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Metabolic Syndrome Features and Excess Weight Were Inversely Associated with Nut Consumption after 1-Year Follow-Up in the PREDIMED-Plus Study

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ABSTRACT

Background: High nut consumption has been previously associated with decreased prevalence of metabolic syndrome (MetS) regardless of race and dietary patterns.

Objectives: The aim of this study was to assess whether changes in nut consumption over a 1-y follow-up are associated with changes in features of MetS in a middle-aged and older Spanish population at high cardiovascular disease risk.

Methods: This prospective 1-y follow-up cohort study, conducted in the framework of the PREvención con DIeta MEDiterránea (PREDIMED)-Plus randomized trial, included 5800 men and women (55–75 y old) with overweight/obesity [BMI (in kg/m^2) ≥27 and <40] and MetS. Nut consumption (almonds, pistachios, walnuts, and other nuts) was assessed using data from a validated FFQ. The primary outcome was the change from baseline to 1 y in features of MetS [waist

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circumference (WC), glycemia, HDL cholesterol, triglyceride (TG), and systolic and diastolic blood pressure] and excess weight (body weight and BMI) according to tertiles of change in nut consumption. Secondary outcomes included changes in dietary and lifestyle characteristics. A generalized linear model was used to compare 1-y changes in features of MetS, weight, dietary intakes, and lifestyle characteristics across tertiles of change in nut consumption.

Results: As nut consumption increased, between each tertile there was a significant decrease in WC, TG, systolic blood pressure, weight, and BMI ($P < 0.05$), and a significant increase in HDL cholesterol (only in women, $P = 0.044$). The interaction effect between time and group was significant for total energy intake ($P < 0.001$), adherence to the Mediterranean diet (MedDiet) ($P < 0.001$), and nut consumption ($P < 0.001$). Across tertiles of increasing nut consumption there was a significant increase in extra virgin olive oil intake and adherence to the MedDiet; change in energy intake, on the other hand, was inversely related to consumption of nuts.

Conclusions: Features of MetS and excess weight were inversely associated with nut consumption after a 1-y follow-up in the PREDIMED-Plus study cohort. This trial was registered at isrctn.com as ISRCTN89898870. *J Nutr* 2020;150:3161–3170.

Keywords: nut consumption, Mediterranean diet, metabolic syndrome, features of metabolic syndrome, PREDIMED-Plus study, excess weight, overweight, obesity, older adults, lifestyle

Introduction

Metabolic syndrome (MetS) represents a common clinical condition in countries with a high prevalence of obesity. Moreover, as obesity continues to rise, the prevalence of MetS is also increasing, and with it, a series of associated conditions such as cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), and, among others, nonalcoholic fatty liver disease (1). The high prevalence of MetS has been linked to poor nutrition, alcohol consumption, smoking, and lack of exercise (2, 3). According to a recent comparative risk assessment study, 45.4% of cardiometabolic deaths which occurred in the adult population of the United States during 2012 were associated with dietary factors, such as high intakes of sodium and processed meats and low intakes of fruits and vegetables (4). Similarly, another comparative risk assessment study of the WHO (European Region) attributed 22.4% of all deaths and 49.2% of CVD deaths that occurred in 2016 to dietary risk factors (5).

Based on current scientific evidence, nuts may be a key food component of a healthy dietary pattern because they are a rich source of proteins, unsaturated fatty acids, fiber, vitamins, minerals, polyphenols, and plant sterols (6, 7). Previous epidemiological and intervention studies have reported high nut consumption to be associated with a decreased incidence of MetS regardless of race and dietary patterns (8–11). Nut intake lowers blood concentrations of total cholesterol, LDL cholesterol, non-HDL-cholesterol, triglycerides (TGs), and apoB (7), as well as blood pressure levels (12). In addition, regardless of its fat content, nut consumption does not contribute to increased adiposity (13), but rather it could help with maintaining a healthy weight (14, 15). Recently, it has been suggested that middle-aged and elderly subjects might benefit from the inclusion of nuts in their diet to counterbalance

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The data used in this article are not publicly available owing to signed data-sharing agreements, which protect against misuse of the data and ensure their use under the approval of the provider. The data are available upon request from the PREDIMED-Plus trial Steering Committee chair (e-mail: jordi.salas@urv.cat). Requests will be reviewed and deliberated by the members of the PREDIMED-Plus Steering Committee.

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Abbreviations used: CVD, cardiovascular disease; DBP, diastolic blood pressure; er-MedDiet, energy-restricted traditional Mediterranean diet; EVOO, extra virgin olive oil; HbA1c, glycated hemoglobin; MedDiet, Mediterranean diet; MET, metabolic equivalent of task; MetS, metabolic syndrome; PREDIMED, PREvención con DIeta MEDiterránea; RAPA, Rapid Assessment of Physical Activity Questionnaires; SBP, systolic blood pressure; TG, triglyceride; T2DM, type 2 diabetes mellitus; WC, waist circumference.

the effects of aging (7). It is therefore of great importance to investigate the effect of nut consumption in a middle-aged and older cohort with MetS and at high CVD risk.

The aim of this study was to assess the association between changes in nut consumption and changes in features of MetS after a 1-y follow-up in middle-aged and older Spanish adults at high CVD risk and included in the PREvención con DIeta MEDiterránea (PREDIMED)-Plus study.

Methods

Study design

This is a prospective cohort study of participants from the PREDIMED-Plus trial who had undergone a 1-y follow-up.

Briefly, the PREDIMED-Plus study is an ongoing 6-y multicenter, parallel-group, randomized, single-blind clinical trial involving 6874 participants recruited in 23 Spanish centers, the aim of which is to evaluate the long-term effects of an intensive weight loss program, based on an energy-restricted traditional Mediterranean Diet (er-MedDiet), physical activity promotion, and behavioral support, on cardiovascular events and mortality, in comparison with an energy-unrestricted MedDiet (control group). Details on the protocol have been published (16) and are available at http://predimedplus.com/. Results of a pilot study (17) and changes in food and nutrient consumption during the first year of follow-up (18) have also been published. The trial was registered in 2014 at the International Standard Randomized Controlled Trial registry as number 89898870 (http://www.isrctn.com/ISRCTN89898870). All participants provided written informed consent, and the study protocol and procedures were approved according to the ethical standards of the Declaration of Helsinki by all the participating institutions and the Research Ethics Committees from all recruiting centers.

Participants and data collection procedures

Eligible participants were community-dwelling men aged 55–75 y and women aged 60–75 y, without documented history of CVD at baseline, who were overweight or obese [BMI (in kg/m^2) ≥27 and <40] and met ≥3 of the 5 criteria for MetS according to the updated harmonized definition of the International Diabetes Federation and the American Heart Association and National Heart, Lung, and Blood Institute (19): abdominal obesity for European individuals [waist circumference (WC) ≥88 cm in women and ≥102 cm in men], hypertriglyceridemia (≥150 g/dL) or receiving drug treatment for high plasma TG concentrations, low HDL cholesterol (≤50 mg/dL in women and ≤40 mg/dL in men), high blood pressure [systolic blood pressure (SBP) ≥130 mm Hg or diastolic blood pressure (DBP) ≥85 mm Hg or antihypertensive drug treatment], or high fasting plasma glucose (≥100 mg/dL) or receiving drug treatment for T2DM. The sex–age range was chosen depending on the age that each gender is at high risk of suffering noncommunicable diseases, the association of MetS with CVD, and the increasing prevalence of MetS with age.

Between September 2013 and December 2016, a total of 6874 participants were recruited and randomly allocated, in a 1:1 ratio, to either the intervention or the control group. Randomization was performed using a centrally controlled, computer-generated random-number, Internet-based system and stratified according to center, sex, and age categories (<65, 65–70, >70 y). The randomization procedure was blinded to all staff members and principal investigators. For participant couples sharing the same household, randomization was done by cluster, with the couple as the unit of randomization.

The present study included only participants who completed the same FFQ at baseline and at 1 y. Of a total of 6874 participants, 53 and 813 subjects did not complete the baseline and the 1-y FFQ, respectively, and were excluded from the analysis. Participants with a total energy intake outside of prespecified limits (<500 or >3500 kcal/d for women or <800 or >4000 kcal/d for men) (20, 21) were also excluded (n = 188 at baseline and n = 20 at 1 y). Finally, data from a total of 5800 participants (3005 men and 2795 women) were analyzed (**Figure 1**).

Dietary assessment

Registered dietitians collected data on dietary intake at baseline and at 1 y using a semiquantitative 143-item FFQ, which assesses dietary habits over the previous year (22). Detailed information about the development, reproducibility, and validity of the FFQ in the PREDIMED cohort has been previously reported (22–24). For each item, a typical portion size was included and consumption frequencies were registered in 9 categories that ranged from "never or almost never" to "≥6 times/d." Energy and nutrient intakes were calculated as frequency multiplied by the nutrient composition of the specified portion sizes for each food item, using a computer program based on available information in food composition tables (25). Nut consumption, defined as consumption of almonds, pistachios, walnuts, and other nuts, was also assessed using the FFQ, with 1 portion corresponding to 30 g in weight.

Baseline adherence to the er-MedDiet was appraised by the total score of a 17-item questionnaire, modified from a previously validated version (26). This tool was used to evaluate compliance with the intervention and as a key element to guide the motivational interviews during follow-ups. Each of the 17 items related to a specific MedDiet habit and according to whether the participant was compliant or not, a score of 1 or 0 was given. The total score could therefore range between 0 and 17, with 0 meaning no adherence and 17 meaning maximum adherence to the MedDiet. Participants completed the questionnaire at baseline and at 1-y follow-up.

Nondietary variables

At baseline and at 1-y follow-up, information on sociodemographic and lifestyle aspects (i.e., education level, smoking habits, alcohol intake, physical activity, individual and family medical history, and current medication use) was collected. Physical activity was measured using the Rapid Assessment of Physical Activity Questionnaires (RAPA-1 and RAPA-2) (27) and the validated Minnesota-Regicor Short Physical Activity questionnaire (28–30) [energy expenditure was expressed as metabolic equivalents of task (MET) · min/d].

At each visit, anthropometric variables were measured by trained personnel: weight (using high-quality electronic calibrated scales), height (using a wall-mounted stadiometer), WC (midway between lowest rib and iliac crest, using an anthropometric tape), and BMI (in kg/m^2). Blood pressure was measured 3 times using a validated semiautomatic oscillometer (Omron HEM-705CP) after 5 min of rest in between measurements while the participant was in a seated position. All anthropometric variables were determined in duplicate, except for blood pressure which was determined in triplicate. At baseline and at 1 y, fasting plasma total cholesterol, HDL cholesterol, glucose, and TG concentrations were measured in blood samples collected after an overnight fast of 8 h minimum and using standard enzymatic methods.

Outcomes

The primary outcome was the change from baseline to 1 y in features of MetS (including WC; fasting plasma glucose, HDL cholesterol, and TG concentrations; and SBP and DBP) and excess weight (body weight and BMI) across tertiles of change in nut consumption. Secondary outcomes were changes from baseline to 1 y in dietary and lifestyle characteristics including total energy intake, 17-item MedDiet score, extra virgin olive oil (EVOO) consumption, and total physical activity.

Statistical analyses

Analyses were performed using the Statistical Package for the Social Sciences version 25.0 (SPSS Inc.). The database used belongs to the PREDIMED-Plus trial and was dated 12 March, 2019. Analyses for the present study were performed on the entire cohort, regardless of allocation group.

Baseline characteristics are expressed as means ± SDs (quantitative variables) or percentages (ns) (categorical variables). Participants were classified into tertiles of change in nut consumption from baseline to 1 y (tertile 1: <4.6 g/d, n = 1941; tertile 2: 4.6–21.7 g/d, n = 1965; tertile 3: ≥21.8 g/d, n = 1894). Differences in baseline characteristics between tertiles of nut consumption were explored using 1-factor ANOVA and

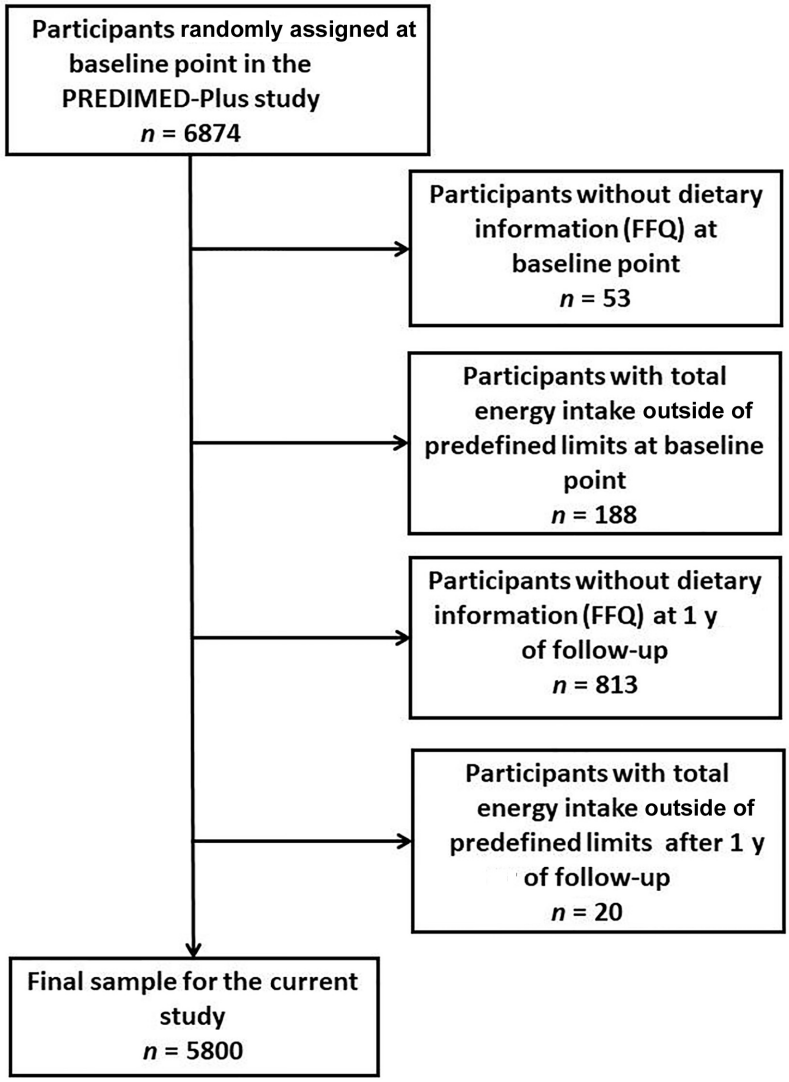

FIGURE 1 Flowchart of participants. PREDIMED, PREvención con DIeta MEDiterránea.

Bonferroni's post hoc analysis, or Kruskal–Wallis models and Pearson's chi-square test, according to the distribution of the variables.

A generalized linear model was used to compare 1-y change in dietary intake, features of MetS, and excess weight across tertiles of change in nut consumption. The interaction effect between time (baseline compared with 1 y) and group (nut consumption) was explored using repeated-measures ANCOVA, with sex, age (continuous variable), energy intake (continuous variable), EVOO consumption (continuous variable), MedDiet score (continuous variable), and total physical activity (continuous variable, expressed as MET · min/wk) as covariates. The Bonferroni post hoc test was used to compare differences in the effects of each tertile within and between groups. In addition, intragroup 1-y differences (dependent variable) were assessed after a further adjustment for the baseline values of each variable. Results were considered statistically significant at P value (2-tailed) <0.05.

Results

Table 1 shows baseline characteristics of the study population as a whole and divided by tertiles of 1-y change in total nut consumption. The mean age was 65.0 ± 5.0 y and BMI was 32.5 ± 3.4. No differences in baseline age, sex, BMI, education levels, and smoking status were observed between the tertiles.

Table 2 summarizes information on dietary and lifestyle characteristics at baseline and 1-y follow-up according to tertiles of 1-y change in nut consumption. Interactions between time and group for total energy intake ($P < 0.001$), adherence to the MedDiet ($P < 0.001$), and nut consumption ($P < 0.001$) were observed. After the 1-y behavioral intervention, mean nut consumption for tertile 1, tertile 2, and tertile 3 was 18.4 ± 14.4, 24.6 ± 11.2, and 44.7 ± 18.9 g/d, respectively ($P < 0.001$). Significant increases in EVOO consumption and adherence to the MedDiet were observed across the 3 tertiles, from tertile 1 to tertile 3. A significant decrease in energy intake was observed across tertiles, from tertile 3 to tertile 1. No significant changes were associated with EVOO intake and levels of physical activity. When changes between tertiles were compared, participants in tertile 3 had a greater dietary change than the other groups (except for change in energy intake, which was highest in tertile 1).

Table 3 shows changes in features of MetS and excess weight from baseline to 1 y across tertiles of changes in nut consumption. Between each tertile WC, plasma TG concentrations, SBP, weight, and BMI decreased significantly ($P < 0.05$), whereas

TABLE 1 Baseline lifestyle characteristics of older adults with overweight or obesity according to tertiles of 1-y change in nut consumption during the follow-up[1]

	Total participants	Tertile 1 (<4.6 g/d)	Tertile 2 (4.6–21.7 g/d)	Tertile 3 (≥21.8 g/d)	P^2
Participants, *n*	5800	1941	1965	1894	
Age, y	65.0 ± 5.0	65.1 ± 4.8	65.1 ± 5.0	64.9 ± 4.9	0.310
Women, %	48.2	49.2	46.7	48.7	0.260
BMI, kg/m^2	32.5 ± 3.4	32.5 ± 3.4	32.3 ± 3.5	32.6 ± 3.4	0.050
Smoking habit, %					
Current	12.4	12.5	13.1	11.4	0.330
Former	43.1	43.9	43.0	42.3	
Never	44.6	43.6	43.9	46.2	
Education, %					
Primary	49.6	48.8	50.2	49.7	0.500
Secondary	28.8	28.7	28.0	29.8	
University or graduate	21.6	22.5	21.8	20.5	
Total physical activity, MET · min/d	359 ± 332	358 ± 325	362 ± 334	358 ± 336	0.550
Men	419 ± 374	412 ± 352	425 ± 383	419 ± 386	0.590
Women	295 ± 266	302 ± 285	290 ± 250	293 ± 260	0.990

[1] All values are means ± SDs unless otherwise indicated. MET, metabolic equivalent of task.
[2] Difference in means of nut consumption was tested with 1-factor ANOVA and Bonferroni's post hoc analysis when variables followed a normal distribution or with the Kruskal–Wallis test for nonnormally distributed variables. Difference in percentages was tested by the chi-square test.

plasma HDL-cholesterol concentrations increased significantly only in women ($P = 0.044$). No significant changes were observed in glycemia and DBP. When between-group differences in change were compared, participants in tertile 3 had a greater decrease in WC (men), TG, total body weight, and BMI than those in tertile 1 ($P < 0.05$).

Discussion

In this study, increased nut consumption was associated with the amelioration of some features of MetS (reduction in WC, plasma TG concentrations, SBP, body weight, and BMI and, in women only, an increase in plasma HDL-cholesterol concentrations) and excess weight. No association was observed between changes in nut consumption and plasma glucose concentrations or DBP.

It has been previously reported that a weight loss >5% is a strong predictor of long-term weight loss and is inversely related to metabolic disturbances; nevertheless, even a more modest weight loss (2.5%–5%) may be beneficial and, to a lesser degree, improve risk factors associated with weight as well as cardiometabolic imbalances (31).

Results of this study are in agreement with those of previous longitudinal studies examining the relation between consumption of nuts and MetS. In a 13-y follow-up Iranian cohort study, a higher intake of nuts (walnuts) was associated with a lower risk of MetS (8). Similarly, the NHANES, with a 5-y follow-up, reported that nut consumption was associated with a decreased prevalence of selected CVD risk factors, such as T2DM and MetS (9). Similarly, a systematic review and meta-analysis of randomized controlled trials showed that nut consumption may decrease or preserve some components of MetS (11), and evidence from observational studies has shown that nut consumption was negatively associated with MetS (32).

A systematic review and meta-analysis on the effects of nuts on MetS concluded that nut consumption had no effect on WC (11). Our results, on the other hand, show an inverse association between nut consumption and WC, and are in accordance with previous studies (9, 33, 34). In the aforementioned Iranian cohort study, abdominal obesity was significantly and inversely related with nut consumption (8). In another study, patients following the recommendation to consume 20% of their total energy intake in the form of pistachios for 24 wk showed a decrease in WC without significant reduction in body weight (34). In contrast, our results showed a lower body weight and BMI in the upper tertiles of nut consumption. The same observation was made in a recent meta-analysis, which concluded that for every 1-serving/wk increase in nut consumption, the risk of MetS was reduced by 4%, the risk of overweight/obesity by 3%, and of obesity only by 5% (35).

In regard to blood lipids, previous studies reported that nut consumption may ameliorate the blood lipid profile in patients with MetS. A systematic review and meta-analysis (11) reported that increased nut consumption may decrease plasma TG while preserving HDL-cholesterol concentrations. Such findings are consistent with our results except for an observed increase in plasma HDL-cholesterol concentration in women. Other authors also reported that nut and/or tree nut consumption was associated with an increase in plasma HDL-cholesterol concentration for both sexes (9, 10). Previous studies on nut consumption (30 g/d) in Mediterranean (33, 36), Iranian (10), and Korean (37) adults with MetS also found a significant improvement in plasma total cholesterol (36, 37), TG (10, 36), and LDL-cholesterol (33) concentrations (only in women) (37) and a shift of LDL-cholesterol size to a less atherogenic pattern (33). One study including subjects with similar characteristics and consuming the same amounts of nuts, however, observed no changes in serum LDL cholesterol, HDL cholesterol, and TG over a period of 12 wk (38).

Our finding on the relation between increased nut consumption and reduction of SBP is in line with a previous study that showed lower SBP in nut consumers than in non–nut consumers (9), and with the PREDIMED trial, where a MedDiet supplemented with nuts decreased blood pressure more than a low-fat diet after a 3-mo follow-up (36). Several studies, on the other hand, found no association between nut consumption and hypertension (11, 39, 40). Interestingly, in a systematic review and meta-analysis it was found that overall nut consumption had no significant effect on SBP; however, when looking at the type of nuts, pistachios significantly decreased both

TABLE 2 Changes in dietary and lifestyle characteristics of older adults with overweight or obesity categorized by tertiles of 1-y change in nut consumption[1]

	Total participants ($n = 5800$)	Tertile 1 (<4.6 g/d) ($n = 1941$)	Tertile 2 (4.6–21.7 g/d) ($n = 1965$)	Tertile 3 (≥21.8 g/d) ($n = 1894$)	Between-group difference in change: repeated-measures ANCOVA[2]	Between-group difference in change: P[3]		
					Time × group	T2 vs. T1	T2 vs. T3	T3 vs. T1
Energy, kcal/d								
Baseline	2368 ± 550	2450 ± 561^{a,b}	2334 ± 542^{a}	2319 ± 537^{b}				
1 y	2243 ± 476	2191 ± 481^{b}	2222 ± 485^{c}	2318 ± 450^{b,c}				
Δ	−125 ± 537	−259 ± 526^{*d,e}	−112 ± 523^{*e,f}	−1 ± 530^{d,f}	<0.001	<0.001	<0.001	<0.001
Men								
Baseline	2517 ± 557	2593 ± 571^{a,b}	2492 ± 552^{a}	2467 ± 541^{b}				
1 y	2352 ± 483	2313 ± 494^{b}	2338 ± 492^{c}	2408 ± 457^{b,c}				
Δ	−164 ± 561	−280 ± 544^{*d,e}	−154 ± 565^{*e,f}	−59 ± 553^{*d,f}	<0.001	<0.001	<0.001	<0.001
Women								
Baseline	2208 ± 493	2303 ± 510^{a,b}	2154 ± 468^{a}	2164 ± 487^{b}				
1 y	2125 ± 438	2066 ± 433^{b}	2089 ± 442^{c}	2223 ± 423^{b,c}				
Δ	−83 ± 506	−237 ± 506^{*d,e}	−65 ± 467^{*e,f}	60 ± 498^{*d,f}	<0.001	<0.001	<0.001	<0.001
17-item MedDiet, score								
Baseline	8.5 ± 2.7	8.9 ± 2.7^{a,b}	8.4 ± 2.7^{a}	8.3 ± 2.6^{b}				
1 y	11.7 ± 2.9	11.3 ± 3.0^{a,b}	11.8 ± 2.8^{a,b}	12.3 ± 2.7^{b,c}				
Δ	3.2 ± 3.3	2.2 ± 3.2^{*d,e}	3.4 ± 3.2^{*e,f}	4.0 ± 3.3^{*d,f}	<0.001	<0.001	<0.001	<0.001
Nut consumption, g/d								
Baseline	15.0 ± 17.2	26.3 ± 22.0^{a,b}	11.0 ± 10.6^{a,c}	7.8 ± 9.4^{b,c}				
1 y	29.1 ± 18.8	18.4 ± 14.4^{a,b}	24.6 ± 11.2^{a,c}	44.7 ± 18.9^{b,c}				
Δ	14.1 ± 22.3	−7.9 ± 15.0^{*d,e}	13.7 ± 4.7^{*e,f}	37.0 ± 16.1^{*d,f}	<0.001	<0.001	<0.001	<0.001
EVOO consumption, g/d								
Baseline	32.0 ± 20.7	33.5 ± 20.6	32.0 ± 20.7	30.4 ± 20.8				
1 y	43.0 ± 16.6	42.8 ± 17.5^{a}	43.9 ± 16.5^{a,c}	42.4 ± 15.8^{c}				
Δ	11.1 ± 22.8	9.3 ± 23.0*	11.9 ± 22.5*	12.0 ± 22.8*	0.080	0.200	<0.001	0.006
Total physical activity, MET · min/d								
Baseline	359 ± 332	358 ± 325	362 ± 334	358 ± 336				
1 y	446 ± 518	437 ± 649	442 ± 497	459 ± 367				
Δ	86.7 ± 515	79.6 ± 649*	79.9 ± 498*	101 ± 351*	0.370	1.000	0.120	0.040
Men								
Baseline	419 ± 374	412 ± 352	425 ± 383	419 ± 386				
1 y	517 ± 549	499 ± 588	517 ± 612	534 ± 421				
Δ	97.9 ± 549	87 ± 584*	92.0 ± 627*	115 ± 404*	0.560	1.000	0.490	0.450
Women								
Baseline	295 ± 266	302 ± 285	290 ± 250	293 ± 260				
1 y	370 ± 471	374 ± 700	356 ± 297	379 ± 279				
Δ	74.7 ± 475	72 ± 711^{*e}	66.0 ± 286^{*e}	86.0 ± 283*	0.630	1.000	0.290	0.040

[1] All values are means ± SDs. Different letters indicate statistically significant differences between tertile groups (^{a,b,c}), between times (*), and between time × group interactions (^{d,e,f}) by the Bonferroni post hoc test ($P < 0.05$). EVOO, extra virgin olive oil; MedDiet, Mediterranean diet; MET, metabolic equivalent of task; Δ, Difference 1 y - Baseline.

[2] Data analyzed by 2-factor repeated-measures ANCOVA with age, gender, energy intake, EVOO consumption, MedDiet, and physical activity (except the value of each variable) as covariates ($P < 0.05$).

[3] Data analyzed by ANCOVA ($P < 0.05$) and adjusted for gender, age, energy intake, EVOO consumption, MedDiet, physical activity, and the baseline value of each variable.

TABLE 3 Changes in features of metabolic syndrome and excess weight of older adults with overweight or obesity according to tertiles of changes in nut consumption[1]

	Total participants ($n = 5800$)	Tertile 1 (<4.6 g/d) ($n = 1941$)	Tertile 2 (4.6–21.7 g/d) ($n = 1965$)	Tertile 3 (≥21.8 g/d) ($n = 1894$)	Between-group difference in change: repeated-measures ANCOVA[2]	Between-group difference in change: P[3]		
					Time × group	T2 vs. T1	T2 vs. T1	T3 vs. T1
Weight, kg								
n	5796	1940	1963	1983				
Baseline	86.3 ± 12.9	86.0 ± 12.9	86.0 ± 12.9[c]	86.8 ± 12.9[c]				
1 y	84.0 ± 13.1	84.3 ± 13.2	83.8 ± 13.0	83.9 ± 13.1				
Δ	−2.2 ± 4.1	−1.7 ± 4.0*[d,e]	−2.2 ± 3.9*[e,f]	−2.9 ± 4.3*[d,f]	<0.001	0.023	<0.001	<0.001
BMI, kg/m^2								
n	5788	1938	1960	1890				
Baseline	32.5 ± 3.4	32.5 ± 3.4	32.3 ± 3.5	32.6 ± 3.4				
1 y	31.6 ± 3.6	31.9 ± 3.6[a,b]	31.5 ± 3.6[a]	31.5 ± 3.7[b]				
Δ	−0.8 ± 1.6	−0.6 ± 1.5*[d,e]	−0.8 ± 1.5*[e,f]	−1.1 ± 1.6*[d,f]	<0.001	0.020	<0.001	<0.001
WC, cm								
Women, *n*	2786	953	915	918				
Baseline	104 ± 9.1	104 ± 9.0	103 ± 9.3[c]	105 ± 9.0[c]				
1 y	101 ± 9.6	102 ± 9.5	101 ± 9.6	102 ± 9.7				
Δ	−2.4 ± 5.1	−2.0 ± 4.7*[d]	−2.3 ± 5.2*	−2.8 ± 5.3*[d]	0.002	1.000	0.540	0.340
Men, *n*	2992	981	1044	967				
Baseline	112 ± 8.7	111 ± 8.7	110 ± 8.6[c]	111 ± 8.8[c]				
1 y	108 ± 9.4	109 ± 9.2[a,b]	107 ± 9.3[a]	108 ± 9.6[b]				
Δ	−3.0 ± 5.2	−2.3 ± 4.8*[d,e]	−2.8 ± 5.1*[e,f]	−3.8 ± 5.5*[d,f]	<0.001	0.110	0.050	<0.001
Fasting plasma glucose, mg/dL								
n	5599	1856	1907	1836				
Baseline	113 ± 29.0	114 ± 31.2	112 ± 26.7	114 ± 28.9				
1 y	111 ± 28.2	112 ± 28.4	110 ± 27.4	111 ± 28.7				
Δ	−2.5 ± 22.4	−2.2 ± 23.5*	−2.5 ± 21.1*	−2.8 ± 22.7*	0.760	1.000	1.000	1.000
Plasma HDL-C, mg/dL								
Women, *n*	2681	909	884	888				
Baseline	52.7 ± 11.7	52.9 ± 11.6	52.6 ± 12.2	52.4 ± 11.4				
1 y	53.7 ± 11.8	53.7 ± 11.9	53.4 ± 12.0	54.0 ± 11.4				
Δ	1.0 ± 7.6	0.8 ± 7.7*	0.8 ± 7.5*	1.6 ± 7.7*	0.040	1.000	0.080	0.210
Men, *n*	2907	948	1013	946				
Baseline	43.8 ± 10.3	42.9 ± 9.4[a,b]	44.0 ± 11.2[a]	44.3 ± 10.0[b]				
1 y	45.6 ± 11.0	45.0 ± 10.9[b]	45.5 ± 11.2	46.3 ± 10.8[b]				
Δ	1.9 ± 7.4	2.1 ± 7.7*	1.5 ± 7.3*	2.1 ± 7.1*	0.160	0.490	0.610	1.000
Plasma TGs, mg/dL								
n	5631	1867	1914	1850				
Baseline	152 ± 77.5	152 ± 82.6	153 ± 78.2	151 ± 71.1				
1 y	144 ± 73.6	148 ± 78.4[b]	144 ± 74.2	139 ± 67.5[b]				
Δ	−7.8 ± 68.9	−4.1 ± 77.0*[d]	−8.6 ± 68.3*	−10.6 ± 60.1*[d]	0.020	0.210	0.610	0.008

(*Continued*)

TABLE 3 (*Continued*)

	Total participants ($n = 5800$)	Tertile 1 (<4.6 g/d) ($n = 1941$)	Tertile 2 (4.6–21.7 g/d) ($n = 1965$)	Tertile 3 (≥21.8 g/d) ($n = 1894$)	Between-group difference in change: repeated-measures ANCOVA[2]	Between-group difference in change: P[3]		
					Time × group	T2 vs. T1	T2 vs. T1	T3 vs. T1
Blood pressure, mm Hg								
n	5716	1912	1938	1866				
Systolic blood pressure								
Baseline	139.7 ± 16.9	139.8 ± 17.1	139.4 ± 16.9	140.0 ± 16.7				
1 y	136.6 ± 16.6	137.1 ± 16.9	136.7 ± 16.4	136.1 ± 16.6				
Δ	−3.0 ± 15.1	−2.7 ± 15.3[a,d]	−2.6 ± 15.0[a,f]	−3.9 ± 14.9[a,d,f]	0.019	1.000	0.242	0.096
Diastolic blood pressure								
Baseline	80.8 ± 9.9	80.9 ± 9.8	80.6 ± 9.5	80.8 ± 10.3				
1 y	78.8 ± 9.8	79.0 ± 9.8	78.9 ± 9.4	78.5 ± 10.1				
Δ	−1.9 ± 8.3	−1.9 ± 8.3*	−1.7 ± 8.3*	−2.2 ± 8.3*	0.129	1.000	0.159	0.399

[1] All values are means ± SDs unless otherwise indicated. Different letters indicate statistically significant differences between tertile groups ([a,b,c]), between times (*), and between time × group interactions ([d,e,f]) by the Bonferroni post hoc test ($P < 0.05$). EVOO, extra virgin olive oil; HDL-C, HDL cholesterol; MedDiet, Mediterranean diet; TG, triglyceride; WC, waist circumference; Δ, Difference 1 y - Baseline.
[2] Data analyzed by 2-factor repeated-measures ANCOVA with age, gender, energy intake, EVOO consumption, MedDiet, and physical activity as covariates ($P < 0.05$).
[3] Data analyzed by ANCOVA ($P < 0.05$) and adjusted for gender, age, energy intake, EVOO consumption, MedDiet, physical activity, and the baseline value of each variable.

SBP and DBP, whereas mixed nuts decreased DBP only (12). Furthermore, trials with higher fiber intakes in the tree nut intervention arms showed larger reductions in SBP (11).

It is also worth noting that no associations were observed between changes in nut consumption and glycemia. It was previously reported that nut consumption may decrease fasting serum insulin but not glycemia (38). However, in a recent meta-analysis of randomized controlled trials, contrarily to our results, nut consumption was observed to decrease fasting glycemia (11). Similarly, subjects with MetS who consumed 3 servings of nuts per week showed 22% lower prevalence of diabetes than those consuming 1 serving/wk (39). The NHANES study also reported that increased consumption of tree nuts or walnuts was associated with lower prevalence of diabetes and with lower levels of fasting glycemia (9) and glycated hemoglobin (HbA1c) (41). Of interest, a previous meta-analysis (42) established that consumption of peanuts or tree nuts decreased HOMA-IR and fasting insulin but had no effect on HbA1c or fasting blood glucose.

Strengths and limitations

Our study has several strengths and limitations that should be mentioned. The strengths are linked to the sample size and to the design of the study: the study sample used is large ($n = 5800$) and highly representative of the Spanish older adult population with MetS; the study also uses a standardized protocol which reduces information bias about food intake, socioeconomic, and lifestyle variables; moreover, the robust epidemiological design (randomized, controlled feeding trial) delivers the highest-quality level of evidence. Limitations, on the other hand, regard study subjects: by being older, overweight/obese, and presenting with the MetS and a high CVD risk, they may present results which cannot be applied to other types of populations. Secondly, the FFQ could overestimate the intakes of certain food groups despite having been validated. Thirdly, the use of self-reported data to evaluate nutritional changes could be a source of information bias; for this reason, participants with energy intakes outside the prespecified range (20, 21) were excluded. Fourthly, the strategy of donating food items was used as an incentive for attendance at educational sessions and to foster adherence. However, this strategy can also represent a limitation regarding the generalizability of these results to populations in which access to or affordability of high-quality olive oil and nuts might be a barrier. Lastly, these findings are based on interim and preliminary analyses of an ongoing randomized controlled trial, and whether and how these results may be related to long-term cardiovascular and other health outcomes are unknown.

Conclusions

Our findings showed that in older patients with MetS and at increased CVD risk, increased nut consumption related to improvement of different features of the MetS and excess weight, over a 1-y follow-up. Nut consumption may be beneficial in this type of population and it could be included as part of the recommendations for a healthy diet, given the increasing proportion of aging people and the relation between adult age and CVD.

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