Intake of fried foods is associated with obesity in the cohort of Spanish adults from the European Prospective Investigation into Cancer and Nutrition1–3

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ABSTRACT

Background: Consumption of fried food has been suggested to promote obesity, but this association has seldom been studied.

Objective: We aimed to assess the association of energy intake from fried food with general and central obesity in Spain, a Mediterranean country where frying with oil is a traditional cooking procedure.

Design: This was a cross-sectional study of 33,542 Spanish persons aged 29–69 y who were participating in the European Prospective Investigation into Cancer and Nutrition between 1992 and 1996. Dietary intake was assessed by a diet history questionnaire. Height, weight, and waist circumference were measured by trained interviewers. Analyses were performed with logistic regression and were adjusted for total energy intake and other confounders.

Results: The prevalence of general obesity [body mass index (in kg/m²) ≥ 30] was 27.6% in men and 27.7% in women. Respective figures for central obesity (waist circumference ≥ 102 cm in men and ≥ 88 cm in women) were 34.5% and 42.6%. The average proportion of energy intake from fried food was 15.6% in men and 12.6% in women. The adjusted odds ratios for general obesity in the highest versus the lowest quintile of fried food intake were 1.26 (95% CI: 1.09, 1.45; P = 0.001) in men and 1.25 (1.11, 1.41; P for trend < 0.001) in women. The corresponding values for central obesity were 1.17 (1.02, 1.34; P for trend < 0.003) in men and 1.27 (1.13, 1.42; P for trend < 0.001) in women.

Conclusion: Fried food was positively associated with general and central obesity only among subjects in the highest quintile of energy intake from fried food. Am J Clin Nutr 2007;86:198–205.

KEY WORDS Fried food, general obesity, central obesity, olive oil, Spain

INTRODUCTION

In Spain and in other Mediterranean countries, frying with oil is a traditional cooking procedure. Frying with oil modifies the fatty acid composition of food, increases the energy density, and reduces the water content (1). Frying may also improve food palatability by making food crunchy and aromatic (1, 2). However, the consumption of fried food may promote obesity through greater fat intake (3) and energy density (4).

Few studies have assessed the relation between fried food and obesity. In US children and adolescents, eating fried food away from home was associated with a higher body mass index (BMI; in kg/m²) and with greater weight gain (5). In the United States, fried food eaten away from home is usually prepared by deep-frying, and it is considered a proxy indicator for fast food intake (6). In Mediterranean countries, however, fried food is consumed at home as frequently as away from home, and both pan-frying and deep-frying are commonly used (7). Other studies assessing the association of fried food with obesity have been limited by having no account of total energy intake (EI) (8), by including fried food along with other types of food (9), or by considering only a limited number of items, such as potato chips (8, 10, 11) or fried snacks (8, 12–18).

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The objective of this analysis was to assess the association of EI from fried food with general and central obesity in Spain. We aimed to accomplish this objective by using data from a large study with a detailed assessment of food intake and food preparation techniques.

SUBJECTS AND METHODS

Study design

We used baseline data from the Spanish cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC). The design and methods of the EPIC study have been described elsewhere (19, 20). Briefly, EPIC is a cohort study of 520,000 European men and women that assesses the role of diet, lifestyle, and genetic and environmental factors with respect to the risk of cancer and other chronic conditions. EPIC-Spain is composed of 41,440 participants aged 29–69 y who were recruited from 1992 through 1996 in 5 regions in Spain: Asturias, Gipuzkoa, and Navarra in the north and Granada and Murcia in the south.

Of 41,440 participants, we excluded 816 with poor quality of dietary reports (defined as a ratio of estimated to required EI below the 1st percentile or above the 99th percentile; 21); 3,546 who declared that they had modified their diet in the previous year; 2,553 with a self-reported diagnosis of angina, myocardial infarction, stroke, cancer, or diabetes; and 33 with a BMI < 18.5 and 374 with a BMI > 40. Subjects with a BMI > 40 were excluded because of a possible predominant role of genetic factors in morbid obesity (22). We also excluded 143 participants with missing values for weight, height, or waist circumference (WC); 236 with missing data on educational attainment; 17 with no data on smoking; and 180 women who lacked information on parity. As a result, the final database for analyses included 33,542 subjects (12,905 men and 20,637 women). For analyses of the type of oil used for frying, we further excluded 3,322 participants (1,946 men and 1,376 women) who used mixed oils for frying and 1,725 (78 men and 94 women) with missing data for this variable. These analyses were thus conducted with 30,048 subjects (10,881 men and 19,167 women).

All participants gave written informed consent before enrollment. The study protocol was approved by the ethics committees of the International Agency for Research on Cancer (Lyon, France) and of the Bellvitge Hospital (Barcelona, Spain).

Diet history

Usual food consumption in the previous year was assessed with the use of a computerized diet history questionnaire (23, 24), previously validated in Spain (25) and administered by trained interviewers. The average length of the diet history interview was 41 min. Each subject was asked about his or her food consumption in a typical week of the previous year; 2,553 with a self-reported diagnosis of angina, myocardial infarction, stroke, cancer, or diabetes; and 33 with a BMI < 18.5 and 374 with a BMI > 40. Subjects with a BMI > 40 were excluded because of a possible predominant role of genetic factors in morbid obesity (22). We also excluded 143 participants with missing values for height, weight, or waist circumference (WC); 236 with missing data on educational attainment; 17 with no data on smoking; and 180 women who lacked information on parity. As a result, the final database for analyses included 33,542 subjects (12,905 men and 20,637 women). For analyses of the type of oil used for frying, we further excluded 3,322 participants (1,946 men and 1,376 women) who used mixed oils for frying and 1,725 (78 men and 94 women) with missing data for this variable. These analyses were thus conducted with 30,048 subjects (10,881 men and 19,167 women).

Other variables

Standing height, weight, and WC were measured by trained observers according to standardized procedures (28). Anthropometric measures were made when participants were wearing light clothes and no shoes and after they had emptied the bladder. Height and weight were measured with electronic scales that were calibrated on a regular schedule. WC was measured at the point of smallest circumference between the iliac crest and the lowest rib, after a normal expiration. In obese subjects without a natural waist, WC was measured at the midpoint between the iliac crest and the lowest rib. General obesity was defined as a BMI ≥ 30. Central obesity was defined as WC ≥ 102 cm in men and ≥ 88 cm in women (28).

Information on sociodemographic and lifestyle characteristics and reproductive history was obtained through interview. Physical activity was assessed by using a previously validated questionnaire (29) that included activity at work, during leisure time, and during household chores. For activity at work, each participant was asked to classify his or her occupation as sedentary, standing, manual work, heavy manual work, or nonworker. The following activities during leisure time were ascertained in the previous year: walking, riding a bicycle, gardening, do-it-yourself work, and participation in sports (30). Energy expenditure, during either leisure-time activity or at household chores, was obtained as the sum of the products of the time spent in each activity by its assigned metabolic equivalent (MET), and was expressed in METs · h/wk (31). Education was assessed as the highest completed educational level, which was classified into 5 categories from uncompleted primary school to completed university. Participants were grouped into 3 categories of consumption of any type of tobacco (current smoker, ex-smoker, or never smoker), and the number of cigarettes consumed was recorded for smokers. Data on parity were obtained by asking the women how many children they have had. Women were classified as being postmenopausal when >1 y had passed since their last menstrual cycle.
Statistical analysis

Participants were classified in sex-specific quintiles of EI from fried food. The association of fried food intake with obesity was modeled with mixed-effects logistic models, with the study center as a random effect to account for regional differences in food preparation. We estimated the odds ratios of obesity for each of the 4 upper quintiles of percentage of the EI from fried food compared with the lowest quintile. Linear trends in odds ratios were tested for by modeling quintiles of intake as a continuous variable. Separate analyses were done for general and central obesity and for men and women.

Logistic regression models were adjusted for age (in 5-y periods), physical activity at work (sedentary occupation, standing occupation, manual work, heavy manual work, and nonworker), leisure-time physical activity (METs-h/wk in quintiles), household activity (METs·h/wk in quintiles), tobacco consumption (ex-smoker, and number of cigarettes smoked per day), education level (no formal education, primary studies, vocational training, secondary studies, and university studies), and total EI as a continuous variable. Analyses for women were further adjusted for parity, menopausal status, and use of hormone replacement therapy. We fitted an energy-adjusted model by using the multivariate nutrient density method. In these models (33), the association of EI from fried food with obesity is interpreted as the odds ratio for obesity associated with replacing a given percentage of energy from nonfried food with the same percentage of energy from fried food.

The association of the consumption of specific groups of fried food with general and central obesity was assessed with logistic regression models and after adjustment for the same variables as previously described. Reported P values are 2-tailed. Random-effects logistic analyses were performed with the glimmix macro (33) and SAS statistical software (version 8.2; SAS Institute, Cary, NC).

RESULTS

The prevalence of general obesity was 27.6% in men and 27.7% in women; the prevalence of central obesity was 34.5% and 42.6%, respectively. The mean ± SD proportion of EI from fried food was 15.6 ± 7.3% in men and 12.6 ± 6.7% in women. A total of 206 different fried foods were recorded at least once, and the oils used for frying were olive oil, virgin olive oil, sunflower oil, corn oil, soy oil, seed oils (the specific seed oil consumed was not reported), and mixed oils.

Increased EI from fried food was associated with greater intake of energy from lipids in both sexes and with higher total EI in women (Table 1). Participants of both sexes who were in sedentary occupations and those with a university education had a lower intake of fried food than did those who were more active and had less than a university education. In men, former smokers had a lower consumption of fried food than did women; among women, those with lower fried food intake were more likely to be older and postmenopausal. All of these associations were significant (P < 0.01).

The prevalence of general and central obesity increased with increasing intake of energy from fried food (Table 2). The odds ratios for general obesity in the highest versus the lowest quintile of EI from fried food were 1.26 (95% CI: 1.09, 1.45; P for linear trend < 0.001) in men and 1.25 (1.11, 1.41; P for linear trend < 0.001) in women. Corresponding odds ratios for central obesity were 1.17 (1.02, 1.34; P for linear trend = 0.003) and 1.28 (1.15, 1.42; P for linear trend < 0.001), respectively.

Overall, 69.6% of men and 68.3% of women reported using olive oil (regular or virgin), and the rest of the participants reported using other oils (sunflower, corn, or soy). Subjects in the highest quintile of fried food intake were more likely than were those in the lowest quintile to have both general and central obesity regardless of the type of oil used for frying, although the associations were not significant for general or central obesity and consumption of other oils in women or for central obesity and consumption of olive oil in men (Table 3).

Fried meat, fish, potatoes, and eggs were the 4 groups of fried food most frequently consumed by study participants, with >75% of men and women consuming each of these groups of food. EI in men and women, respectively, ranged from to 2.0% and 1.5% for fried eggs to 5.0% and 3.6% for fried meat. Consumption of fried meat was positively associated with general obesity in men, and the intake of fried fish was associated with general obesity in women. The same pattern was observed for central obesity. In addition, consumption of fried egg was associated with central obesity in men (Figure 1).

DISCUSSION

In this large cross-sectional analysis of the EPIC-Spain cohort, fried food intake was positively associated with general and central obesity regardless of total EI only in the subjects in the highest quintile of EI from fried foods, corresponding to >21.7% of total calorie intake in men and >18.0% of that in women. This association was observed in both sexes and in participants who reported using olive oil or other types of oil for frying.

During frying, food is totally or partially immersed in oil that is heated above 180 °C. This process modifies both the foods and the frying medium. In contact with hot frying oil, food loses water, absorbs oil, and exchanges lipids with the frying oil. The amount of oil absorbed by frying food depends on the type of food and the frying conditions, but it may be >20% of its weight. French fries, for example, may absorb 19% of their weight as oil during frying (34). Fried food also undergoes pyrolytical decomposition in surface layers, which results in the formation of heterocyclic amines. Finally, frying food absorbs degradation products of the frying oil, such as polymers and polar compounds. These products have been associated with different types of cancer (35–40), endothelial dysfunction (41), and hypertension (42).

Several mechanisms may explain a positive association between fried food intake and obesity. Fried foods are crunchy, aromatic, highly palatable, and rich in fats. As a consequence, eating fried food in ad libitum conditions may result in higher absolute intake of foods with high energy density and low satiety index. The relatively low satiety index of fats (43) may be related to their low ability to stimulate insulin and leptin production (44). In addition, fat intake may stimulate food consumption beyond its effect on satiety. For instance, when lunch and snacks with different content of fat and carbohydrates but with similar effects on postmeal satiety were offered, subjects consuming the high-fat lunch and snacks had higher fat and EI over the whole day than did subjects consuming high-carbohydrate foods (45).

Fried food may also induce obesity by increasing food energy density. Energy density, palatability, and EI are highly related, and
**TABLE 1**
Characteristics of the study population by quintile (Q) of percentage of energy intake from fried food

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 12905)</th>
<th>Women (n = 20637)</th>
<th>P for trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
<td>Q3</td>
<td>Q5</td>
</tr>
<tr>
<td>Energy from fried food (%)</td>
<td>6.0 ± 2.0 **</td>
<td>15.1 ± 1.1</td>
<td>26.4 ± 4.4</td>
</tr>
<tr>
<td>Total energy (kcal/d)</td>
<td>2738.6 ± 738.7</td>
<td>2865.7 ± 682.0</td>
<td>2708.2 ± 658.8</td>
</tr>
<tr>
<td>Energy from lipids (%)</td>
<td>33.8 ± 6.3</td>
<td>35.0 ± 5.8</td>
<td>36.5 ± 5.6</td>
</tr>
<tr>
<td>Age (y)</td>
<td>50.5 ± 7.6</td>
<td>50.2 ± 7.0</td>
<td>50.9 ± 6.9</td>
</tr>
<tr>
<td>Physical activity at work (%)</td>
<td>37.5</td>
<td>33.6</td>
<td>30.3</td>
</tr>
<tr>
<td>Sedentary occupation</td>
<td>36.2</td>
<td>34.7</td>
<td>31.3</td>
</tr>
<tr>
<td>Standing occupation</td>
<td>15.4</td>
<td>22.7</td>
<td>27.8</td>
</tr>
<tr>
<td>Manual work</td>
<td>6.5</td>
<td>4.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Heavy manual work</td>
<td>4.5</td>
<td>4.3</td>
<td>5.2</td>
</tr>
<tr>
<td>Nonworker</td>
<td>36.2</td>
<td>34.7</td>
<td>31.3</td>
</tr>
<tr>
<td>Leisure-time physical activity (METs · h/wk)</td>
<td>33.9 ± 29.0</td>
<td>33.4 ± 28.2</td>
<td>31.7 ± 25.8</td>
</tr>
<tr>
<td>Physical activity in household (METs · h/wk)</td>
<td>18.8 ± 23.1</td>
<td>18.1 ± 22.5</td>
<td>17.7 ± 21.9</td>
</tr>
<tr>
<td>Educational level (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No formal education</td>
<td>29.9</td>
<td>23.7</td>
<td>26.4</td>
</tr>
<tr>
<td>Primary school</td>
<td>31.8</td>
<td>38.5</td>
<td>42.1</td>
</tr>
<tr>
<td>Vocational training</td>
<td>8.9</td>
<td>14.3</td>
<td>15.3</td>
</tr>
<tr>
<td>Secondary school</td>
<td>8.8</td>
<td>8.1</td>
<td>6.6</td>
</tr>
<tr>
<td>University</td>
<td>20.5</td>
<td>15.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Former smoker (%)</td>
<td>34.9</td>
<td>27.4</td>
<td>26.1</td>
</tr>
<tr>
<td>Current smoker (%)</td>
<td>33.4</td>
<td>32.6</td>
<td>27.0</td>
</tr>
<tr>
<td>Never smoker (%)</td>
<td>31.7</td>
<td>40.0</td>
<td>46.9</td>
</tr>
<tr>
<td>Cigarettes (no./d)</td>
<td>17.3 ± 11.3</td>
<td>16.8 ± 11.3</td>
<td>16.7 ± 11.2</td>
</tr>
<tr>
<td>Reproductive history</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parity</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Menopausal status (%)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Hormone replacement treatment (%)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

\* Cutoffs for quintiles of energy intake from fried food were 9.0%, 13.3%, 17.1%, and 21.7% in men and 6.7%, 10.0%, 13.5%, and 18.0% in women. Linear regression or logistic regression models were used to obtain the P value for linear trend, by introducing the quintiles of fried food as a continuous variable.

\**x ± SD (all such values).

\* Chi-square test.
Energy density is a primary determinant of voluntary EI (46). Studies have shown that energy density is a better predictor of total EI than macronutrient composition (3, 45). Unlike those mechanisms described above, this type of potential mechanism does not involve greater EI. It has been argued that body weight may depend on macronutrient composition in addition to total EI (50–53) and that low-fat, high-protein, and high-complex carbohydrate diets should be recommended for obesity prevention.

### TABLE 2

Odds ratios (and 95% CIs) of general and central obesity by quintile (Q) of percentage of energy intake from fried food

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>P for linear trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General obesity</strong>&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (n = 12 905)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevalence&lt;sup&gt;2&lt;/sup&gt;</td>
<td>27.4</td>
<td>27.1</td>
<td>26.3</td>
<td>28.1</td>
<td>32.6</td>
<td></td>
</tr>
<tr>
<td>Odds ratio (95% CI)</td>
<td>1 (Ref)</td>
<td>0.99 (0.87, 1.12)</td>
<td>0.96 (0.84, 1.10)</td>
<td>1.03 (0.89, 1.19)</td>
<td>1.26 (1.09, 1.45)</td>
<td>0.0009</td>
</tr>
<tr>
<td><strong>Central obesity</strong>&lt;sup&gt;3&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Men (n = 12 905)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevalence&lt;sup&gt;2&lt;/sup&gt;</td>
<td>25.8</td>
<td>25.7</td>
<td>25.3</td>
<td>26.8</td>
<td>29.3</td>
<td></td>
</tr>
<tr>
<td>Odds ratio (95% CI)</td>
<td>1 (Ref)</td>
<td>1.01 (0.91, 1.12)</td>
<td>1.01 (0.91, 1.12)</td>
<td>1.10 (0.99, 1.23)</td>
<td>1.25 (1.11, 1.41)</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

1 Ref, reference. General obesity: BMI (in kg/m²) ≥ 30.
2 Prevalence of obesity: adjusted for center (Asturias, Gipuzkoa, Granada, Murcia, or Navarra).
3 Waist circumference: ≥ 102 and ≥ 88 cm in men and women, respectively. Logistic regression models were adjusted for age (29–≤40, >40–≤45, >45–50, >50–<55, >55–≤60, or >60 y), physical activity at work (sedentary occupation, standing occupation, manual work, heavy manual work, or nonworker), leisure-time physical activity (metabolic equivalents·h⁻¹·wk⁻¹ in quintiles), physical activity in household (metabolic equivalents·h⁻¹·wk⁻¹ in quintiles), smoking status (former smoker or current no. of cigarettes/d), educational level (no formal education, primary school, vocational training, secondary school, or university), energy intake, and center (Asturias, Gipuzkoa, Granada, Murcia, or Navarra). Center was modeled as a random effect. For women, the model was also adjusted for parity, menopausal status, and hormone replacement treatment. Cutoffs for quintiles of energy intake from fried food were 9.0%, 13.3%, 45–50, or 60, or >60 y.

### TABLE 3

Odds ratios (and 95% CIs) of general and central obesity by quintile (Q) of percentage of energy intake from fried food according to type of oil consumed (olive oil or other oils)

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>P for linear trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General obesity</strong>&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Men (n = 10 881)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive oil&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>1.04 (0.88, 1.22)</td>
<td>0.96 (0.81, 1.15)</td>
<td>1.00 (0.83, 1.20)</td>
<td>1.36 (1.13, 1.63)</td>
<td>0.0062</td>
</tr>
<tr>
<td>Other oils&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>1.02 (0.77, 1.34)</td>
<td>1.06 (0.80, 1.41)</td>
<td>1.06 (0.79, 1.41)</td>
<td>1.39 (1.05, 1.85)</td>
<td>0.0146</td>
</tr>
<tr>
<td>Women (n = 19 167)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive oil&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>1.03 (0.91, 1.17)</td>
<td>1.02 (0.89, 1.17)</td>
<td>1.10 (0.95, 1.26)</td>
<td>1.31 (1.12, 1.52)</td>
<td>0.0013</td>
</tr>
<tr>
<td>Other oils&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>0.89 (0.73, 1.09)</td>
<td>1.02 (0.84, 1.25)</td>
<td>1.09 (0.89, 1.35)</td>
<td>1.11 (0.90, 1.37)</td>
<td>0.0955</td>
</tr>
<tr>
<td><strong>Central obesity</strong>&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
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</tr>
<tr>
<td>Men (n = 10 881)</td>
<td></td>
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<tr>
<td>Olive oil&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>0.85 (0.72, 0.99)</td>
<td>0.96 (0.81, 1.13)</td>
<td>0.93 (0.78, 1.11)</td>
<td>1.12 (0.93, 1.34)</td>
<td>0.1236</td>
</tr>
<tr>
<td>Other oils&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>1.15 (0.89, 1.50)</td>
<td>1.05 (0.80, 1.38)</td>
<td>1.22 (0.93, 1.62)</td>
<td>1.47 (1.11, 1.94)</td>
<td>0.0051</td>
</tr>
<tr>
<td>Women (n = 19 167)</td>
<td></td>
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<td></td>
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<tr>
<td>Olive oil&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>1.07 (0.95, 1.21)</td>
<td>1.07 (0.95, 1.22)</td>
<td>1.25 (1.10, 1.42)</td>
<td>1.35 (1.17, 1.55)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Other oils&lt;sup&gt;4&lt;/sup&gt;</td>
<td>1 (Ref)</td>
<td>0.95 (0.78, 1.15)</td>
<td>0.89 (0.73, 1.08)</td>
<td>0.96 (0.79, 1.17)</td>
<td>1.11 (0.92, 1.36)</td>
<td>0.1935</td>
</tr>
</tbody>
</table>

1 BMI (in kg/m²) ≥ 30.
2 Olive oil: regular virgin.
3 Other oils: sunflower oil, corn oil, or soy oil.
4 Waist circumference: ≥ 102 and ≥ 88 cm in men and women, respectively. Logistic regression models were adjusted for age (29–≤40, >40–≤45, >45–50, >50–<55, >55–≤60, or >60 y), physical activity at work (sedentary occupation, standing occupation, manual work, heavy manual work, or nonworker), leisure-time physical activity (metabolic equivalents·h⁻¹·wk⁻¹ in quintiles), physical activity in household (metabolic equivalents·h⁻¹·wk⁻¹ in quintiles), smoking status (former smoker or current no. of cigarettes/d), educational level (no formal education, primary school, vocational training, secondary school, or university), energy intake, and center (Asturias, Gipuzkoa, Granada, Murcia, or Navarra). Center was modeled as a random effect. For women, the model was also adjusted for parity, menopausal status, and hormone replacement treatment. Cutoffs for quintiles of energy intake from fried food were 9.0%, 13.3%, 17.1%, and 21.7% in men and 6.7%, 10.0%, 13.5%, and 18.0% in women.
This view, however, is controversial. Although short-term studies show a modest reduction in body weight with low fat diets, long-term studies suggest that total EI is much more important than macronutrient composition for body weight (54).

Because the analyses were adjusted for EI, mechanisms not involving a greater EI are the most likely explanation for our findings. However, given that the estimation of EI in epidemiologic studies is less than perfect, other mechanisms implicating higher EI, such as increased food consumption and energy density, cannot be ruled out as contributors to the association between fried food intake and obesity.

A priori, we expected that the association between fried food and obesity would be linear. In women, there is certain indication of linearity because the ORs tended to increase fairly monotonically from the lowest quintile of fried food consumption. Moreover, given that the association between fried food and obesity is only modest for the highest quintile, we were not surprised that such an association was not observed in the intermediate quintiles. Our results, however, do not permit a conclusion as to whether the association is graded or whether it represents a threshold.

In our study, the association of fried food intake with obesity was observed both in subjects who reported using olive oil for frying and in those using other oils. Olive oil is more resistant to oxidation than are other oils (55), and it has been considered the oil of choice for frying. Deep frying in olive oil may not adversely affect postprandial endothelial function (41). Furthermore, insulin resistance was lower in subjects using olive oil for cooking than in those using sunflower oil or mixed oils (56). However, our results do not support a differential association of olive oil used for frying with general or central obesity.

Because the association between fried food and obesity is only modest in the highest quintile of consumption, it is more likely that we would find associations for fried food as a whole than for any individual type of fried food. This situation is comparable to others in nutritional epidemiology: in that field of study, it is easier to detect associations between health and certain overall dietary patterns (eg, “prudent patterns” defined as a priori or Mediterranean diet scores defined as a posteriori) than to detect associations between health and the individual dietary components (57). Nevertheless, we have found associations in the expected direction for fried meat and fried eggs in men and for fried fish in women.

An important strength of our study was the availability of a detailed diet history, which allowed the ascertainment of a wide variety of commonly consumed foods and of food-preparation methods. Information on cooking methods was available for 99% of the foods recorded. Other strengths included the use of a large sample of free-living participants from diverse geographic areas in Spain and the collection of information on many potentially important covariates, such as total EI and physical activity.

Several potential limitations, however, should be considered in the interpretation of our findings. The cross-sectional design of our analysis did not allow us to establish a causal relation between fried food intake and obesity. We cannot know whether a higher intake of fried food preceded the development of obesity or was a consequence of it. In addition, it is possible that obese subjects changed their food intake, including that of fried food, in an attempt to lose weight. Furthermore, we cannot exclude differential biases in the reporting of fried food intake in obese compared with nonobese participants. In a study of 38 healthy females, underreporting of the intakes of fried food and candy was greater in the obese than in the nonobese participants (58). Indeed, fried foods that are widely perceived as unhealthy, such as fried potatoes, had no relation with obesity in our study. We speculate that this difference may be due to a combination of changes in dietary habits by obese participants to avoid fried potatoes and to differential underreporting of these food items by obese participants. In the EPIC-Spain cohort, total EI was underestimated by 5.5% in obese males and by 17.5% in obese females according to the discrepancy between reported intake and anthropometric measurements (59). Unfortunately, no data are available on the extent of differential underreporting of different types of foods, including fried foods, among obese subjects.

Deep-frying, in which frying foods are totally immersed in oil, and pan-frying, in which frying foods are only partially immersed in oil, have different effects on the absorption of fat by the
frying foods, depending on the food, the oil used, and the frying conditions (60, 61). Our study, however, could not distinguish between the 2 frying methods. As a final limitation, it was not possible to separate the effect of a specific food from the effect of the cooking method.

Despite these limitations, our study provides important observational evidence of a positive association between fried food intake and obesity, a major public health problem. The prevalence of obesity in Mediterranean countries is already very high. Of the 10 European countries participating in EPIC, Spain, Italy, and Greece had the highest prevalences of obesity (28). Indeed, the prevalence of obesity in our study is only slightly lower than that in the United States, although the prevalence of morbid obesity was lower than that in the United States (62). Because fried food contains potentially carcinogenic products of degradation, a potential effect of fried food on the risk of obesity would add to the rationale for recommending other methods of cooking when possible and for reducing or avoiding some foods when frying is the only possible cooking procedure (eg, fried snacks). Because frying in oil is a common and widely accepted form of cooking, confirmation of our findings in prospective studies and in randomized controlled trials should be a priority in public health nutrition.

The authors’ responsibilities were as follows—CAG: coordinator of the European Prospective Investigation of Cancer and Nutrition–Spain; PG-C and FR-A: the concept of the study and writing the draft of the manuscript; CAG, AB, MDI, CM, JRQ, and CN: provision of the original data and information on the respective populations and input on the study design and analysis; and all authors: interpretation of results and contributions to the writing of the manuscript. None of the authors had a personal or financial conflict of interest.

REFERENCES

34. Pokorny J. Changes of nutrients at frying temperatures. In: Boskou D,.
54. Willett WC, Leibel RL. Dietary fat is not a major determinant of body fat. Am J Med 2002;113(suppl)B:47S–59S.