Original article

Consumption of fried foods and risk of metabolic syndrome: The SUN cohort study


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1. Introduction

Metabolic syndrome (MS) is a term that has been used to describe a constellation of metabolic abnormalities that increase the risk of heart disease, and type 2 diabetes. These metabolic abnormalities include hypertriglyceridemia (triglycerides >150 mg/dL or specific medication), low levels of high-density lipoprotein cholesterol (HDL-C) (<40 mg/dL and <50 mg/dL for men and women respectively, or specific medication), elevated blood pressure (systolic ≥130 and/or diastolic ≥85 mmHg or antihypertensive drug treatment in a patient with a history of hypertension), impaired glucose metabolism (fasting plasma glucose >100 mg/dL, specific medication, or previous diagnosis of type 2 diabetes), and central obesity (in Europids, waist circumference >80 cm, for men and women respectively). The prevalence of this syndrome is dramatically growing, mainly due to the increasing prevalence of obesity and sedentary lifestyles, being now a priority public health problem.

Consumption of fried foods is also increasing and this might be due to their unique sensory properties (taste, flavor, aroma, and texture). Frying is a fast and convenient method of food processing. In Spain, as in other Mediterranean countries, frying with oil is a traditional cooking procedure. The frying process is complex, and it involves many factors, some of them are dependent on the process itself, and others on the food and type of fat used. A critical aspect of frying food is the high amount of oil that is absorbed during the process, reaching up to 40% of the total food product weight in some cases.
In addition, several epidemiological studies have demonstrated that the consumption of fried foods contributes to a greater weight gain, as well as a higher risk of overweight, obesity, and central adiposity. On the other hand, the association between cardiovascular disease and the consumption of fried foods is not clear with studies reporting a positive association or a null association. Additionally, consumption of fried food has been reported to increase the risk of hypertension and to be associated to decreased levels of HDL-C. Only one long-term prospective study from the USA has evaluated the relationship between fried food consumption and the incidence of MS finding a positive association.

Therefore, until now there is scarce evidence from long-term prospective studies linking fried food consumption to the incidence of MS. The aim of this study was to assess the association between fried food consumption and the incidence of MS in a relatively young cohort of Mediterranean subjects.

2. Subjects and methods

2.1. Study population

The Seguimiento Universidad de Navarra (SUN) project is a Spanish, multipurpose, dynamic, and prospective cohort that was designed to establish associations between diet and the occurrence of several diseases and chronic conditions including overweight and obesity. Participants have been continually followed-up using biennial mailed questionnaires. The recruitment of participants started in December 1999, and it is permanently open. Therefore the follow-up time is variable for each participant depending of his/her entry date in the cohort. All participants are university graduates where the age ranged from 20 to 90 years. For the present study, we included a subsample of the cohort. As we established a minimum follow-up of 6 years, only participants recruited before September 2005 could be included (n = 15 633). To avoid reverse causality bias, we excluded 3963 participants who met at least one MS criterion at baseline; as recommended in nutritional epidemiology, we also excluded 1197 participants who reported values for total energy intake at baseline out of predefined limits (less than 800 kcal/d in men and 500 kcal/d in women or more than 4000 kcal/d in men and 3500 kcal/d in women). Further exclusions were 577 participants without any follow-up who were considered lost to follow-up (retention rate = 94%), 1487 participants who did not provide the relevant information about diagnostic criteria for the metabolic syndrome at the 6th and 8th-year follow-up, and 120 participants with missing values in other variables of interest. These exclusions left a total of 8289 participants available for the final analysis (Fig. 1).

The study was approved by the Human Research Ethical Committee of the University of Navarra. Voluntary completion of the first self-administrated questionnaire was considered to imply informed consent.

2.2. Dietary assessment

The baseline questionnaire included a semi-quantitative food frequency questionnaire (FFQ) repeatedly validated in Spain with 136 food items. Nutrient scores were calculated as frequency multiplied by nutrient composition of specified portion sizes. Frequencies were measured in 9 categories (never/almost never, 1–3 servings/meal, 1 serving/meal, 2–4 servings/meal, 5–6 servings/meal, 1 serving/day, 2–3 servings/day, 4–6 servings/day, >6 servings/day) for each food item. Fried food consumption was evaluated in 2 of these items: the consumption of fried food at home and the consumption of fried food away from home. We estimated total fried food consumption per person using the sum of these two

MS was defined according to the American Heart Association and the International Diabetes Federation criteria as outlined in the harmonized definition for MS. According to this definition, MS diagnosis needs the presence of at least 3 of the 5 criteria: hypertriglyceridemia, low levels of high-density lipoprotein cholesterol, elevated blood pressure, impaired glucose metabolism, and central adiposity (in our study waist circumference: ≥94 cm in males and ≥80 cm in females).

In the 6th and 8th year follow-up questionnaires, self-reported data about each specific MS criterion were collected. A measure tape and an explanation of how to measure their own waist were sent to participants with both questionnaires. Validation of each MS criterion was previously assessed in a subsample of the cohort. Additionally, another validation study on the diagnosis of
MS was conducted in a subsample of the cohort finding a proportion of confirmed MS of 91.2% (95% CI: 80.7–97.1%) and non-confirmed MS of 92.2% (95% CI: 85.1–96.4%) between self-reported diagnosis of MS and MS diagnosed by the medical records of the participants.23

We defined as incident cases of MS all participants who did not have MS at baseline, and reported 3 or more criteria of MS in the 6th or the 8th year follow-up questionnaire.

2.5. Statistical analyses

Participants were classified into three categories according to their fried food consumption: 0–2/week, >2–4/week, and >4/week. We considered the group with the lowest frequency of consumption (0–2/week) as the reference category.

Cox regression models were fitted to assess the relationship between the consumption of fried foods at baseline and the risk of developing incident MS during follow-up. Hazard Ratios (HR) and their 95% CI were calculated. Tests for linear trend across increasing categories of fried food consumption were conducted by assigning the median frequency of consumption within each category and treating this variable as a continuous variable.

We performed separate analyses for the participants who used olive oil to fry at home and for those who used other types of fat to fry. We evaluated the interaction between the type of fat used for frying and the frequency of consumption of fried foods at home through likelihood ratio test after introducing the product-term in fully adjusted model.

For all the analyses, we fitted a crude model (without any adjustment), an age- and sex-adjusted model, and a multivariable-adjusted model after additional adjustment for the following potential confounders: baseline BMI (kg/m²), physical activity (METs-hours/week), smoking status (non-smoker, smoker, former smoker), snacking between meals (yes/no), sitting (hours/day), consumption of sugared-soft drinks (ml/day), dietary fiber intake (g/day), consumption of fast food (yes/no), carbohydrate intake (g/day), fat intake (g/day) sodium intake (mg/day), and adherence to Mediterranean diet (low, medium and high).

All p values presented are two-tailed; p < 0.05 was considered statistically significant. Analyses were performed using STATA/SE version 12.0 (StataCorp, College Station, TX, USA).

3. Results

We included in our analyses 2813 men and 5476 women. The main characteristics of participants according to their frequency of fried food consumption are presented in Table 1. The mean age of participants was 35.9 y (SD: 10.4) and the mean BMI was 22.7 kg/m² (SD: 2.7). Participants in the highest fried food consumption category had a higher BMI, were less physically active, spent more hours sitting, and had the highest total energy intake, fat intake, fast food consumption, sugared soft-drinks consumption, the highest proportion of snacking between meals, and the lowest fiber intake.

During the follow-up period (median of 8.3 y) we observed 420 incident cases of MS. As displayed in Table 2, a higher frequency of fried food consumption was not associated with a higher risk of developing MS. Participants consuming fried foods >2 to 4 and >4 times/week did not exhibit a significantly greater risk of developing MS compared with those who consumed 0–2 times/week [HR = 1.05 (95% CI: 0.83–1.32) and 0.98 (95% CI: 0.77–1.26) p for trend = 0.862], after adjusting for potential confounders (Table 2).

Seventy three percent of the participants used olive oil for frying at home, and twenty seven percent used other types of oils or fat for frying (e.g. sunflower oil, corn oil, butter, margarine). Among participants who used olive oil for frying at home we did not find any association between frequent consumption of fried foods at home (>4 times per week) and the incidence of MS compared with those who consumed 0–2 times/week [HR = 0.91 (95% CI: 0.68–1.23) (p for trend = 0.853)]. In the group of participants who used other types of oil for frying at home the multivariable HR for the highest category of consumption was 1.34 (95% CI: 0.77–2.30) (p for trend = 0.062) in comparison with the lowest category of consumption. No statistically significant interaction between type of oil or fat used for frying and the frequency of consumption of fried foods was observed (p for interaction = 0.844) (Table 3).

The risk of developing each criterion of MS in the highest category of consumption is shown on Fig. 2. From the 5 criteria of MS, we observed that those participants who consumed fried foods more frequently were at a significantly increased risk of developing MS (Table 2).

We performed a Crude model (without any adjustment), an age- and sex-adjusted model, and a multivariable-adjusted model after additional adjustment for the following potential confounders: baseline BMI (kg/m²), physical activity (METs-hours/week), smoking status (non-smoker, smoker, former smoker), snacking between meals (yes/no), sitting (hours/day), consumption of sugared-soft drinks (ml/day), dietary fiber intake (g/day), consumption of fast food (yes/no), carbohydrate intake (g/day), fat intake (g/day) sodium intake (mg/day), and adherence to Mediterranean diet (low, medium and high).

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Table 3
Hazard Ratio (HR) and 95% CI of incident MS according to frequency of consumption of fried foods in 8289 participants of the SUN project (1999–2012), stratified by type of oil used to fry.

<table>
<thead>
<tr>
<th>Consumption of fried food (times per week)</th>
<th>0–2/week</th>
<th>&gt;2–4/week</th>
<th>&gt;4/week</th>
<th>p for trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frying with olive oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incident cases</td>
<td>123</td>
<td>114</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Person-years</td>
<td>18,697</td>
<td>15,785</td>
<td>13,126</td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>1.00 Ref.</td>
<td>1.09 (0.84–1.40)</td>
<td>1.14 (0.87–1.50)</td>
<td>0.323</td>
</tr>
<tr>
<td>Age and sex–adjusted model</td>
<td>1.00 Ref.</td>
<td>1.01 (0.78–1.31)</td>
<td>0.89 (0.68–1.18)</td>
<td>0.547</td>
</tr>
<tr>
<td>Multivariable adjusted model*</td>
<td>1.00 Ref.</td>
<td>1.01 (0.77–1.31)</td>
<td>0.85 (0.63–1.15)</td>
<td>0.284</td>
</tr>
<tr>
<td>Frying with oils or fats different from olive oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incident cases</td>
<td>25</td>
<td>37</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Person-years</td>
<td>6189</td>
<td>6050</td>
<td>5487</td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>1.00 Ref.</td>
<td>1.43 (0.86–2.37)</td>
<td>1.54 (0.91–2.63)</td>
<td>0.122</td>
</tr>
<tr>
<td>Age and sex–adjusted model</td>
<td>1.00 Ref.</td>
<td>1.20 (0.72–2.00)</td>
<td>1.28 (0.75–2.19)</td>
<td>0.390</td>
</tr>
<tr>
<td>Multivariable adjusted model*</td>
<td>1.00 Ref.</td>
<td>1.14 (0.66–1.95)</td>
<td>1.26 (0.71–2.23)</td>
<td>0.446</td>
</tr>
</tbody>
</table>

* Adjusted for: age, sex, baseline BMI, time spent sitting down, smoking status, physical activity, sugared soft drinks, fiber, fast food, snacking between meals, categories of Mediterranean diet, and total energy, carbohydrates, fat and sodium intake.

>4 times/week compared with those who consumed ≤2 times/week had a higher risk to develop 2 criteria of MS: central adiposity and high blood pressure. The multivariable adjusted HR for developing central adiposity were 0.98 (95% CI: 0.91–0.96) and 1.10 (95% CI: 1.01–1.19) (p for trend = 0.022) for those who consumed >2–4 times/week and those who consume >4 times/week respectively, compared with those who consumed 0–2 times/week. And the multivariable adjusted HR for developing high blood pressure were 1.14 (95% CI: 1.01–1.29) and 1.16 (95% CI: 1.02–1.32) (p for trend = 0.011) for those who consumed >2–4 times/week and those who consumed >4 times/week respectively, compared with those who consumed 0–2 times/week.

4. Discussion

In this Mediterranean cohort of relatively young university graduates, more frequent consumption of fried foods was not associated with the risk of incident MS among 8289 initially free of MS participants with a median follow-up of 8.3 years. However, a higher consumption of fried foods was associated with 2 of the MS criteria (central adiposity and high blood pressure) after controlling for several potential confounders.

The Atherosclerosis Risk in Communities (ARIC) a prospective study from the US has previously evaluated the association between fried food consumption and the risk of MS. That study found that more frequent consumption of fried foods was associated with a slightly higher risk of incident MS in 9514 middle aged (mean age: 53.6 years) men and women. After 9 years of follow-up they found a HR of 1.25 (95% CI: 1.14–1.37; p for trend 0.02) for the highest versus the lowest tertile of fried foods consumption.15 This difference could be explained because of the different studied population, the different type of oils or fats used to fry or the different mean age of the participants. In addition, the incidence of MS that we found in our cohort was only 5.1% which is lower than the incidence reported for the general Spanish population,24 as is to be expected in a cohort of relatively young, slim, educated and healthy subjects. Our low incidence led us to find a considerably lower number of new cases (n = 420) than the ARIC cohort, that observed 3782 incident cases. This lower incidence in our highly educated cohort could provide another alternative explanation to the divergent findings.

Prospective studies linking fried food consumption and MS are scarce; however, there are some reports in the literature relating the consumption of fried foods with specific isolated criteria of the MS (central adiposity, low high-density lipoprotein cholesterol, elevated blood pressure).

Prospective studies have found that fried food consumption is associated with higher risk of overweight and obesity,8 and also with greater central adiposity.9 In concordance with previous studies, in our study we found that participants who consumed fried foods more than 4 times/week had a significantly higher risk of central adiposity after adjusting for potential confounders.

The 2nd component of MS that we studied was impaired glucose metabolism or type 2 diabetes mellitus. We did not find any association of fried foods consumption at baseline with the likelihood of meeting this criterion after 6 or 8 years of follow-up. Fried foods are potentially a source of TFA.25 Observational studies have found that a high intake of TFA was associated with higher risk of type 2 diabetes mellitus or insulin resistance.26,27 Those studies also suggested beneficial effects on insulin sensitivity when TFA were replaced by monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA); as a Mediterranean cohort, 73% of our participants used MUFA-rich olive oil for cooking and frying. This fact may explain the apparent null association between fried food consumption and glucose abnormalities in our cohort.

When we analyzed high triglycerides and low HDL-C, we did not find any association with frequent fried food consumption. It has been demonstrated by short-term studies that diets high in carbohydrates, particularly sugars, increase serum triglycerides concentrations and decrease serum HDL-C.28,29 Therefore, blood triglycerides and HDL-C levels are modified mainly by carbohydrates but not by fat or fried food consumption, except for trans-fatty acids (TFA).30 As discussed above, TFA are not very likely to be formed when frying with olive oil.

Finally, when we analyzed high blood pressure, we found a direct significant association with frequent fried food consumption. Our results are consistent with a previous cross-sectional study of 1226 persons, which found that oil polar compounds that are formed during the frying process were positively and independently associated with higher risk of hypertension.13

When we analyzed each type of oil or fat used to fry, there was a suggestion of a higher risk of developing MS among participants who used other oils or fats different from olive oil to fry foods. But, the observed differences were not statistically significant. Only 27% of the participants fried with these other types of fat. Therefore, possibly we did not have enough variability to assess this hypothesis.
A potential limitation of our study is the self-reported outcome. However, self-reported MS components were previously validated in our cohort finding intraclass correlation coefficients between 0.5 and 0.9 (< 0.001) depending on the criteria, using as gold standard direct assessments by an experienced physician. Additionally, weight and BMI were also validated in a subsample of the cohort finding a mean relative error for weight and BMI of 1.45% and 2.64% respectively.

Our study has several strengths, including its prospective design, which avoids the possibility of reverse causation bias. Other strengths are the previous validation of each component of the MS and the metabolic syndrome itself, as well as the methods used to assess the main variables, such as weight, BMI, physical activity and the FFQ, the large sample size, and also their high educational level which allows a better understanding of the questionnaire.

In conclusion, in this Mediterranean cohort of relatively young adults who mainly use olive oil for frying, frequent fried food consumption was not found to be associated with MS. Only two (central adiposity and high blood pressure) out of the five components of MS were positively associated with frequent fried food consumption.

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Statement of authorship

MAM-G helped to design the study and collect data. MB-R and CS-O analyzed the data and drafted the manuscript. All authors edited and critically reviewed the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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