism (Lamon-Fava *et al.* 1996). Because of the strong relationship between an excessive body weight and these diseases, it is important to provide information on the determinants of overweight and obesity from population-based surveys. Overweight and obesity are very common in Europe (Seidell, 1995*c*; Bianchini *et al.* 2002), and are one of the most important health problems in the USA where their prevalence has risen by approximately 0·5 % annually since the early 1980s (Gutiérrez-Fisac *et al.* 2000; Flegal *et al.* 1998, 2002). Prevalence of overweight and obesity in Spain increased from 1987 to 1997 in men and women by 9·1 and 5·3 % respectively (Artalejo *et al.* 2002). Although the aetiology of an excessive body weight is still unclear (Rosenbaum *et al.* 1997), energy metabolism and dietary intake may have a role in its development and progression. However, the most important cause of overweight and obesity is the excess of energy consumption leading to a positive energy balance, which results in an accumulation of body fat. Another factor that may contribute to a gain in weight is a sedentary lifestyle (Moore, 2000).

BMI is an easily and reliably obtained measure of relative body size. BMI is often used as an indirect

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index of adiposity and has been strongly associated with cardiovascular disease risk (Ferrannini, 1995). BMI is often directly associated with total and LDL-cholesterol plasma concentrations, whereas an inverse relationship has been reported between HDL-cholesterol and BMI (McNamara *et al.* 1992; Ernst *et al.* 1997). However, the effect of gender on the relationship between BMI and blood lipid parameters has not been clearly established, due to the inconsistent results of previous studies (Anderson *et al.* 1988; Assman & Schulte, 1992).

The objective of the present study was to analyse the relationship of BMI with other cardiovascular risk factors, leisure-time physical activity, energy consumption and fat, carbohydrate and protein intake in a southern European Mediterranean population.

Subjects and methods

Subjects

A representative sample of non-institutionalised Spanish men and women, aged 25–74 years, participated in a population-based cross-sectional study conducted in the province of Gerona from September 1994 to January 1996. Details of the survey methods have been previously described (Masiá *et al.* 1998). In brief, 3000 subjects were randomly selected from the general population of Gerona, according to the 1991 census, with a two-stage sampling stratified by sex and five age groups. After excluding census errors, 2404 eligible subjects were left; 1748 (72·7 %) agreed to participate. Dietary intake data were recorded by 1577 subjects.

Blood collection and analysis

Blood samples were obtained after a 14 h fast. Serum was immediately frozen at −120°C in liquid N_2 for transportation and stored at −80°C for final conservation. Total cholesterol was determined enzymically (Roche Diagnostica, Basel, Switzerland). HDL-cholesterol was measured as cholesterol after precipitation of apoprotein B-containing lipoproteins with phosphotungstic Mg^{++} (Boehringer Mannheim, Mannheim, Germany). Interassay CV were 2·47 and 4·46 % for total cholesterol and HDL-cholesterol, respectively. External quality assessment was performed with EQA-WHO (World Health Organization, Prague, Czech Republic).

Measurements

Leisure-time physical activity was measured by the Minnesota physical leisure-time questionnaire, which had been previously validated for Spanish men and women (Elosua *et al.* 1994, 2000). Food intake was reported on a validated 72 h recall questionnaire (Schröder *et al.* 2001) that was administered by a trained interviewer. The questionnaire contained a food list. Participants were requested to describe precisely their food and non-alcoholic beverage intake during the previous 3 d, usually including weekends. Each food listed was characterized by a full description of the usual serving size. Energy consumption and fat, carbohydrate and protein intakes were calculated from the 72 h recalls with the software *Diet Analysis Nutritionist IV* (N Squared Computing, San Bruno, CA). The database of this software includes 9879 food items complemented with items from Spanish food composition tables.

In brief, the validity of the questionnaire, i.e. its ability to classify study subjects according to a rank of nutrient intake, was reflected by several parameters: (a) Pearson's correlation coefficients (0·42 for the 72 h recall); (b) intraclass correlation coefficients (0·55 for the 72 h recall); (c) the proportion of correct classification (average of 37·0 % for the 72 h recall) into the same and extreme quartile and that of misclassification (average of 5·3 % for the 72 h recall). Furthermore, the range of correlation coefficients between dietary intakes of protein, β-carotene, and selenium and its corresponding biomarkers in urine and plasma were comparable with those found by other dietary assessment methods (Schröder *et al.* 2001).

To increase the reliability of energy consumption and macronutrient intake, the estimated BMR by the Harris & Benedict (Linder, 1985) equation were calculated (for men, $\text{BMR} = 66{\cdot}4730 + (13{\cdot}7551 \times \text{weight}) + (5{\cdot}0033 \times \text{height}) - (6{\cdot}7550 \times \text{age})$; for women, $\text{BMR} = 65{\cdot}5095 + (9{\cdot}463 \times \text{weight}) + (1{\cdot}8496 \times \text{height}) - (4{\cdot}6756 \times \text{age})$. Individuals with an energy intake:BMR value less than 1·2 were excluded from further analysis. This low value is rare and, therefore, such values are probably reflecting under-reporting of dietary intakes (Goldberg *et al.* 1991).

Current alcohol intake was recorded separately by asking participants how many glasses of wine, bottles of beer, and drinks or shots of brandy or similar beverages were consumed during the previous week.

A precision scale of easy calibration was used for weight measurement. Readings were rounded to 200 g. Individuals wore underwear. Height was measured in the standing position and measurements rounded to 5 mm. BMI was determined as weight divided by height squared (kg/m^2). Weight groups were defined according to the WHO BMI classification: underweight $<18{\cdot}5\,kg/m^2$; normal weight $18{\cdot}5–24{\cdot}9\,kg/m^2$; overweight $25{\cdot}0–29{\cdot}9\,kg/m^2$; obese $\geqslant 30\,kg/m^2$ (World Health Organization, 1998).

Information on smoking habits of the participants was also obtained by a structured interview. Participants were categorized as those who had never smoked, former smokers, and current smokers. The latter were asked for average daily amount of cigarettes smoked.

Maximum level of education attained was elicited and for analysis purpose categorized as less than primary school (illiterate or less than 8 years of schooling), primary school (8 years of schooling), secondary school (9–12 years of schooling), and more than secondary school.

Statistical analysis

ANOVA was used to estimate energy consumption, dietary intakes, and leisure-time physical activity according to weight-groups. Age-adjusted Pearson correlation coefficients were calculated to analyse the bivariate association of BMI with total cholesterol, LDL-cholesterol and HDL-cholesterol, and dietary intakes of fat, protein, carbohydrates, saturated and unsaturated fatty acids (all in g and percentage of energy intake) and energy (MJ) and alcohol consumption. Correlation of BMI with leisure-time physical activity was also analysed. Multiple linear regression adjusted models were fitted to determine whether these variables were independently related to BMI. Interaction between sex and these independent variables was also tested. All models were adjusted for age (in years, continuously), education (coded 1, more than secondary school; coded 2, secondary school; coded 3, primary school; coded 4, less than primary school), leisure-time physical activity (in MJ, continuously), smoking (in units, continuously) and alcohol consumption (in g, continuously). Energy-generating nutrients were mutually adjusted in linear regression analysis. Analysis of the data was conducted using SPSS for Windows (version 9.0) statistical software package (SPSS Inc., Chicago, IL). In all statistical tests performed, P values of $<0{\cdot}05$ were considered significant.

Results

A 72 h recall was completed by 1577 subjects. After exclusion of subjects with an energy intake:BMR value $<1{\cdot}2$, 1248 participants were retained in the analysis. Characteristics of the sample are shown separately for men and women according to BMI classification in Table 1. Generally, normal-weight participants of both sexes were younger than those with excessive body weight. Cardiovascular risk factors were more frequent in overweight and obese compared with normal-weight subjects of both sexes. These observations were statistically significant after adjusting for age only in women (results not shown).

Table 2 shows the average energy consumption, macronutrient intake, and saturated and unsaturated fatty acid intake reported by the participants. There were no differences among male groups of BMI classification concerning energy consumption and energy-generating nutrient intake. In contrast, obese female subjects had lower intakes of total fat (expressed as percentage of energy consumption) and saturated fatty acids (expressed as percentage of energy consumption and g of intake) compared with normal-weight subjects. The latter showed a lower intake of unsaturated fatty acids. Fat intake (expressed as percentage of energy consumption) was similarly reported among weight-groups of under- and non-under-reporters (results not shown).

Bivariate, age-adjusted association of BMI and cardiovascular risk factors are shown in Table 3. Statistically significant direct correlations were observed between BMI and total cholesterol ($P<0{\cdot}01$) and LDL-cholesterol ($P<0{\cdot}001$) in men, and between BMI and LDL-cholesterol in women ($P<0{\cdot}05$). A statistically significant inverse correlation of HDL-cholesterol and BMI was observed for both sexes ($P<0{\cdot}001$; Table 3). BMI significantly correlated with energy ($P<0{\cdot}001$ and $P<0{\cdot}01$ for men and women, respectively) and protein intake ($P<0{\cdot}001$ and $P<0{\cdot}01$ for men and women, respectively) after adjusting for age. However, statistically significant correlations for fat, carbohydrate, saturated fat intake and unsaturated fat intake and BMI were only observed in men (all $P<0{\cdot}001$; Table 3).

Interaction was significant between gender and total cholesterol, LDL-cholesterol, energy consumption and intake of energy-generating nutrients. Therefore, multiple linear regression models were fitted for men and women separately to estimate the effects of the variables of interest on BMI (Tables 4 and 5). All models were adjusted for age, educational level, leisure-time physical activity (except model 1; see Table 4) and smoking and alcohol consumption.

Significant direct associations of BMI and total cholesterol ($P=0{\cdot}05$) and LDL-cholesterol ($P=0{\cdot}06$) were observed in men but not in women. However, HDL-cholesterol was inversely related to BMI in both sexes ($P<0{\cdot}001$).

Energy consumption was directly correlated with BMI in men and women, although in the latter it did not reach statistical significance ($P=0{\cdot}061$). BMI was directly associated with dietary intakes of carbohydrate, total fat and saturated fatty acids in men. In contrast, in women a relationship was observed only for protein intake (Table 5). Furthermore, an inverse relationship was observed between BMI and saturated fatty acid intake in women. In men, BMI increased significantly by 0·74 and 2·194 kg/m^2 with each 100 g of carbohydrate and total fat consumed, respectively, whereas in women BMI increased by 3·1 kg/m^2 with each 100 g of protein intake. Dietary intake of total fat and saturated fatty acids (expressed as percentage of energy intake) was directly associated with BMI in men but not in women. The models that explain the highest percentage of the BMI variance (10·6 % for men and 21·1 % for women) included carbohydrate, protein, and saturated and unsaturated fatty acid intake.

The amount of leisure-time physical activity was significantly inversely associated with BMI only in men ($P=0{\cdot}031$).

Discussion

An excessive body weight is known to be associated with dislipidaemias, cardiovascular disease and mortality (Pi-Sunyer, 1993; Jung, 1997; National Institute of Diabetes and Digestive and Kidney Diseases, 2000). In the ERICA study BMI was a predictor of CHD mortality only in southern Europe after adjusting for total cholesterol (Anonymous, 1991). Prevalence of overweight and obesity in the present cross-sectional population-based study was comparable with that observed in a recently published meta-analysis (Aranceta *et al.* 1998; Gutiérrez-Fisac *et al.* 2000; Rodríguez Artalejo *et al.* 2002). According to our results, women had a higher proportion of subjects with BMI ≥ 30 kg/m^2 (17·5 %) than men (12·9 %) but fewer female (36·7 %) than male (40·1 %) subjects were overweight (BMI 25·0–29·9 kg/m^2). Excessive body weight was strongly related to age in both sexes in our population. In accordance with previous knowledge (Schulte *et al.* 1999) the increase in BMI reached a plateau in the 55–64-year-old age group.

A positive association between BMI and cardiovascular risk factors has been observed in several studies (Rabkin

Table 1. Characteristics of the study participants (under-reporters excluded)
(Mean values and standard errors of the mean)

	Men										Women									
	Under-weight (*n* 3)		Normal (*n* 222)		Overweight (*n* 226)		Obese (*n* 73)		All (*n* 564)		Under-weight (*n* 7)		Normal (*n* 309)		Overweight (*n* 253)		Obese (*n* 121)		All (*n* 690)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Excluded under-reporters (n)	0		47		86*		61*		194		1		30		44		41		116	
Age (years)	56·7	11·6	48·6	14·9	51·9*	13·1	53·7*	12·3	50·8	13·8	34·9	5·8	45·6	13·4	52·9*	11·7	57·5*	11·2	50·3	13·3
Energy intake:BMR	2·17	0·43	1·62	0·31	1·54	0·25	1·50	0·22	1·56	0·28	1·97	0·89	1·65	0·35	1·56	0·35	1·38	0·31	1·56	0·36
Total cholesterol (mmol/l)	6·07	0·89	5·47	1·05	5·88*	1·23	5·88*	1·13	5·72	1·11	3·39	0·99	3·55	0·96	4·05*	1·18	4·13*	1·03	3·83	1·09
LDL-cholesterol (mmol/l)	3·61	0·99	3·67	0·95	4·11*	1·02	4·09*	1·01	3·93	1·01	3·34	0·99	3·55	0·96	4·05*	1·18	4·12*	1·03	3·93	1·01
HDL-cholesterol (mmol/l)	2·14	0·34	1·31	0·37	1·21*	0·33	1·15*	0·32	1·24	0·36	1·68	0·32	1·54	3·89	1·46	0·35	1·41	0·37	1·24	0·36*
Leisure-time physical activity (MJ)	3·26	3·09	1·67	1·80	1·44	1·15	1·44	1·45	1·54	1·49	0·56	0·28	0·87	0·98	0·92	0·79	0·77	0·96	0·87	0·91
Current smoker (%)	66·7		40·8		29·7		22·0		30·7		62·5		23·1		11·8		7·4		15·9	
Former smoker (%)	33·3		23·6		38·0		40·9		32·7		0		7·7		4·7		1·2		5·4	
Non-smoker (%)	0		35·6		32·3		37·1		36·6		37·5		69·2		83·4		91·4		78·7	
Cigarette consumption of current smokers (units/d)	15·0	7·1	16·3	11·7	17·4	14·6	17·2	9·3	17·2	12·1	14·8	20·1	13·1	8·7	11·9	7·8	20·6	9·4	13·0	9·5
Age of menopause (years)											44·5	0·7	48·0	5·5	48·7	5·2	49·6	4·4	48·7	5·1
Hypercholesterolaemia (%)†	33·3		41·3		62·7*		56·3		53·2		28·6		41·3		55·6*		62·5*		50·0	
LDL-cholesterol risk (%)‡	33·3		28·2		48·4		50·7		40·6		14·3		23·7		40·7*		49·1*		34·2	
HDL-cholesterol risk (%)§	0		10·8		17·5		22·5		15·4		0		12·5		11·9		17·9		13·1	
Current alcohol consumers (%)	100		76·0		84·0		79·0		80·3		83·0		49·0		40·0		31·0		43·0	
Educational status (%)																				
More than secondary school	33·3		35·6		33·0		32·9		33·3		71·4		39·2		32·4		19·8		33·6	
Secondary school	33·3		35·1		38·3		34·2		36·5		14·3		33·7		34·0		40·5		34·8	
Primary school	33·3		18·0		19·2		27·3		19·3		14·3		17·5		17·0		18·2		17·4	
Less than primary school	0		11·3		10·5		9·6		10·8		0		9·7		16·6		21·5		14·2	

* Significantly different ($P<0·05$) to normal-weight subjects.
† Total cholesterol ≥5·64 mmol/l.
‡ LDL-cholesterol >4·14 mmol/l.
§ HDL-cholesterol for men <0·91 mmol/l; for women <1·09 mmol/l.

Table 2. Average daily energy consumption, macronutrient intake, and saturated and unsaturated fatty acid intakes†
(Mean values and standard errors of the mean)

	Men										Women									
	Underweight (*n* 3)		Normal (*n* 222)		Overweight (*n* 226)		Obese (*n* 73)		All (*n* 564)		Underweight (*n* 7)		Normal (*n* 309)		Overweight (*n* 253)		Obese (*n* 121)		All (*n* 690)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Energy (MJ)	11·1	2·6	10·1	2·1	10·4	1·8	10·9	1·9	10·4	1·9	11·0	4·8	9·1	1·7	9·2	1·7	9·08	1·6	9·2	1·7
Energy including alcohol intake (MJ)	12·2	3·7	10·7	2·8	11·2	2·5	11·6	2·6	11·1	2·6	11·6	5·4	9·3	1·9	9·4	2·00	9·2	1·8	9·3	2·0
Fat (% total energy intake)	37·7	2·9	35·0	4·3	35·7	4·3	35·9	4·0	35·4	4·4	38·1	7·6	35·6	4·8	35·5	3·9	34·2*	5·1	35·4	4·6
Carbohydrates (% total energy intake)	42·0	5·0	43·7	5·3	43·0	5·3	43·2	4·8	43·3	5·2	41·9	11·6	42·6	5·3	42·7	4·7	43·7	5·6	42·8	5·2
Protein (% total energy intake)	20·7	2·3	21·3	2·7	21·3	2·5	20·9	2·3	21·3	2·5	20·1	4·6	21·8	2·8	21·7	2·9	22·0	2·9	21·8	2·9
Fat (g)	111·9	18·2	95·4	26·3	99·9	22·6	105·0	21·7	98·8	24·2	105·4	24·8	86·9	21·2	87·7	19·8	83·3	19·9	86·8	20·6
Carbohydrates (g)	288·2	92·1	265·2	57·0	270·0	56·4	283·6	61·2	270·0	57·6	299·8	245·0	232·5	51·0	236·8	51·3	239·7	52·9	236·0	56·4
Protein (g)	136·6	29·4	129·6	30·2	133·3	23·6	137·4	26·5	132·4	26·8	123·3	20·6	118·2	22·5	119·6	24·2	119·9	21·4	119·1	22·9
Saturated fatty acids (g)	36·2	8·1	29·4	10·2	30·2	9·0	32·6	9·8	30·3	9·6	41·4	20·6	27·8	8·8	27·7	7·9	25·3*	8·1	27·5	8·7
Unsaturated fatty acids (g)	65·2	8·2	57·4	16·0	60·2	13·6	62·4	11·7	59·5	14·5	56·2	14·2	51·7	12·7	52·3	11·8	50·7	12·1	51·8	12·3
Saturated fatty acids (% total energy intake)	13·3	0·7	11·8	2·6	11·9	2·4	12·2	2·2	11·9	2·4	15·1	1·9	12·4	2·6	12·3	2·3	11·3*	2·5	12·2	2·5
Unsaturated fatty acids (% total energy intake)	22·8	1·2	23·4	1·8	23·6	1·7	23·4	1·7	23·5	3·2	20·6	4·1	23·0	1·9	23·1	1·8	23·6*	2·0	23·2	3·5
Alcohol intake of consumers (g/d)	64·5	62·8	46·7	42·3	53·7	39·3	53·5	38·5	51·2	40·7	43·6	33·2	21·4	16·0	21·7	16·7	21·0	20·7	21·8	17·4

* Significantly different ($P < 0·05$) to normal-weight subjects.
† For details of subjects and procedures, see Table 1 and pp. 432–433.

Table 3. Association between body mass index and several cardiovascular risk factors, dietary factors, and leisure-time physical activity§

(Age-adjusted Pearson correlation coefficients)

	Men	Women
Cholesterol (mmol/l)	0·14†	0·07
HDL-cholesterol (mmol/l)	−0·19‡	−0·18‡
LDL-cholesterol (mmol/l)	0·16‡	0·09*
Energy (MJ)	0·23‡	0·16†
Fat (g)	0·22‡	0·04
Carbohydrate (g)	0·17‡	0·07
Protein (g)	0·18‡	0·12†
Fat (% total energy intake)	0·11*	−0·05
Carbohydrate (% total energy intake)	−0·06	0·01
Protein (% total energy intake)	−0·04	0·06
Saturated fatty acids (g)	0·20‡	−0·01
Unsaturated fatty acids (g)	0·21‡	0·05
Saturated fatty acids (% total energy intake)	0·08*	−0·08 *
Unsaturated fatty acids (% total energy intake)	0·08	−0·01
Leisure-time physical activity (MJ/d)	−0·10*	−0·03
Alcohol (g/d)	0·07	0·02

Variables were significantly associated with BMI: **P*<0·05, †*P*<0·01, ‡*P*<0·001.

§ For details of subjects and procedures, see Table 1 and pp. 432–433.

et al. 1997; Siervogel *et al.* 2000). The effect of gender on the relationship between BMI and blood lipid parameters is not clearly understood, due to the inconsistent results of previous studies (Anderson *et al.* 1988; Assman & Schulte, 1992). In the present study, the association of total and LDL-cholesterol with BMI was found to be lower in women than in men. Furthermore, these sex-specific differences were also observed when levels of these two cardiovascular risk factors were compared across tertiles of BMI distribution (data not shown).

Physical activity and diet are strongly related to CHD (Ferro-Luzzi & Martino, 1996; Klör *et al.* 1997). The laws of energy balance suggest that an increase in energy expenditure through physical activity would be associated with a body weight decrease. However, effects of physical activity on BMI have been shown to be inconsistent. Schmitz *et al.* (1997) observed an inverse association between BMI and physical activity in both sexes, whereas Klesges *et al.* (1990) found this association only for women. In agreement with the results of a study that used a subset of worldwide data on the relationship between obesity and physical activity (Ferro-Luzzi & Martino, 1996), a significant inverse association of leisure-time physical activity with BMI was observed only in men ($P=0·031$). However, in the present study, energy expenditure spent during leisure time was measured but not occupational activity.

Weight gain is a consequence of an energy imbalance. However, there are controversial results on the association of energy intake with obesity or indices of body mass. Several studies clearly showed a positive association between these variables (Ravussin *et al.* 1994; Astrup *et al.* 2000), whereas a number of population-based surveys did not (Dreon *et al.* 1988; Gutiérrez-Fisac *et al.* 2000). It has been suggested that the inconsistency of this association in epidemiological studies is related to an underestimation of dietary intake (Lichtman *et al.* 1992). For these reasons it was decided to eliminate under-reporters (19·7 %) from the analysis. After calculating the age-adjusted partial correlation and fitting a multiple linear regression model, a direct association was found between energy intake and BMI in both sexes. Increases of 1·9 and 0·8 kg/m^2 of BMI in men and women, respectively, were observed for each 4·18 MJ.

Carbohydrates, protein and fat are energy-generating nutrients, and dietary fat is the most energy-dense macronutrient. Energy consumption, and especially fat intake, has increased since 1960 in Spain (Rodríguez Artalejo *et al.* 1996). However, several population-based surveys did not observe a positive association of the proportion of energy consumption, and/or energy intake, covered by fat with BMI (Dreon *et al.* 1988; Gutiérrez-Fisac *et al.* 2000). Energy imbalance can be promoted by an excessive consumption of macronutrients, and particularly by dietary fat (Donato & Hegsted, 1985; Astrup, 1993). However, there is no conclusive evidence that low-fat diets are more prone to cause obesity, than isoenergetic high-fat diets (Seidell, 1998; Willet, 1998). On the other hand, reducing dietary fat intake may have other health benefits, such as lowering plasma LDL-cholesterol and triacylglycerols.

In the present study a strong association between BMI and protein intake was observed in women. This relationship was also observed by Trichopoulou *et al.* (2002) in both sexes, although more pronounced in women. In contrast to findings of these authors, BMI was directly related to carbohydrate intake in men in the present study.

Table 4. Multiple linear regression models of body mass index and blood lipid parameters and leisure-time physical activity*

	Men				Women			
	R	B	SEM	*P*	*R*	B	SEM	*P*
Model 1†								
Leisure time physical activity (×0·184 MJ/d)	0·211	−0·096	0·001	0·031	0·437	−0·032	0·001	0·666
Model 2‡								
Total cholesterol (mmol/l)	0·240	0·400	0·143	0·005	0·438	0·258	0·154	0·093
Model 3‡								
HDL-cholesterol (mmol/l)	0·322	−1·965	0·452	< 0·001	0·460	−1·758	0·464	< 0·001
LDL-cholesterol (mmol/l)	0·322	0·426	0·154	0·006	0·460	0·232	0·164	0·157

* For details of subjects and procedures, see Table 1 and pp. 432–433.

† Adjusted for age, educational status, smoking and alcohol consumption.

‡ Adjusted for variables of model 1.

Table 5. Multiple linear regression models of body mass index and dietary factors*

	Men				Women			
	R	B	SE	*P*	*R*	B	SE	*P*
Model 1†								
Energy intake (4·18 MJ)	0·320	1·921	0·001	< 0·001	0·443	0·764	0·001	0·061
Model 2†								
Percentage of total energy intake								
Carbohydrate	0·248	0·420	0·284	0·140	0·442	−0·071	0·347	0·838
Protein	0·248	0·515	0·282	0·069	0·442	0·034	0·342	0·921
Fat	0·248	0·579	0·284	0·042	0·442	−0·080	0·346	0·819
Model 3†								
Percentage of total energy intake								
Carbohydrate	0·255	0·517	0·282	0·068	0·444	−0·064	0·347	0·854
Protein	0·255	0·428	0·284	0·133	0·444	0·039	0·342	0·909
Saturated fatty acids	0·255	0·656	0·290	0·024	0·444	−0·122	0·350	0·727
Unsaturated fatty acids	0·255	0·530	0·286	0·065	0·444	−0·046	0·349	0·894
Model 4†								
Carbohydrate (100 g)	0·322	0·743	0·305	0·015	0·456	−0·029	0·334	0·932
Protein (100 g)	0·322	0·374	0·821	0·649	0·456	3·098	0·967	0·001
Fat (100 g)	0·322	2·194	0·947	0·021	0·456	−1·185	1·122	0·276
Model 5†								
Carbohydrate (100 g)	0·326	0·767	0·304	0·012	0·460	0·546	0·337	0·871
Protein (100 g)	0·326	0·532	0·814	0·514	0·460	3·106	0·958	0·001
Saturated fatty acids (100 g)	0·326	5·187	2·481	0·037	0·460	−5·048	2·733	0·065
Unsaturated fatty acids (100 g)	0·326	0·301	1·787	0·866	0·460	0·874	0·188	0·643

* For details of subjects and procedures, see Table 1 and pp. 432–433.
† All models were adjusted for age, educational status, leisure-time physical activity, and smoking and alcohol consumption. For models 2, 3, 4 and 5, nutrients were mutually adjusted.

Conflicting results have been reported on the association of dietary fat intake and BMI (Seidell, 1998; Willet, 1998). Interestingly, after adjusting for non-dietary variables associated with BMI, the effect of total fat intake, and particularly saturated fatty acids, was different between sexes. BMI was directly associated with total fat and saturated fatty acids intake only in men. A positive association of total fat and BMI in men, but also in women, was observed by Macdiarmid *et al.* (1998).

Trichopoulou *et al.* (2002) observed a significant positive association between saturated fatty acids and BMI only when macronutrients were not mutually adjusted for among men. After mutual adjustment of macronutrients, the association became inverse (Trichopoulou *et al.* 2002). Therefore, the authors concluded that the results regarding saturated fatty acids were not convincing. In the present study a strong direct association of BMI with total fat and with saturated fatty acids was observed in men, in both adjusted and further mutually adjusted for energy-generating nutrients models (Table 5; models 4 and 5). Furthermore, the regression coefficient was seven times higher for saturated fatty acids than for carbohydrates. The observed differences between men and women regarding associations of BMI and nutrient intake in the present study might be partially explained through different dietary preferences of sexes. Furthermore, different dietary habits and other lifestyle factors among populations might give an explanation for the contradicting results of this relationship among studies.

The association between nutrition and CHD is in part due to the effect of nutrients on serum lipids and lipoproteins. Epidemiological and clinical studies provided evidence that saturated fatty acid intake strongly affects CHD risk factors (Klör *et al.* 1997). The inverse association between saturated fatty acids intake and BMI in women and the opposite finding in men might account for part of the differences observed in blood lipid parameters between both sexes. It has been described that the CHD risk of obesity increases in the presence of other risk factors (Manson *et al.* 1990). The increase in BMI may be more deleterious in populations in which this increase is accompanied by a higher intake of saturated fatty acids or by lower physical activity. The data presented here support this hypothesis.

In Mediterranean areas the CHD mortality is among the lowest worldwide (Chambless *et al.* 1997; Perez *et al.* 1998). However, although on a low level, the men:women mortality rate value is high in this region (Chambless *et al.* 1997). The Mediterranean diet is considered to have an important impact on the low incidence of CHD mortality observed in these regions. The differences in dietary components associated with BMI in both sexes, observed in the present study, might increase the risk of CHD in men, through their impact on blood lipids, as compared with women of similar BMI.

When carbohydrate, protein, saturated and unsaturated fatty acids were used as the sole independent variable, the percentage of BMI variance was 2·0 and 6·1 % in women and men, respectively in the present study. The magnitude of these associations could be considered to be low, but is slightly higher than that found by other authors (Obarzanek *et al.* 1994; Gonzales *et al.* 2000), and might be of importance at the population level. Furthermore, obesity is a multi-causal disease and diet is an important, but not the sole, factor involved in its aetiology. Hence, other lifestyle factors (i.e. educational level, smoking, alcohol consumption and leisure-time physical activity), and dietary habits, should be included in statistical models that attempt to explain the association of dietary components with BMI. In the present study 4·5 and 19·1 % of BMI variance (Table 4; model 1) accounted for these lifestyle factors (adjusted for age) in men and women, respectively. This sex-specific difference has been previously observed (Gonzales *et al.* 2000). However, the reason why the impact of lifestyle factors on BMI is more than twofold higher in women than in men remains unclear. Inclusion of carbohydrate, protein, saturated fatty acids, and unsaturated fatty acids in the model (Table 4; model 6) increased the magnitude of association to 10·6 % in men and 21·1 % in women. This degree of BMI variance is high from the population perspective.

The results of the present study indicate that energy-generating nutrients might be possible determinants for BMI. However, cross-sectional studies such as the present work cannot provide conclusive evidence of a causal relationship. The increasing prevalence of obesity, particularly in Spain, and the resulting health problems and public-health costs associated require more, and larger, population-based studies. Ideally, such studies should be of prospective nature and include several lifestyle factors in addition to dietary assessment.

It is concluded that increasing BMI was associated with higher levels of the classic cardiovascular risk factors in both sexes, particularly in men. Total and LDL-cholesterol, energy consumption, physical activity, and dietary intake of carbohydrate, total fat and saturated fatty acids were determinants of BMI in men, but not in women. Protein was a better determinant of BMI than fat in women.

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