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Original article

Baseline drinking water consumption and changes in body weight and waist circumference at 2-years of follow-up in a senior Mediterranean population

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Background & aims: The association between drinking water consumption and adiposity has been poorly explored. Therefore, we aimed to analyse the associations between the frequency of drinking water consumption and body weight and waist circumference changes in an elderly Mediterranean cohort.
Methods: A total of 1832 elderly participants (aged 55–75 years) with metabolic syndrome from the PREDIMED-Plus study with baseline data on drinking water and other beverages assessed by a validated 32-item Spanish fluid-intake questionnaire and with data on body weight (BW) and waist circumference (WC) at 1-year and 2-year were included in these prospective analyses. Multivariable linear regression models were fitted to assess the β-coefficients and 95% confidence interval (CI) for BW and WC changes

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Alcoholic beverages
Sugary drinks

in terms of categories of baseline drinking water consumption (tap water and bottled water). The theoretical effect on BW and WC of replacing several beverages with drinking water was assessed using mathematical models.
Results: The baseline frequency of drinking water consumption was inversely associated with 1-year and 2-year changes in BW. β-coefficients (95%CI) across categories of water consumption (<2.5, 2.5 to <5, 5 to < 7.5, ≥7.5 servings/d) expressed in % of weight changes at 2 years of follow-up were 0.0, −0.80 (−1.48, −0.12), −1.36 (−2.18, −0.54), and −1.97 (−3.09, −0.86), respectively. Individuals in the two highest categories of drinking water consumption (5 to < 7, and ≥7.5 servings/d) also showed a higher decrease in WC (expressed as % of change) after 2 years of follow-up: −1.11 (−1.96, −0.25) and −1.45 (−2.66, −0.24) compared to the reference intake (<2.5 servings/day), after adjustment for potential confounding factors. The theoretical replacement of soups, beers, spirits, hot beverages, dairy beverages, and other beverages group with drinking water was associated with greater reductions in BW at one- and two-years of follow-up.
Conclusions: Drinking water consumption was inversely associated with 2-year adiposity changes in an elderly Mediterranean cohort at high cardiovascular risk. Our results also suggest that the consumption of drinking water instead of energy-containing beverages is associated with lower weight gain.
The trial registration: ISRCTN89898870.

1. Introduction

Excess body weight (BW) is a recognized worldwide public health concern because it is a risk factor for the development of non-communicable chronic diseases such as diabetes and cardiovascular disease [1]. The onset of overweight and obesity is the result of an energy imbalance, with a multifactorial background that includes genetics, a sedentary lifestyle, and excessive caloric intake, among others [2]. As its incidence and prevalence have increased worldwide in recent decades [3], intervention strategies have been proposed to prevent its onset and also for treatment [4,5]. The most common recommendations concern lifestyle factors, such as a lower caloric intake, a healthy dietary pattern, physical activity, less sedentary behaviours, and stress and anxiety management, among others [5]. Although drinking water is recommended for the maintenance of healthy hydration status [6,7], in recent decades the consumption of other types of beverage has increased in parallel with the rise in incidence of overweight/obesity [8]. Beverages can be dietary sources of water, vitamins, and minerals, but also of carbohydrates, proteins, and fat, which can contribute to increase total energy intake [6,9]. Consequently, in recent years health professionals have stressed the importance of decreasing the consumption of high-calorie beverages, especially sugary drinks, and increasing the consumption of drinking water [10]. It has been reported that replacing caloric beverages [11–13], such as sugary drinks and beer with drinking water, contributes to decreasing total energy intake, and thus might prevent weight gain. Unfortunately, the association between drinking water consumption and body weight (BW) changes in the long-term has been poorly explored and results are inconclusive. Due to the lack of evidence in the field, the study of the potential associations between drinking water and body weight or adiposity has greater relevance for public health. Therefore, the present analysis aimed to assess the associations between drinking water consumption and changes in BW and waist circumference (WC) in a cohort of overweight/obese elderly adults with metabolic syndrome (MetS). We hypothesized that individuals who consumed more drinking water at baseline will be more likely to lose weight after 1 and 2 years of follow-up.

2. Materials and methods

2.1. Study design and participants

A prospective analysis was conducted within the frame of the PREDIMED-Plus (PREvención con DIeta MEDiterránea) cohort. PREDIMED-Plus is a large, multicentre, parallel-group, randomized controlled clinical trial conducted in Spain to compare the effect on cardiovascular disease (CVD) morbi-mortality of two interventions: an intensive weight loss program based on an energy-restricted traditional Mediterranean diet (MedDiet), physical activity (PA) promotion and behavioural support (intervention group, IG), and an energy-unrestricted traditional MedDiet (control group, CG). A detailed explanation of the trial design has been published elsewhere [14] and the study protocol can be accessed at www.predimedplus.com. The trial was registered in 2014 as ISRCTN89898870.

Eligible participants were overweight or obese males and females (BMI 27–40 kg/m^2 and aged 55–75 years) who satisfied at least three of the following criteria for the metabolic syndrome (MetS): waist circumference >102 cm in men and >88 cm in women; serum triglyceride ≥150 mg/dL or drug treatment for elevated triglycerides; HDL-c <40 mg/dL in men and <50 mg/dL in women or drug use for low HDL-c; blood pressure ≥130/85 mmHg or antihypertensive drug treatment; and fasting plasma glucose level ≥100 mg/dL or hypoglycemic treatment [15]; and were free from CVD at baseline. Detailed PREDIMED-Plus inclusion and exclusion criteria have been extensively described elsewhere [16]. Between October 2013 and December 2016, 6874 participants were recruited from 23 centres in Spain (universities, hospitals, and research institutes), and randomly allocated in a 1:1 ratio to an intensive lifestyle intervention or the usual medical care group.

The fluid intake assessment is a PREDIMED-Plus sub-study in which only 10 of the 23 centres agreed to participate. The present analysis has been conducted with data from those recruiting centres, where information on water and beverage consumption was collected using a specific validated beverage questionnaire. A total of 2067 individuals completed the validated 32-item Spanish fluid-intake questionnaire [17]. Of these, we excluded participants who had not responded to the baseline food frequency questionnaires (FFQ) or who reported implausible total energy intakes (≤500 and ≥ 3500 kcal/day in women and ≤800 and ≥ 4000 kcal/day in men; n = 55), and those who reported a total fluid intake above or below two standard deviations from the median value (≤397 and ≥ 3590 mL/day in men and ≤490 and ≥ 3262 mL/day women; n = 107). For our main analysis, we included those participants with data on BW after a 1-year (n = 1832) and 2-year follow-up (n = 1813). Figure 1 shows participants flow diagram.

All participants provided written informed consent and the institutional review boards of each participating centre approved the final protocol and procedures.

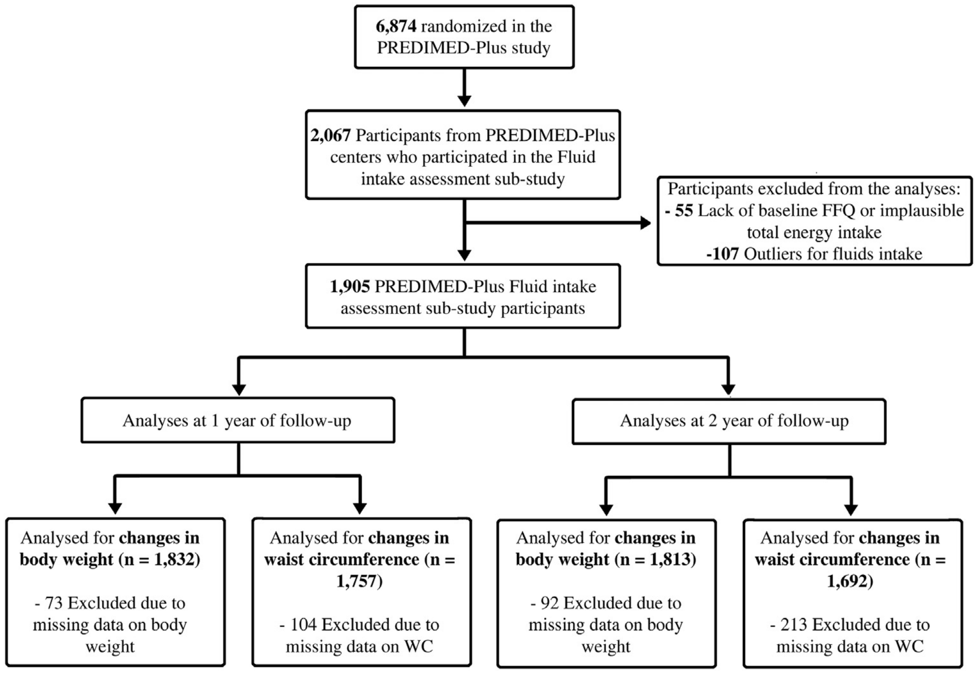

Fig. 1. Flow diagram for study participants. FFQ, food frequency questionnaire; WC, waist circumference.

2.2. Beverage assessment

At baseline, a trained dietitian held a face-to-face interview with participants and completed a validated 32-item Spanish fluid-intake questionnaire [17], which recorded the frequency of consumption of various beverage types over the previous month. For each type, frequencies of consumption were measured in eight categories, ranging from never/almost-never to >8 servings/day. The daily total fluid intake from beverages was computed as the sum of all beverages consumed.

For the present analysis, beverages were categorized into eight groups: drinking water (tap and bottled water), total dairy beverages (sub-categorized into whole-dairy beverages, which include whole milk, milkshakes, and other milk beverages; and reduced-dairy beverages, which include reduced-fat and skimmed milk), hot beverages (coffee, tea, and other infusions), sugary drinks (including carbonated soft drinks, natural and bottled fruit juice, energy drinks and sports drinks), artificially sweetened beverages (including light/zero carbonated soft drinks), alcoholic beverages (spirits, mixed alcoholic drinks, wine, beer/cider), broths (soups and natural and bottled vegetable juice), and other beverages (plant-based drinks, non-alcoholic beer, sorbets and jellies, and meal replacement shakes; we decided to categorize these beverages as a group since their consumption in our cohort is too low to be analysed separately). A serving of drinking water, dairy beverages (whole and reduced dairy beverages), sugary beverages and artificially sweetened beverages was defined as 200 mL, a serving of soups was defined as 100 mL. The hot beverage group includes servings of all kinds of coffee (50 mL) and tea (200 mL). The alcoholic beverage group includes servings of wine (100 mL), beer (200 mL), spirits (50 mL) and mixed alcoholic beverages (200 mL). A serving of the other beverage group was defined as 180 mL. Serving size reported in the fluid-intake questionnaire assessment tool was considered for beverages servings size categorization.

2.3. Outcomes and assessment of covariables

The primary outcome of the current study was BW changes at 1-yr and 2-yr of follow-up according to categories of drinking water consumption at baseline. We also assessed WC changes at 1 and 2-years of follow-up using the same exposure categories.

At baseline and yearly, participants provided information, by responding to general questionnaires on sociodemographic characteristics, physical activity, lifestyle and MedDiet adherence, among others. Also, in accordance with the study protocol, height, weight, and WC were measured in duplicate by PREDIMED-Plus trained staff using standardized techniques and calibrated scales. Weight and height were measured with participants wearing light clothes and no shoes. Body mass index (BMI) was calculated as the weight in kg divided by the square of the height in meters. WC was measured using an anthropometric tape midway between the lowest rib and the iliac crest. Measurement averages were calculated later for analysis purposes. Adherence to the MedDiet was evaluated using the 14-item Mediterranean diet score [18], where the adherence to each item reflecting the MedDiet were scored with 1 point, and with 0 points otherwise, therefore a total score equal to 14 means maximum adherence. When the beverage that we evaluated was included in this score (fruit juices, soft drinks, or wine), it was recalculated after the item that we analysed had been excluded to avoid overlap with the main exposure.

2.4. Statistical analysis

For the present study, we used the PREDIMED-Plus database updated until June 2020. Study participants were categorized according to servings per day (s/d) of drinking water consumption into < 2.5, 2.5 to < 5.5, 5.5 to < 7.5, and ≥ 7.5 servings per day. To compare the baseline characteristics of the study participants in terms of categories of drinking water consumption the Chi-square test and the ANOVA test were used, as appropriate.

Multivariable linear regression models were fitted to assess the β-coefficients and 95% confidence interval (CI) for BW and WC changes according to categories of drinking water consumption. Model 1 was adjusted for age (years) and sex; Model 2 was additionally adjusted for intervention group (CG/IG), smoking (never, former, or current), educational level (primary, secondary or academic/graduate), BMI (kg/m^2), leisure-time physical activity (METs.min/week) and the 14-point MedDiet adherence score (continuous); Model 3 was additionally adjusted for total energy intake (kcal/day, continuous) and total fluid intake (mL/day, continuous).

To assess the linear trend across categories of drinking water consumption and changes in BW and WC, we assigned the median value to each drinking water category and treated the variable as continuous. We also assessed the possible interactions between categories of drinking water consumption and sex, age, and intervention group of the trial by including cross-product terms in adjusted models.

Moreover, we used mathematical models to assess the association between substituting one serving per day of water for each beverage or beverage group (increasing by one serving of water and decreasing by one serving of the beverage/group in question) and the adjusted absolute mean BW and WC changes (and 95% CI). The theoretical effect of substituting one type of beverage for another was assessed by simultaneously adding both variables to the model and we estimated the theoretical effect of substituting one type of beverage for another by using the difference in beta-coefficients from the same model. These substitutions were made only to the consumption reported at baseline; changes in beverage intake over time were not assessed. The multivariable model was adjusted for the baseline covariates age (years), sex, intervention group (CG/IG), smoking habit (never, former, or current), educational level (primary, secondary or academic/graduate), baseline body mass index (kg/m^2), leisure-time physical activity (METs.min/week), the 14-point MedDiet adherence score (continuous), and total energy intake from fluids other than the exchanged beverages (continuous). When the analyses were carried out for a beverage group, we additionally adjusted for servings per day of other groups.

All analyses were conducted with robust variance estimators to correct for intra-cluster correlations in linear regression models (considering the members of the same household to be clusters). Analyses were performed using Stata software, version 15.0 (StataCorp LP) and the level of significance for all of them was set at $P < 0.05$.

3. Results

The general characteristics of the studied population according to categories of drinking water consumption at baseline are shown in Table 1. Compared to participants in the lowest category of drinking water consumption, those in the highest category were younger, had higher body weight and BMI, and reported higher total fluid intake. For other groups and subgroups of beverages, the participants in the highest category of drinking water consumption reported a lower consumption frequency of total and reduced dairy beverages, sugary and artificially sweetened drinks, alcoholic beverages, wine, and beer, than participants in the lowest category. No other significant associations were observed.

Table 2 displays non-standardized β-coefficients and 95%CI for BW changes at 1- and 2-year follow-up according to categories of drinking water consumption at baseline. Participants in higher consumption categories (2.5 to < 5.5 servings/day, 5.5 to < 7.5, and ≥7.5 servings/day) showed significant BW reductions after one-year follow-up after adjustment for potential confounders including total energy intake and total fluid intake compared to participants who consumed less than 2.5 servings per day of drinking water, after adjusting for potential confounders. Results were similar at the two-year follow-up for all consumption categories of drinking water compared to the reference category, even after adjustment for potential confounders.

Table 3 shows non-standardized β-coefficients (95%CI) for WC changes at the 1- and 2-year follow-up according to categories of drinking water consumption at baseline. At two-years of follow-up, participants who consumed between 5 and 7.5 servings/day and those consuming ≥7.5 servings/day showed higher reductions in WC compared to the reference category of consumption (<2.5 servings/day) after adjustment for total energy intake and total fluid intake.

We did not observe significant interactions between sex, age, randomized intervention group and drinking water consumption categories. Additionally, sensitivity analyses were performed excluding participants who reported total energy intake <1200 kcal/day (n = 18), being the results similar (data not shown).

The mean absolute BW and WC changes and 95%CI of the substitution of one serving/day of water for beverage subgroups at 1- and 2-year follow-up are shown in Table 4 and Table 5, respectively. At 1-year follow-up, the replacement of one serving of soups/vegetable juices, alcoholic beverages, beer, spirits/mixed-alcoholic beverages and other beverages by one serving of drinking water was associated with a reduction of −403 (95%CI, −602, −205), −150 (95%CI, −278, −22), −230 (95%CI, −385, −74), 702 (95% CI, −1329, −76) and 343 (95%CI, −641, −45) grams in body weight, respectively. The substitution of one serving of spirits/mixed-alcoholic beverages with drinking water was associated with a decrease of −1.16 cm (95%CI, −2.04, −0.29) in WC at one-year follow-up. At 2-year follow-up, significant inverse associations were observed between the consumption of one serving of drinking water instead of one serving of hot beverages (−152 (95%CI,-279, −25)), total dairy beverages (−279 (95%CI,-479, −77)), reduced dairy beverages (−268 (95%CI,-480, −56)), soups and vegetable juices (−277 (95%CI,-499, −56)), and other beverages (−385 (95% CI,-715, −54)) and absolute BW changes in grams. No other significant associations were observed in the substitution models.

4. Discussion

To the best of our knowledge, this is the first epidemiological study to prospectively analyse the association between drinking water consumption and long-term BW changes in an elderly population with overweight/obesity and MetS. The results of our analyses showed that participants who reported a higher consumption of drinking water at baseline had a greater reduction in BW at 1- and 2- years of follow-up. Furthermore, the theoretical substitution of alcoholic beverages (beer and spirits/mixed alcoholic beverages), soups/vegetable juices, and other beverages by water was significantly associated with a greater reduction in weight at one year of follow-up. At two years of follow-up the consumption of one serving of drinking water instead of one serving of hot beverages, total and reduced-dairy beverages, and soups/vegetable juices was associated with a significant decrease in BW.

The association between drinking water consumption and BW in the long-term has been poorly studied [11,19]. To date, most research efforts have focused on the short-term effects of drinking water on total energy intake [20–23] and BW [24]. Intervention studies which have explored the effect of fluid consumption before a meal on energy intake have reported inconsistent results [20–23]. Two of them reported that participants who drank fluids before meals had lower energy intakes than those who did not drink any [20,21], although this association was not observed in other studies [22,23]. In a 12-week intervention trial [24], pre-meal

Table 1
Baseline characteristics of study participants with data on BW at a 1-year follow-up according to categories of baseline drinking water consumption.

N	Categories of Drinking Water Consumption (servings/day)				
	<2.5	2.5 - < 5	5 - < 7.5	≥7.5	P value
	357	713	515	247	
Drinking water consumption,[1] mL	355 (0, 500)	892 (800, 1000)	1300 (1071, 1400)	1800 (1800, 3100)	<0.01
Intervention group, % (n)	52 (185)	50 (353)	45 (234)	52 (128)	0.20
Women, % (n)	48 (173)	51 (364)	51 (264)	51 (126)	0.85
Age, years	65 ± 5	65 ± 5	65 ± 5	64 ± 5	<0.01
Body weight, kg	85.7 ± 13.0	86.0 ± 12.7	85.6 ± 11.9	89.5 ± 14.3	<0.01
BMI, kg/m^2	32.2 ± 3.4	32.7 ± 3.5	32.4 ± 3.5	33.5 ± 3.4	<0.01
Waist circumference, cm	107.1 ± 9.6	107.7 ± 9.9	107.3 ± 9.5	108.8 ± 10.4	0.15
Smoking status, % (n)					0.29
Current	11.5 (41)	14.0 (100)	11.5 (59)	8.5 (21)	
Former	41.5 (148)	41.1 (293)	39.8 (205)	45.3 (112)	
Never	47.0 (168)	44.9 (320)	48.7 (251)	46.2 (114)	
Education, % (n)					0.43
Primary or less	48.5 (173)	53.4 (381)	55.3 (285)	51.0 (126)	
Secondary	28.9 (103)	27.6 (197)	26.4 (136)	30.8 (76)	
Academic/graduate	22.7 (81)	18.9 (135)	18.3 (94)	18.2 (45)	
Leisure-time physical activity, METs.min/week	2351 ± 2275	2416 ± 2303	2580 ± 2472	2481 ± 2290	0.50
Total energy intake, Kcal/day	2431 ± 560	2396 ± 528	2372 ± 545	2368 ± 534	0.39
14-points MedDiet score	8.0 ± 2.2	7.8 ± 2.0	8.1 ± 1.9	8.1 ± 2.0	0.19
Total fluid intake, mL	1368 ± 537	1798 ± 457	2170 ± 438	2600 ± 390	<0.01
Groups and subgroups of beverages (servings/week)					
Drinking water	12.4 ± 4.3	31.2 ± 1.1	45.5 ± 0.5	63.7 ± 4.6	<0.01
Hot beverages	21.9 ± 18.5	21.7 ± 17.0	23.4 ± 17.3	22.9 ± 17.3	0.34
Total dairy beverages	10.0 ± 7.9	9.5 ± 7.2	8.6 ± 7.7	7.4 ± 7.2	<0.01
Whole-fat dairy beverages	1.8 ± 4.7	1.4 ± 3.9	1.2 ± 3.7	1.1 ± 3.3	0.10
Reduced-fat dairy beverages	8.2 ± 7.5	8.1 ± 7.1	7.4 ± 7.3	6.2 ± 7.0	<0.01
Soups	3.6 ± 6.3	3.6 ± 6.1	4.3 ± 6.4	4.6 ± 7.4	0.05
Sugary beverages	4.7 ± 7.3	4.1 ± 6.3	3.9 ± 6.0	2.5 ± 4.4	<0.01
Artificially sweetened beverages	2.1 ± 6.0	1.2 ± 4.3	1.0 ± 3.5	1.0 ± 3.6	<0.01
Alcoholic beverages	9.7 ± 14.0	8.1 ± 12.1	6.1 ± 10.3	5.3 ± 8.7	<0.01
Wine	5.6 ± 8.6	4.6 ± 7.3	3.7 ± 6.5	3.2 ± 6.4	<0.01
Beer	3.6 ± 9.2	3.0 ± 8.0	2.1 ± 6.3	1.9 ± 4.9	<0.01
Spirits and mixed alcoholic beverages	0.5 ± 2.2	0.5 ± 2.0	0.4 ± 1.5	0.2 ± 1.1	0.15
Other beverages	1.3 ± 4.0	1.3 ± 4.1	1.6 ± 4.8	1.9 ± 4.9	0.24

Data expressed as percentage (number) and mean ± standard deviation or [1] Median, minimum and maximum.
BMI, Body Mass Index; MedDiet, Mediterranean diet. P-value for comparisons between servings of drinking water consumption was calculated by Pearson's chi-square test for categorical variables or One-factor ANOVA for continuous variables.
A serving of water, dairy beverages (whole and reduced dairy beverages), sugary beverages and artificially sweetened beverages is defined as 200 mL; a serving of soups is defined as 100 mL; the hot beverage group includes servings of any kind of coffee (50 mL) and tea (200 mL); the alcoholic beverage group includes servings of wine (100 mL), beer (200 mL), spirits (50 mL) and mixed alcoholic beverages (200 mL); a serving from other beverages group (plant-based drinks, non-alcoholic beer, sorbets and jellies, and meal replacement shakes) is defined as (180 mL).

water intake combined with a hypocaloric diet was associated with a greater weight loss than a hypocaloric diet alone in middle-aged and older adults. In a prospective study conducted by Pan et al. [11] it was observed that each 1 cup/day increment of water intake was associated with less weight gain in three separate large prospective cohorts of healthy individuals. Moreover, our analyses showed that baseline consumption of five or more servings per day of drinking water was also associated with a decrease in WC, at one and two years of follow-up. These results are in line with observations reported by Stookey et al. [19] and Dennis et al. [24] who reported a positive association between increased water consumption and weight loss.

Some of the mechanisms by which drinking water may contribute to weight maintenance are: a) liquid volume can increase gastric distension and satiety, which contributes to a lower energy intake at subsequent meals [24], and b) the replacement of energy-containing beverages with water might contribute to a reduction in overall energy intake [19]. Moreover, the adjustment by total energy intake and total fluid intake at baseline, as stable variables, give robustness to our observed results suggesting that drinking water has potential effects on body weight and adiposity in the long-term, independently of caloric or fluid intake. Actually, experimental studies have reported that drinking water may induce thermogenesis and slightly increase metabolic rate, thus increasing energy expenditure [25,26], although this has to be further explored [27].

The associations between alcohol consumption, BW and WC have been explored but the results from different studies are inconclusive [28,29]. The effect of alcohol on weight seems to be conditioned by the type of alcoholic beverage consumed, the habitual amount consumed and sex differences [30]. Our results are supported by prospective studies that have demonstrated positive associations between changes in the consumption of alcoholic beverages and gain in BW and WC in different populations [28,31–33]. Similar to our observations, Fresán et al. [12], reported that the theoretical replacement of beer with one serving of water per day was related to a greater weight loss and lower incidence of obesity over a four-year period in a Mediterranean cohort of healthy young adults. Additionally, as in our study, Fresán and collaborators [12] did not observed this association for wine. The detrimental effects of alcoholic beverages (beer and spirits) on BW and adiposity have been explained by their high energy content, which increases the overall energy intake [34], and their ability to increase appetite and disturb lipid metabolism [28].

Contrary to what has been reported by other authors [11,19], our analysis did not show a significant decrease in BW or WC when sugary drinks were theoretically replaced by drinking water. The differences in the type of participants, the drinking pattern and

Table 2
Crude and multivariate β-coefficients and 95% CI of 1- and 2-year changes (%) in body weight per servings of drinking water at baseline.

	Categories of Drinking Water Consumption (servings/day)						
	<2.5 s/d	2.5 - < 5 s/d	5 - < 7.5 s/d	≥7.5 s/d	P value	Per 200 mL increase[a]	P trend
Change in weight at 1-year follow-up							
N	357	713	515	247			
Drinking water consumption, mL/d[b]	355 ± 122	892 ± 30	1300 ± 13	1821 ± 130	<0.01		
Body weight at baseline, kg[b]	85.7 ± 13.0	86.0 ± 12.7	85.6 ± 11.9	89.5 ± 14.3	<0.01		
Body weight 1-year follow-up, kg[b]	83.4 ± 13.1	83.5 ± 12.9	83.2 ± 12.1	86.6 ± 14.3	<0.01		
Change in weight (%)[b]	−3.0 ± 5.2	−3.2 ± 5.0	−3.1 ± 5.3	−3.6 ± 5.4	0.47		
Model 1[c]	0 (ref.)	−0.28 (−0.93, 0.38)	−0.14 (−0.59, 0.56)	−0.68 (−1.55, 0.19)		−0.07 (−0.18, 0.04)	0.22
Model 2[c]	0 (ref.)	−0.35 (−0.95, 0.25)	−0.44 (−1.09, 0.20)	−0.67 (−1.50, 0.15)		−0.09 (−0.20, 0.01)	0.09
Model 3[c]	0 (ref.)	−0.69 (−1.33, −0.06)	−1.07 (−1.79, −0.36)	−1.64 (−2.59, −0.68)		−0.24 (−0.36, −0.12)	<0.01
Change in weight at 2-year follow-up							
N	360	707	503	243			
Drinking water consumption, mL/d[b]	355 ± 122	892 ± 30	1300 ± 13	1821 ± 131	<0.01		
Body weight at baseline, kg[b]	85.7 ± 13.0	86.0 ± 12.7	85.6 ± 11.9	89.5 ± 14.3	<0.01		
Body weight 2-years follow-up, kg[b]	83.7 ± 13.3	83.7 ± 13.1	83.3 ± 12.3	86.6 ± 14.3	<0.01		
Change in weight (%)[b]	−2.6 ± 5.5	−2.9 ± 5.3	−2.9 ± 5.6	−3.5 ± 5.8	0.29		
Model 1[c]	0 (ref.)	−0.35 (−1.04, 0.35)	−0.33 (−1.08, 0.43)	−0.98 (−1.92, −0.04)		−0.11 (−0.22, 0.01)	0.06
Model 2[c]	0 (ref.)	−0.44 (−1.09, 0.21)	−0.69 (−1.39, 0.02)	−0.97 (−1.86, −0.08)		−0.13 (−0.24, −0.02)	0.02
Model 3[c]	0 (ref.)	−0.80 (−1.48, −0.12)	−1.36 (−2.18, −0.54)	−1.97 (−3.09, −0.86)		−0.28 (−0.42, −0.13)	<0.01

Linear regression models and median regression analyses: Model 1 was adjusted for age (years) and sex; Model 2 was additionally adjusted for intervention group (a/b), smoking habit (never, former or current), educational level (primary, secondary or academic/graduate), body mass index (kg/m^2), leisure time physical activity (METs.min/week) and the 14-item Mediterranean diet score (continuous); Model 3 was additionally adjusted for total energy intake (Kcal/day) and total fluid intake (mL/day).
The p-value for comparisons between servings of drinking water consumption and changes in weight were calculated by One-factor ANOVA.
[a] Calculated per 200 mL increment on drinking water.
[b] Data were expressed as means ± SD.
[c] Non-standardized coefficient (Confidence Interval).

Table 3
Crude and multivariate β-coefficients and 95% CI of 1- and 2-year changes in waist circumference per servings of drinking water at baseline.

	Categories of Drinking Water Consumption (servings/day)						
	<2.5 s/d	2.5 - < 5 s/d	5 - < 7.5 s/d	≥7.5 s/d	P value	Per 200 mL increase[a]	P trend
Change in waist circumference at 1-year follow-up							
N	344	682	494	237			
Drinking water consumption, mL/d[b]	354 ± 123	892 ± 31	1300 ± 13	1821 ± 133	<0.01		
Waist circumference at baseline, kg[b]	107.1 ± 9.6	107.7 ± 9.9	107.3 ± 9.5	108.8 ± 10.4	0.15		
Waist circumference 1-year follow-up, kg[b]	103.7 ± 10	104.6 ± 10.1	104.2 ± 9.9	105.7 ± 10.8	0.12		
Change in waist circumference (%)[b]	−3.5 ± 5.5	−3.2 ± 5.2	−3.0 ± 5.4	−3.2 ± 5.4	0.50		
Model 1[c]	0 (ref.)	0.37 (−0.34, 1.07)	0.56 (−0.20, 1.32)	0.28 (−0.62, 1.18)		0.05 (−0.07, 0.16)	0.36
Model 2[c]	0 (ref.)	0.24 (−0.42, 0.90)	0.26 (−0.45, 0.97)	0.20 (−0.67, 1.07)		0.02 (−0.09, 0.13)	0.61
Model 3[c]	0 (ref.)	−0.08 (−0.77, 0.60)	−0.33 (−1.13, 0.47)	−0.70 (−1.70, 0.30)		−0.11 (−0.25, 0.02)	0.15
Change in waist circumference at 2-year follow-up							
N	325	666	476	225			
Drinking water consumption, mL/d[b]	353 ± 124	892 ± 31	1300 ± 14	1819 ± 126	<0.01		
Waist circumference at baseline, kg[b]	107.1 ± 9.6	107.7 ± 9.9	107.3 ± 9.5	108.8 ± 10.4	0.15		
Waist circumference 2-years follow-up, kg[b]	104.4 ± 10.2	105.1 ± 10.5	104.3 ± 10.1	105.8 ± 10.3	0.25		
Change in waist circumference (%)[b]	−2.6 ± 5.6	−2.8 ± 5.8	−2.7 ± 5.7	−3.0 ± 5.8	0.92		
Model 1[c]	0 (ref.)	−0.14 (−0.90, 0.61)	−0.07 (−0.87, 0.74)	−0.35 (−1.34, 0.63)		−0.03 (−0.15, 0.09)	0.58
Model 2[c]	0 (ref.)	−0.27 (−0.99, 0.44)	−0.39 (−1.15, 0.38)	−0.38 (−1.34, 0.58)		−0.05 (−0.17, 0.07)	0.36
Model 3[c]	0 (ref.)	−0.66 (−1.40, 0.08)	−1.11 (−1.96, −0.25)	−1.45 (−2.66, −0.24)		−0.21 (−0.36, −0.05)	0.01

Linear regression models and median regression analyses: Model 1 was adjusted for age (years) and sex; Model 2 was additionally adjusted for intervention group (a or b), smoking habit (never, former or current), educational level (primary, secondary or academic/graduate), body mass index (kg/m^2), leisure time physical activity (METs.min/week) and the 14-item Mediterranean diet score (continuous); Model 3 was additionally adjusted for total energy intake (Kcal/day) and total fluid intake (mL/day).
The p-value for comparisons between servings of drinking water consumption and changes in waist were calculated by One-factor ANOVA.
[a] Calculated per 200 mL increment on drinking water.
[b] Data were expressed as means ± SD.
[c] Non-standardized coefficient (Confidence Interval).

methods used to assess drinking water and the time of follow-up might explain the discrepancies between the aforementioned studies and our results. However, our results are in line with those reported by Fresán et al. [12] who did not find a correlation between substitution of water for sugary drinks and weight changes. A long follow-up would probably be needed to achieve statistical significance in the replacement models [35]. Besides, the consumption of sugary drinks in the PREDIMED-Plus cohort [36] might be too low for any association to be detected. Artificially sweetened beverages (ASB) are commonly consumed as replacements for sugary drinks in an attempt to decrease calorie intake, although their effect on weight loss and weight maintenance remains

Table 4
Mean 1-year body weight and waist circumference changes (95% CI) associated with the substitution of one serving/day of water for different beverage groups (increasing water consumption by 1 serving/day and decreasing the relative beverage consumption by 1 serving/day) at baseline, using mathematical models.

	Absolute weight change (in grams)	Absolute waist circumference change (in centimeters)
Water for Hot beverages[b]	−92 (−197, 13)	0.08 (−0.07, 0.23)
Water for Total dairy beverages[b]	−131 (−301, 40)	−0.11 (−0.35, 0.13)
Water for Whole dairy beverages[a]	−112 (−373, 150)	−0.16 (−0.50, 0.18)
Water for Reduced dairy beverages[a]	−141 (−318, 34)	−0.11 (−0.35, 0.14)
Water for Sugary beverages[b]	−0.04 (−205, 205)	−0.10 (−0.37, 0.18)
Water for Artificially sweetened beverages[b]	−131 (−464, 201)	−0.13 (−0.65, 0.38)
Water for Soups/vegetable juices[b]	−403 (−602, −205)	−0.20 (−0.52, 0.13)
Water for Alcoholic beverages[b]	−150 (−278, −22)	−0.01 (−0.19, 0.17)
Water for Wine[a]	−37 (−220, 146)	0.09 (−0.15, 0.33)
Water for Beer[a]	−230 (−385, −74)	−0.04 (−0.28, 0.19)
Water for Spirits/Mixed alcoholic beverages[a]	−702 (−1329, −76)	−1.16 (−2.04, −0.29)
Water for Other beverages	−343 (−641, −45)	−0.42 (−0.81, 0.02)

[a] Multivariable-adjusted model for baseline covariates: age (years), sex, intervention group (a/b), smoking habit (never, former or current), educational level (primary, secondary or academic/graduate), baseline body mass index (kg/m^2), leisure time physical activity (METs.min/week) and the 14-item Mediterranean diet score (continuous) and total energy intake from fluids other than the exchanged beverages.
[b] Model additionally adjusted for servings per day from other groups of beverages.

Table 5
Mean 2-year absolute body weight and waist circumference changes (95% CI) associated with the substitution of one serving/day of water for different beverage groups (increasing water consumption by 1 serving/day and decreasing relative beverage consumption by 1 serving/day) at baseline, using mathematical models.

	Absolute weight change (in grams)	Absolute waist circumference change (in centimeters)
Water for Hot beverages[b]	−152 (−279, −25)	−0.07 (−0.25, 0.10)
Water for Total dairy beverages[b]	−279 (−479, −77)	−0.13 (−0.42, 0.15)
Water for Whole dairy beverages[a]	−171 (−488, 146)	0.04 (−0.34, 0.42)
Water for Reduced dairy beverages[a]	−268 (−480, −56)	−0.19 (−0.49, 0.10)
Water for Sugary beverages[b]	−22 (−238, 194)	−0.11 (−0.42, 0.20)
Water for Artificially sweetened beverages[b]	−144 (−465, 177)	−0.35 (−0.924, 0.23)
Water for Soups/vegetables juices[b]	−277 (−499, −56)	−0.38 (−0.81, 0.04)
Water for Alcoholic beverages[b]	−103 (−271, 65)	−0.06 (−0.27, 0.14)
Water for Wine[a]	−2.8 (−259, 253)	0.07 (−0.23, 0.37)
Water for Beer[a]	−148 (−381, 86)	−0.15 (−0.51, 0.20)
Water for Spirits/Mixed alcoholic beverages[a]	−367 (−1071, 337)	−0.91 (−1.91, 0.09)
Water for Other beverages	−385 (−715, −54)	−0.38 (−0.87, 0.11)

[a] Multivariable-adjusted model for baseline covariates: age (years), sex, intervention group (a/b), smoking habit (never, former or current), educational level (primary, secondary or academic/graduate), baseline body mass index (kg/m^2), leisure time physical activity (METs.min/week) and the 14-item Mediterranean diet score (continuous) and total energy intake from fluids other than the exchanged beverages.
[b] Model additionally adjusted for servings per day from other groups of beverages.

unclear [37,38]. However, the association between ASB consumption and BW compared to drinking water has been less explored. When we assessed the effect of replacing drinking water with ASB, we observed no effect on BW or WC. Similar results were recently reported in a young Mediterranean cohort [12]. In a parallel randomized-controlled weight-loss trial [39], ASB consumption was reported to be associated with greater weight loss and weight maintenance than water consumption during a structured weight loss program. Unfortunately, authors could not explain the potential mechanism responsible of the differences observed between groups. More studies are needed to clarify the long-term effect of ASB consumption instead of drinking water on BW and WC.

The published results on the association between types of dairy products, BW and WC are inconclusive. The consumption of dairy products has been inversely associated with weight gain and positively associated with improvements in body composition, especially in the short-term and as part of an energy-restricted diet [40]. In the long-term, these associations seem to be controversial [11,41–43]. Although reduced-fat dairy beverages are lower in energy content than whole-fat and sugary dairy beverages, in our study, their substitution by drinking water was associated with a greater decrease in BW at two-years of follow-up. The discrepancies between the aforementioned studies and our results could be attributed to differences in exposure (the amount consumed or changes over time) and to the fact that whole-dairy beverage consumption is low in our cohort, which makes it difficult to detect potential associations. It should also be taken into account that most previous longitudinal studies and meta-analyses focused on total dairy products and milk, and very few studies have analysed this effect on milk subtypes, milkshakes, and liquid yogurt.

The association between coffee and/or tea with BW and adiposity also remains unclear. Discrepancies between studies are mostly related to sex and ethnicity among others [44,45]. Coffee and tea are characterized by their content of caffeine, catechins, and other bioactive compounds which have been proposed as the potential mechanisms by which these beverages could prevent weight gain and promote weight loss [46,47]. However, when we assessed the effect of replacing hot beverages with drinking water a significant association with a decrease in BW was observed at two-years of follow-up. A possible explanation to our observations could be that, although coffee and tea are calorie-free beverages their consumption is often associated with calorie sweeteners, such as sugar, or other beverages such as milk or vegetable drinks (such as soy or almond beverages), which may contribute to increased energy intake, and therefore, their replacement with water could lead to a reduction in total energy intake.

In our analyses, replacing one serving of soups, broths, or vegetable juices with water was associated with weight and WC reductions. The assumption that soups and broths are usually a healthy and low-calorie food might induce people to consume larger portions. However, its nutritional properties and calorie content might vary as a consequence of cooking methods and the addition of other ingredients [48].

In our study, due to the heterogeneity of the other beverages group, it is difficult to clarify which of the beverages has the greatest influence on BW and WC. The few studies that have explored the effect of the consumption of plant-based drinks ("soy, almond, oats, rice milk", etc.) have been conducted in small samples and have focused on how the consumption of plant-based drinks and milk changes anthropometric parameters [40,49]. None of them have studied the association in the long-term. Except for one study that reported slight decreases in WC [49], no significant differences were observed between the effects of consuming milk or plant-based drinks on anthropometric parameters [40]. The nutrient density of plant-based drinks varies considerably between and within types, and their nutritional properties depend on a wide range of variables (food source, processing, fortification with vitamins and minerals, and the addition of other ingredients such as sugar and oils). Meal replacements, usually used to reduce daily energy intake, have proved to be positively associated with weight loss in the short-term, however their effectiveness preventing weight gain and maintaining weight loss still remain controversial [50]. Finally, sorbets and jellies are sources of sugars and saturated fat, with low satiating effects that contribute to increase energy intake [35,51]. All these reasons might explain the reduction observed in BW when these beverages were replaced by drinking water.

Some strengths of our study deserve to be mentioned: its prospective design, which reduces the possibility of reverse causation bias, the use of a specific validated fluid-intake questionnaire to assess beverage consumption, large sample size, and adjustment for several confounding factors. As far as limitations are concerned, we cannot discount that beverage consumption changed during the follow-up, and that the positive associations observed are due to other confounding factors not covered by the statistical analysis. Third, results from substitution models are based on mathematical theoretical estimations, therefore intervention trials are warranted in the future to prove the observed effect. Finally, we focused on elderly individuals with overweight/obesity and MetS and undergoing a planned weight loss program, so our results cannot be generalized to other populations.

5. Conclusions

The results of our study suggest that drinking tap and bottled water is inversely associated with adiposity changes in the long-term in an elderly Mediterranean cohort at high cardiovascular risk. Although further studies are warranted in the future, our results suggest that drinking water rather than energy-containing beverages is associated with lower weight gain. Recommendations to drink water, then, should be part of dietary advice on weight loss and its maintenance in the long-term.

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Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are not expected to be made available outside the core research group, as neither participants' consent forms or ethics approval included permission for open access. However, the researchers will follow a controlled data sharing collaboration model, as in the informed consent participants agreed with a controlled collaboration with other investigators for research related to the project's aims. Therefore, investigators who are interested in this study can contact the PREDIMED Plus Steering Committee by sending a request letter to predimed_plus_scommittee@googlegroups.com. A data sharing agreement indicating the characteristics of the collaboration and data management will be completed for the proposals that are approved by the Steering Committee.

Ethical standards

All participants provided their written informed consent. The study protocol and procedures were approved in accordance with the ethical standards of the Declaration of Helsinki.

Author contributions

Study concept and design: I.P-G, N.B and J.S-S. Statistical analyses: I.P-G, N.B.-T., and J.S-S. Drafting the manuscript: I.P-G, N.B, and J.S-S. All authors reviewed the manuscript for important intellectual content and approved the final version to be published.

Conflict of interest

JS-S serves on the board of (and is provided grant support by his institution from) the International Nut and Dried Fruit Council and the Eroski Foundation. He also serves on the Executive Committee of the Instituto Danone, Spain, and on the Scientific Committee of the Danone International Institute. He has received research support from the Patrimonio Comunal Olivarero, Spain, and Borges S.A., Spain. He receives consulting fees or travel expenses from

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnu.2021.05.014.

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