Cross-sectional association of nut intake with adiposity in a Mediterranean population

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Received 31 August 2009; received in revised form 13 November 2009; accepted 20 November 2009

KEYWORDS
BMI; Waist circumference; PREDIMED study; Dietary patterns; Nuts; Meat; Vegetables

Abstract  Background and aims: Nut intake has been inversely related to body mass index (BMI) in prospective studies. We examined dietary determinants of adiposity in an elderly Mediterranean population with customarily high nut consumption.
Methods and results: A cross-sectional study was conducted in 847 subjects (56% women, mean age 67 years, BMI 29.7 kg/m²) at high cardiovascular risk recruited into the PREDIMED study. Food consumption was evaluated by a validated semi-quantitative questionnaire, energy expenditure in physical activity by the Minnesota Leisure Time Activity questionnaire, and anthropometric variables by standard measurements. Nut intake decreased across quintiles of both BMI and waist circumference (P-trend <0.005; both). Alcohol ingestion was inversely related to BMI (P-trend = 0.020) and directly to waist (P-trend = 0.011), while meat intake was directly associated with waist circumference (P-trend = 0.018). In fully adjusted multivariable models, independent dietary associations of BMI were the intake of nuts inversely (P = 0.002) and that of meat and meat products directly (P = 0.042). For waist circumference, independent dietary associations were intake of nuts (P = 0.002) and vegetables (P = 0.040), both inversely, and intake of meat and meat products directly (P = 0.009). From the regression coefficients, it was predicted that BMI and waist circumference decreased by 0.78 kg/m² and 2.1 cm, respectively, for each serving of 30 g of nuts. Results were similar in men and women.

Abbreviations: BMI, Body mass index; MedDiet, Mediterranean diet; CVD, Cardiovascular disease.
* Support for research: This study was funded, in part, by the Spanish Ministry of Health (Instituto de Salud Carlos III, Fondo de Investigaciones Sanitarias) projects PI101839, G03/140 and RD06/0045.
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doi:10.1016/j.numecd.2009.11.010

Please cite this article in press as: Casas-Agustench P, et al., Cross-sectional association of nut intake with adiposity in a Mediterranean population, Nutr Metab Cardiovasc Dis (2009), doi:10.1016/j.numecd.2009.11.010
Introduction

Obesity has reached worldwide epidemic proportions. More than 1 billion adults are overweight and at least 300 million of them are clinically obese. These conditions are associated with an increased risk for serious chronic conditions, including hypertension, type 2 diabetes, coronary heart disease, stroke, and certain types of cancer [1]. There is general agreement that obesity is a complex multifactorial disorder, in which both genetic and environmental factors are involved. Among the environmental factors, physical activity and diet are important in the prevention and management of overweight or obesity and related co-morbidities.

Several dietary factors, such as total fat, protein or fiber intake, the glycemic load of the diet, and energy density are believed to be adiposity determinants. However, the nutritional etiology of obesity remains unclear [2]. Prudent or healthy dietary patterns, which are high in whole grains, fruits and vegetables and low in dairy fat, red and processed meat, fast food, and soda drinks have been associated with smaller gains in BMI and waist circumference [2], whereas unhealthy dietary patterns (rich in red meat, sugar-sweetened soft drinks or fast food) have been consistently associated with a higher risk of weight gain and obesity [3].

Tree nuts and peanuts (henceforth collectively called nuts) are energy-dense foods rich in bioactive nutrients and phyttochemicals, and there is convincing scientific evidence that incorporating them into healthy diets has many health benefits [4]. Although nuts are high-fat foods, evidence from epidemiological and clinical studies suggests that regular nut intake might have a positive impact on adiposity, insulin resistance and related metabolic abnormalities [4,5]. Recently, we reported that a traditional Mediterranean diet (MedDiet) supplemented with one daily serving of mixed nuts was associated with a reduction in the 1-year prevalence of metabolic syndrome, which was accounted for mainly by decreased waist circumference, in participants of the PREDIMED study, a large, parallel-group, randomized, multicenter dietary intervention trial testing the effects of two MedDiets and a low-fat diet on cardiovascular events in asymptomatic persons at high risk of cardiovascular disease (CVD) [6]. Our recruiting PREDIMED center (NURETA) is located in Reus (north-eastern Spain), one of the largest nut growing areas in Spain, where inhabitants have a good adherence to the MedDiet and show customarily high average nut intake [7]. The wide dispersion of nut intake in Reus thus provides a better opportunity of finding associations with adiposity than studies in other populations with lower nut intakes. Therefore, we performed a cross-sectional study to examine the dietary determinants of adiposity (especially the intake of nuts and other components of the MedDiet) in our PREDIMED study cohort.

Methods

Study population

The present cross-sectional analysis was performed with the baseline data of the PREDIMED participants from the NURETA center in Reus (Catalonia, Spain). From October 2003 to July 2008, volunteers were recruited by primary care physicians to participate in the PREDIMED study, a dietary primary prevention trial [8]. Eligible subjects included men aged 55–80 and women aged 60–80 years with no history of cardiovascular disease, but having a diagnosis of type 2 diabetes or disclosing at least three risk factors for CVD (family history of early-onset CVD, smoking, overweight or obesity, hypertension, hyperlipidemia, and low HDL-cholesterol). The local Institutional Review Board approved the study protocol and participants signed an informed consent. The methodology of the study has been described previously [8].

Baseline evaluation

The baseline examination included the assessment of: (i) weight and height measured with calibrated scales and a wall-mounted stadiometer, respectively, with subjects in indoor clothing and no shoes, and waist circumference measured midway between the lower rib margin and the iliac crest using an anthropometric tape; (ii) BMI calculated as weight in kilograms divided by the square of height in meters; (iii) blood pressure measured using a validated semiautomatic sphygmomanometer (Omron HEM-705CP, Hoofddorp, The Netherlands) in triplicate with a 5-min interval between each measurement; (iv) energy expenditure in physical activity determined by the validated Spanish version of the Minnesota Leisure Time Physical Activity Questionnaire; and (v) lifestyle, health conditions, smoking habits and socio-demographic variables assessed by a general questionnaire.

Nutritional assessment

A trained dietician determined food consumption by a previously validated semi-quantitative 137-item food questionnaire. In this questionnaire, nut intake was categorized as walnuts and other nuts. Energy and nutrient intake were calculated from Spanish food composition tables. A 14-item MedDiet questionnaire, an extension of a previously validated questionnaire, was also administered to assess adherence to the traditional MedDiet (values of 0 or 1 were assigned to each of 14 dietary components).

Biochemical measurements

Fasting blood samples were obtained after an overnight fast and stored at –80 °C until assay. Serum glucose, cholesterol...
and triglyceride concentrations were determined by standard enzymatic methods in an automatic analyzer. HDL-cholesterol was measured by a precipitation technique and LDL-cholesterol was calculated as total cholesterol minus HDL-cholesterol minus triglycerides/5. Metabolic syndrome was defined by updated National Cholesterol Education Program Adult Treatment Panel III criteria.

Statistical analyses

We categorized the participants by quintiles of BMI and quintiles of waist circumference to assess the associations of baseline biochemical, lifestyle, health conditions, smoking habits, socio-demographic variables and the consumption of selected food items by ANOVA statistics or the Kruskal–Wallis test, as appropriate. We also used stepwise linear regression analyses to assess independent associations of BMI and waist circumference with food intake (olive oil, cereals, vegetables, fruits, legumes, nuts, fish and seafood, meat and meat products, commercial bakery products, dairy products, wine and total alcohol), forcing the adjustment for relevant non-dietary factors (gender, age, total energy intake, energy expenditure in physical activity, and educational level) or dietary fiber. Analyses were performed with the whole population and by gender. SPSS 15.0 software (SPSS Inc, Chicago, IL, USA) was used for statistical analyses, with significance set at \( P < 0.05 \).

Results

A total of 847 participants (375 men and 472 women) with a mean age of 67.4 ± 5.9 years were included in the study. The mean values of BMI (29.0 ± 3.1 and 30.1 ± 3.4 kg/m² in men and women, respectively), waist circumference (103.4 ± 8.3 and 99.4 ± 9.3 cm in men and women, respectively) and the prevalence of CVD risk factors (68.7% of the total population presented hyperlipidemia, 84.3% hypertension, 49.0% diabetes and 61.6% metabolic syndrome) showed that the participants belonged to a high-risk cohort.

Table 1 shows the anthropometric features, lifestyle variables, risk factors, and socio-demographic characteristics of the cohort by quintiles of BMI. As expected, body weight, waist circumference, and the prevalence of metabolic syndrome increased and energy expenditure in physical activity decreased across quintiles of BMI. Leaner subjects were older and smoked more than those with higher BMI.

Food and nutrient intake by quintiles of BMI are shown in Table 2. Total nut intake and wine and alcohol ingestion were the only significant (inverse) food associations with BMI. Median (range) daily nut and alcohol intake in the whole population were 9 (0–88) g and 3 (0–48) g. Nutrients were unrelated to quintiles of BMI. Increasing adherence to the MedDiet, as evaluated by the 14-point MedDiet score,
was also inversely associated with BMI. Fig. 1 shows that nut intake as percent of total daily energy decreased across quintiles of BMI.

Median waist circumference ranged from 88.8 cm in Q1 to 113.8 cm in Q5. The only associations of anthropometric characteristics and risk factors with waist circumference were body weight, BMI and prevalence of metabolic syndrome (P for trend <0.001; all). Again, nut intake decreased across quintiles of waist circumference (P for trend 0.004), while meat intake, alcohol ingestion and total energy intake showed direct associations (P for trend 0.018, 0.011 and 0.045, respectively), and fiber intake showed an inverse association (P for trend 0.041). The MedDiet score was nearly significantly (P for trend 0.055) inversely associated with waist circumference.

Table 3 shows independent associations of BMI and waist circumference by stepwise linear regression analysis. Age (inversely), female gender (directly), and energy expenditure in physical activity and educational level (both inversely) were significant non-dietary associations of BMI, whereas nut intake (inversely) and the intake of meat and meat products (directly) were the only significant dietary associations. Female gender and energy expenditure in physical activity (both inversely) were significant non-dietary associations of waist circumference, whereas nut intake (inverse), intake of meat and meat products (directly), and vegetable intake (inversely) were significant dietary associations. From the regression coefficients of Table 3, it was predicted that BMI and waist circumference decreased by 0.78 kg/m² and 2.1 cm, respectively, for each serving of 30 g of nuts. The magnitude of the associations with BMI and waist circumference shown in Table 3 was similar when the nut consumption variable was limited to “walnut consumption” or “other type of nut consumption” separately.

When performing similar multivariate analyses by gender (Table 4), nut intake remained as the sole independent
Table 3  Independent associations of body mass index and waist circumference by stepwise linear regression analysis.

<table>
<thead>
<tr>
<th></th>
<th>Body mass index (kg/m²)</th>
<th>Waist circumference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-standardized coefficient</td>
<td>SE</td>
</tr>
<tr>
<td>Age (per 10 years)</td>
<td>−0.610</td>
<td>0.210</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>0.676</td>
<td>0.269</td>
</tr>
<tr>
<td>Energy expenditure</td>
<td>−0.100</td>
<td>0.000</td>
</tr>
<tr>
<td>in physical activity (per 100 kcal/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Secondary education, technical college or university)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nut intake (per serving of 30 g/day)</td>
<td>−0.781</td>
<td>0.287</td>
</tr>
<tr>
<td>Intake of meat and meat products (per serving of 100 g/day)</td>
<td>0.500</td>
<td>0.200</td>
</tr>
<tr>
<td>Vegetable intake (per serving of 100 g/day)</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

Stepwise linear regression model including body mass index or waist circumference (dependent variables) and food intake variables (independent variables), forcing into the model: gender, age, total energy intake, energy expenditure in physical activity and educational level.

Discussion

In this study, we examined the cross-sectional association of intake of different foods with BMI and waist circumference in an elderly Mediterranean population at high risk of CVD. Results of multivariate analyses with adjustment for various confounders showed that nut intake was the sole dietary component consistently and inversely associated with adiposity measures, whether in the study group as a whole or in men and women separately. High intakes of vegetables (inversely) and of meat and meat products (directly) were also associated with adiposity, albeit less strongly than nut intake.

Results of epidemiological studies have shown associations of various foods with adiposity. A recent review of cross-sectional studies [9] showed that a diet rich in fruits and vegetables and low in meat and total fat was associated with a lower BMI. In prospective studies, the consumption of meat [10] and sweets [11] were positive predictors of body weight or BMI gain, whereas consumption of vegetables [10] or fruits [12] were negative predictors. Several studies have assessed the associations of meat and meat products, vegetables and, particularly, nuts with adiposity measures.

In relation to red meat, the present findings concur with the positive association between the consumption of red meat and meat products and BMI [13–15] or waist circumference [16] observed in cross-sectional and prospective studies [2,17,18].

Regarding vegetables, a significant inverse association between total vegetable consumption and weight gain was reported in a cross-sectional study [19]. In a large prospective study with 12-year follow-up, participants in the top quintile of increase in intake of fruit and vegetables had a 24% lower risk of becoming obese compared to those with the largest decrease in intake after adjustment for various confounders [20]. Recently, the intake of fruit and vegetables was weakly but also inversely associated with weight gain in the European Prospective Investigation into Cancer and Nutrition study [21]. Thus, the results of the present study with regard to vegetable intake and adiposity confirm existing epidemiologic evidence.

Nuts are peculiar natural vegetable products because they are very rich in total fat, which ranges from 44 to 72 g/100 g, although most fatty acids are unsaturated, both mono- and polyunsaturated [22]. However, there is no evidence that nut intake is fattening [5]. Cross-sectional studies showed either that nut consumption was associated with a lower BMI [23] or that there was no relationship between the frequency of nut consumption and BMI [24]. Two large prospective cohort studies showed significant negative associations between consumption of nuts and BMI [25,26], while another study reported no relationship [27]. Recently, frequent nut consumption was associated with a reduced risk of weight gain [28]. Moreover, findings of several intervention trials showed that diets including nuts were not associated with increases in total body weight [6,8,29] or that the minimal weight gain observed was less

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after nut intake and attributed to the fat being contained in adiposity. Furthermore, fat malabsorption has been reported with nut intake. Therefore, the fiber content of nuts probably analyses did not attenuate the strength of the associations and including fiber intake as a confounder in the multivariate association between dietary fiber and adiposity measures confirm earlier findings of epidemiologic studies on BMI and extend them to visceral adiposity, which concurs with the only clinical trial evidence available [6].

There are several mechanistic explanations of why vegetable and nut intake might protect against weight gain, and meat and meat products might lead to weight gain. Vegetables are low energy density foods, rich in water and, as with nuts, rich in fiber. In contrast, nuts are energy-dense, high-fat foods, with a high content of unsaturated fatty acids, whereas meat and meat products are important sources of saturated fatty acids. Evidence suggests that mono-unsaturated and polyunsaturated fatty acids are more readily oxidized [33] and have a greater thermogenic effect [34] than saturated fatty acids, which can lead to less fat accumulation. Nuts are also good sources of plant proteins, which may enhance satiety and suppress subsequent hunger [35]. A high content of dietary fiber, from both vegetables and nuts, is believed to increase satiety and reduce feelings of hunger [36]. However, we did not observe an independent association between dietary fiber and adiposity measures, and including fiber intake as a confounder in the multivariate analyses did not attenuate the strength of the associations with nut intake. Therefore, the fiber content of nuts probably did not contribute to their beneficial effects on adiposity. Furthermore, fat malabsorption has been reported after nut intake and attributed to the fat being contained within walled cellular structures that are incompletely digested in the gut [37], an effect that can be compounded by incomplete mastication [38]. Finally, other mechanisms of protection against adiposity may depend on many other bioactive compounds that are present in nuts [39].

Our study has limitations. Because of the cross-sectional design, we cannot prove causal relationships, and the possibility exists of reverse causation bias, as an increased BMI could be a reason for individuals to decrease intake of fatty foods, among them nuts. Another potential limitation of our cross-sectional study is that of residual confounding, namely that factors unaccounted for in the questionnaires that imply a healthier lifestyle could mediate the inverse association between nut intake and adiposity. Finally, as our cohort was drawn from a population with customarily high nut intake [7], the results cannot be generalized to other populations with lower nut intake.

In conclusion, nut consumption showed a strong inverse association with adiposity, independently of gender, age, educational level, energy expenditure in physical activity, CVD risk factors, and consumption of other foods, energy and fiber. Nut intake can be linked to beneficial effects on adiposity through plausible mechanisms, and results from other studies lend support to our findings. It remains to be explored if residual confounding related to a healthier lifestyle of nut eaters might explain in part of these results.

**Conflict of interest**

J. Salas-Salvadó has received research funding from the International Nut Council, Reus, Spain. He is a non-paid employee of the International Nut Council.
member of the Scientific Advisory Board of the International Nut Council. E. Ros has received research funding from the California Walnut Commission, Sacramento, CA and is a non-paid member of its Scientific Advisory Committee. The authors have no other conflict of interest to declare.

Acknowledgements

We gratefully acknowledge the study’s participants for their enthusiastic collaboration, the PREMIDED personnel for excellent assistance and the personnel of all affiliated primary care centers. Joan Fernandez-Ballart provided expert assistance with statistical analyses. This study was funded in part by the Spanish Ministry of Health (Instituto de Salud Carlos III, Fondo de Investigaciones Sanitarias) projects PI051839, G03/140 and RD06/0045. None of the funding sources played a role in the design, collection, analysis or interpretation of the data or in the decision to submit the manuscript for publication. CIBEROBN is an initiative of ISCIII, Spain. Nureta-PREDIMED investigators not listed as authors: Nancy Babio, Mar Sorli, Cristina Molina, Fabiola Márquez-Sandoval, Naim Izzedini, Joan Marimon, Dolores Gil, Teresa Basora, Roser Pedret and Sergio Giovanny Rojas.

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