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Predictors of weight gain in a Mediterranean cohort: the Seguimiento Universidad de Navarra Study¹⁻³

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ABSTRACT

Background: High consumption of sugar-sweetened drinks has been associated with weight gain and obesity in the United States. This trend may also be affecting populations with different eating patterns who increasingly are adopting typical US dietary patterns.

Objective: We assessed whether the consumption of sweetened drinks and other food items increased the likelihood of weight gain in a Mediterranean population.

Design: This was a prospective cohort analysis of 7194 men and women with a mean age of 41 y who were followed-up for a median of 28.5 mo with mailed questionnaires. Dietary exposure was assessed with a previously validated semiquantitative food-frequency questionnaire.

Results: During follow-up, we observed that 49.5% of the participants increased their weight (\bar{x} weight gain: 0.64 kg; 95% CI: 0.55, 0.73 kg). In the participants who had gained ≥ 3 kg in the 5 y before baseline, the adjusted odds ratio of subsequent weight gain for the fifth quintile compared with the first quintile of sugar-sweetened soft drink consumption was 1.6 (95% CI: 1.2, 2.1; P for trend = 0.02). This association was absent in the participants who had not gained weight in the 5-y period before baseline. The consumption of hamburgers, pizza, and sausages (as a proxy for fast-food consumption) was also independently associated with weight gain (adjusted odds ratio for the fifth compared with the first quintile = 1.2; 95% CI: 1.0, 1.4; P for trend = 0.05). We also found a significant, but weaker, association between weight gain and both red meat and sweetened fruit juice consumption.

Conclusion: In a Mediterranean cohort, particularly in the participants who had already gained weight, an increased consumption of sugar-sweetened soft drinks and of hamburgers, pizza, and sausages was associated with a higher risk of additional subsequent weight gain. *Am J Clin Nutr* 2006;83:362-70.

KEY WORDS Obesity, overweight, body weight, body weight change, soft drinks, fast food, fat, sugar, diet, nutrition, prospective studies, incidence, longitudinal analysis, nutritional epidemiology

INTRODUCTION

The prevalence of obesity is dramatically increasing, and this increase represents a leading public health problem; in fact, at the turn of the millennium, it was a major concern for the clinical

nutrition field (1-3). A public health priority is to reduce the prevalence of obesity.

In the US population, the consumption of fast food and of sugar-sweetened soft drinks (SSSDs) has increased (a 68% increase in carbonated soft drink consumption from 1977 to 1997) in parallel to the obesity epidemic (4-6). North American consumption of soft drinks represents >44% of the total soft drink sales in the world. Europe represents 31% of the total world soft drink consumption, and European consumption is on the rise (7). The consumption of soft drinks, especially cola drinks, has also increased considerably in Spain (an increase of 42% in the period from 1991 to 2001) (8). A higher consumption of SSSDs may contribute to weight gain because soft drinks contain easily absorbable carbohydrates (9, 10) and because of the lower satiety associated with the intake of liquid foods. In addition, cola-based soft drinks contain caramel that is rich in glycated end products, which may increase insulin resistance (9, 11). Two small ($n = 41$ and $n = 30$) experimental trials evidenced that increased consumption of SSSDs led to weight gain (12, 13). Additionally, there has also been an increase in the consumption of sweetened fruit juices (4, 14). Sweetened fruit juices might promote weight gain if they are drunk in large amounts, but the evidence is very scarce (11, 15). On the other hand, the role of meat consumption in obesity remains unclear (16).

We previously reported a trend toward the adoption of a typical westernized dietary pattern (ie, one that is rich in red meat) (17, 18) with frequent consumption of fast foods in Spanish university graduates, especially in younger men (19). Fast foods

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are dense in energy, are consumed in portion sizes that are greater than needed, are highly palatable, and are rich in saturated fats, refined carbohydrates, and added sugars but poor in dietary fiber. Several recent epidemiologic studies have reported that, because of all the characteristics of fast foods, fast-food consumption may be a risk factor for weight gain and might have contributed to the current obesity epidemic in the United States (6, 20).

Observed changes in obesity have not been as dramatic in Europe as in the United States, but they are following the same trend step-by-step (21, 22). Few studies have investigated the effects of the consumption of both SSSDs and fast food on weight gain. Moreover, no epidemiologic studies have assessed this issue in European countries. Longitudinal studies conducted in the United States reported that SSSDs were associated with increased weight gain or obesity in adult women (11) and in children (23, 24). Similar associations have been reported for fast-food consumption (6, 20). If these findings are also confirmed in European countries, the scientific evidence to support public health actions will be strengthened. In addition, a greater opportunity for large-scale preventive interventions with adequate timeliness will be available in Europe before the rates of obesity reach the levels seen in the United States. We investigated the association between the consumption of SSSDs or the consumption of hamburgers, pizza, and sausages (HPS; as an indicator for fast-food consumption) and weight change in a Spanish cohort after 28.5 mo of follow-up.

SUBJECTS AND METHODS

Study population

The Seguimiento Universidad de Navarra (SUN; Follow-up University of Navarra) Project is a prospective cohort study that was designed to establish the associations between diet and the occurrence of several diseases and chronic conditions, including overweight, obesity, or weight change over time (25). The SUN cohort was designed in collaboration with the Harvard School of Public Health to use similar methodologies to those of large American cohorts, such as the Nurses' Health Study and the Health Professionals Follow-up Study (25).

Information for the study is collected from the participants with self-administered questionnaires that are sent by mail every 2 y. The follow-up rate was >90% for the first 2-y period. Participant recruitment started in December 1999 and is permanently ongoing, because this is a dynamic cohort study. All participants are university graduates. The data set of the SUN Project had incorporated 17 170 participants as of December 2004. For the present analyses, we included the participants who had already been followed-up for ≥ 2 y. The participants who reported extremely low or high values for total energy intake (<800 or >4200 kcal/d for men and <600 or >3500 kcal/d for women), those with missing values for the variables of interest, and those with biologically implausible values for weight or height were excluded from the analysis, which left data from 7194 participants. The study was approved by the Human Research Ethical Committee at the University of Navarra. Voluntary completion of the first self-administered questionnaire was considered to imply informed consent.

Assessment of dietary exposure

Dietary exposure was ascertained through a semiquantitative food-frequency questionnaire that included 136 food items and

was previously validated in Spain (26). This questionnaire was included in the general baseline assessment for each participant.

Nutrient scores were calculated as frequency \times nutrient composition of specified portion size; frequencies were measured in 9 categories (>6 servings/d, 4–6 servings/d, 2–3 servings/d, 1 serving/d, 5–6 servings/wk, 2–4 servings/wk, 1 serving/wk, 1–3 servings/mo, and never or almost never) for each food item. Data of food intake were transformed into food consumption (in mL or g). Nutrient intake scores were computed with an ad hoc computer program specifically developed for this aim. A trained dietitian updated the nutrient data bank using the latest available information in food-composition tables for Spain (27, 28). We used separate items to assess the consumption of SSSDs and of diet (sugar-free) carbonated soda drinks. We analyzed the consumption of SSSDs as the main independent variable in our analyses. Milk consumption was assessed from the consumption of 3 different items in the questionnaire: whole milk, low-fat milk, and nonfat milk. We estimated total milk consumption per person using the sum of the 3 items (whole milk + low-fat milk + nonfat milk). The indicator for fast-food consumption (HPS; in g/d) was estimated as the sum of 3 items in the food frequency questionnaire (hamburgers, pizza, and sausages). All dietary intakes were adjusted for total energy intake with use of the residuals method (29).

Assessment of nondietary variables

The baseline assessment also included other questionnaires (totaling 46 items for men and 54 items for women) that assessed the participants' medical history, health habits, lifestyle, and sociodemographic variables. The participants were classified as never smokers, former smokers, or current smokers. A physical activity questionnaire, which included 17 activities, was also completed by each subject at baseline. To quantify the volume of activity during leisure time, an activity metabolic equivalent (MET) index was computed by assigning a multiple of resting metabolic rate (MET score) to each activity (30); the time spent in each of the activities was multiplied by the MET score specific to each activity and then summed over all activities to obtain a value of overall weekly MET-hours, which was shown to adequately correlate (Spearman $\rho = 0.51$; $P = 0.002$) with the objectively measured energy expenditure in a validation subsample of our cohort (31).

Assessment of the outcome

Information on weight was collected at baseline and in the follow-up questionnaire which was completed by the participants ≥ 2 y from baseline (median follow-up time: 28.5 mo). The reproducibility and validity of self-reported weights were assessed in a representative subsample of the cohort. The mean relative error in self-reported weight was 1.45%, and the correlation coefficient between measured and self-reported weight was 0.99 (95% CI: 0.98, 0.99).

The outcomes were the following: 1) any increase in body weight during follow-up categorized as a dichotomous variable (cutoff ≥ 1 kg) and 2) change in body weight during follow-up as a continuous variable [weight at follow-up assessment – weight at baseline]. The baseline evaluation also collected information regarding weight change for each participant in the 5-y period before our baseline assessment. This information (ie, previous weight gain) was not considered as an outcome but as a stratifying variable, which was dichotomized at a cutoff of ≥ 3 kg.



Statistical analysis

Nonconditional logistic regression models were fit to assess the relation between the consumption of SSSDs or HPS and the risk of any weight gain during follow-up. Odds ratios (ORs) and 95% CIs were calculated with the lowest quintile of consumption as the reference category. Tests of linear trend across increasing quintiles of consumption were conducted by assigning the medians of each intake quintile and treating the intake as a continuous variable. Linear regression models were used to assess the association between the consumption of SSSDs or HPS (ie, the exposure, which was categorized as quintiles for both groups) and change in body weight during the follow-up (ie, the outcome, which was considered as a continuous variable). We estimated the β regression coefficients (and 95% CIs) for each of the 4 upper quintiles of consumption, with the lowest quintile as the reference category. These coefficients represent the absolute difference in weight gain between each of the 4 upper quintiles and the lowest quintile.

For each exposure (SSSD or HPS) we fitted a crude (univariate) model, an age- and sex-adjusted model, and a multivariate model with additional adjustment for baseline energy intake (in kcal/d) from non-SSSD sources (or non-fast-food sources), energy-adjusted fiber intake (in g/d), energy-adjusted alcohol intake (in g/d), energy-adjusted milk consumption (in mL/d), leisure-time physical activity (in MET-h/wk), smoking status (never smoker, smoker, or former smoker), snacking between meals (yes or no), TV watching (in h/wk), and baseline weight (in kg). We also conducted similar analyses to assess the association between other food groups (24 groups in total) and weight gain.

We used a product-term included in the fully adjusted models to appraise the interaction (effect modification) between the previous change in body weight (ie, during the 5-y period before the baseline assessment) and the consumption of SSSDs (or of HPS) on subsequent weight gain (ie, during the follow-up period). When the coefficient for this product term was statistically significant (or approached statistical significance, $P < 0.10$), we performed separate analyses for the participants who had increased their weight ≥ 3 kg during the 5 y before baseline and for those who had not.

The estimated basal metabolic rate was calculated separately for sex and age groups according to the World Health Organization equation (32). We repeated the main analyses after excluding the participants with a ratio of energy intake to basal metabolic rate < 1.2 . This low ratio is rare; therefore, such values likely reflect underreporting of dietary intakes (33). All P values presented are 2-tailed; $P < 0.05$ was considered statistically significant, unless otherwise specified. The analyses were conducted with SPSS version 12.0.1 (SPSS Inc, Chicago, IL).

RESULTS

During follow-up we observed that 49.5% of our study population experienced some increase in their body weight. The mean (95% CI) change in body weight was 0.64 kg (0.55, 0.73 kg). The participants with a prior history of weight gain (≥ 3 kg in the 5 y before baseline) experienced a subsequent mean weight gain of 0.21 kg, whereas those without a prior weight-gain history (ie, those with a weight gain of < 3 kg in the 5 y before baseline) subsequently increased an average 0.87 kg (95% CI: 0.78, 0.96 kg; $P < 0.001$).

The characteristics of the participants are shown in **Table 1** according to quintiles of consumption of SSSDs. We stratified this table according to whether participants had increased their weight ≥ 3 kg during the 5-y period before our baseline assessment. Consumption of SSSDs was higher in the men and in the younger participants. Baseline body weight increased in parallel with soft drink consumption. The participants with a higher consumption of SSSDs had a lower fiber intake, lower milk consumption, a higher consumption of fast food, and a higher frequency of between-meals snacking than did the participants with a low SSSD consumption.

When we analyzed the association between the consumption of SSSDs and weight gain during follow-up, the estimates suggested an interaction between the consumption of SSSDs and previous weight gain (P for interaction = 0.07 in the logistic regression model and 0.006 in the linear model). Consequently, we split the database according to whether the participants had gained weight in the 5 y before baseline (cutoff: ≥ 3 kg) and analyzed the relation between SSSDs and subsequent weight gain separately for both groups (**Table 2**). The lowest proportion of participants who gained weight was found in the lowest quintile of SSSD consumption. We observed an increased risk of weight gain associated with higher SSSD consumption only in the participants who reported weight gain during the 5 y before baseline [crude ORs across quintiles 1 to 5 were 1.00 (reference), 1.21, 1.07, 1.20, and 1.39, respectively; P for trend = 0.019]. With additional adjustment for a set of potential dietary and nondietary confounders, we found a 56% increase in the incidence of weight gain for the 5th compared with the 1st quintile of SSSD consumption (multivariate-adjusted OR: 1.56; 95% CI: 1.17, 2.09). These estimates did not materially change after additional adjustment for HPS consumption, and the P for trend remained statistically significant ($P = 0.02$).

When we analyzed the magnitude of weight gain (outcome) as a continuous variable using linear models to assess its association with the consumption of SSSD (exposure, categorized in quintiles), we also split the sample according to previous weight gain (P for interaction = 0.006). In the participants who had previously increased their body weight, a higher consumption of SSSDs (ie, the 4th and 5th quintiles) was associated with a significantly increased weight gain compared with the first quintile (crude β regression coefficients for the 4th and 5th quintile: 0.7 and 0.9 kg, respectively). These associations remained statistically significant (P for trend = 0.001) after adjustment for age and sex and after additional adjustment for other potential confounders [β (95% CI) for the fourth and fifth quintile were 1.0 kg (0.4, 1.6 kg) and 1.2 kg (0.6, 1.8 kg), respectively]. Additional adjustment for HPS consumption did not materially affect the results. On the other hand, these associations were absent in the participants who experienced no weight gain during the period before our baseline assessment.

The results of logistic regression analyses that were conducted to assess the association between HPS consumption and weight gain during follow-up are shown in **Table 3**. We observed the highest risk of weight gain in the participants in the top quintile of HPS consumption (OR: 1.2; 95% CI: 1.1, 1.4; P for trend = 0.004). This association remained statistically significant after adjustment for age and sex and also after additional adjustment for dietary and nondietary confounders, including SSSD consumption. No significant interaction was observed between the



TABLE 1

Characteristics of the participants according to weight gain and to increasing quintiles (Q) of sugar-sweetened soft drink (SSSD) consumption¹

	Weight gain <3 kg in the previous 5 y					Weight gain ≥3 kg in the previous 5 y				
	Quintiles of SSSD consumption					Quintiles of SSSD consumption				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
Participants (n)	974	975	975	975	975	464	464	464	464	464
SSSD consumption (mL/d)	<4.0	4.0–14.8	14.9–27.8	27.9–80.2	≥ 80.3	<5.5	5.5–17.6	17.7–33.3	33.4–87.4	≥ 87.5
Age (y)	40.6 ± 13 ²	38.1 ± 13	36.6 ± 12	35.0 ± 12	32.3 ± 10	41.0 ± 12	39.2 ± 12	37.1 ± 11	33.7 ± 10	32.8 ± 10
Men (%)	37	27	36	47	40	40	35	49	61	62
Baseline weight (kg)	63.3 ± 12	61.8 ± 11	63.8 ± 12	65.5 ± 13	64.4 ± 13	70.2 ± 14	70.5 ± 14	72.6 ± 14	74.0 ± 13	74.5 ± 14
Physical activity (MET-h/wk)	22.1 ± 23	19.4 ± 23	17.2 ± 19	19.2 ± 21	18.6 ± 24	18.9 ± 24	16.6 ± 21	18.3 ± 20	16.7 ± 20	18.7 ± 23
Television watching (h/wk)	10.3 ± 6	10.3 ± 6	10.5 ± 6	10.3 ± 6	9.6 ± 6	10.0 ± 6	10.2 ± 6	10.2 ± 6	9.8 ± 6	9.7 ± 6
Current smokers (%)	20	24	24	28	32	22	21	23	25	30
Former smokers (%)	30	26	24	21	19	34	37	29	23	24
Energy intake from non-SSSD sources (kcal/d)	3306.7 ± 465	2404.3 ± 571	2230.8 ± 560	2388.1 ± 700	2502.2 ± 563	3243.1 ± 495	2356.8 ± 572	2205.5 ± 543	2593.4 ± 722	2563.4 ± 647
Total fat intake (% of energy)	36.0 ± 7	36.2 ± 7	37.2 ± 7	37.7 ± 7	38.0 ± 7	36.9 ± 7	37.4 ± 7	37.6 ± 7	38.3 ± 7	37.6 ± 7
MUFA (% of energy)	15.6 ± 4	15.7 ± 4	16.0 ± 4	16.1 ± 4	16.2 ± 4	16.0 ± 4	16.4 ± 4	16.2 ± 4	16.3 ± 3	16.0 ± 3
SFA (% of energy)	11.9 ± 4	12.3 ± 3	12.7 ± 3	13.1 ± 3	13.3 ± 3	12.4 ± 3	12.7 ± 3	13.2 ± 3	13.4 ± 3	13.4 ± 3
PUFA (% of energy)	5.4 ± 2	5.1 ± 2	5.3 ± 2	5.5 ± 2	5.6 ± 2	5.4 ± 2	5.3 ± 2	5.4 ± 2	5.7 ± 2	5.4 ± 2
Carbohydrate intake (% of energy)	45.5 ± 8	43.8 ± 8	42.8 ± 7	42.5 ± 7	43.0 ± 7	43.8 ± 8	41.9 ± 8	41.9 ± 8	41.9 ± 7	42.7 ± 7
Protein intake (% of energy)	16.8 ± 3	18.3 ± 3	18.4 ± 3	18.0 ± 4	17.1 ± 3	17.4 ± 3	18.4 ± 3	18.3 ± 4	17.4 ± 3	17.2 ± 3
Fiber intake (g/d)	42.2 ± 12	29.6 ± 13	25.8 ± 11	26.1 ± 13	25.5 ± 12	38.4 ± 12	27.1 ± 10	24.1 ± 10	25.5 ± 13	23.6 ± 11
Milk consumption (mL/d)	348.8 ± 294	300.2 ± 242	282.6 ± 228	267.2 ± 228	277.8 ± 228	350.9 ± 276	262.4 ± 222	265.9 ± 198	281.1 ± 227	264.0 ± 213
HPS consumption (g/d)	17.9 ± 21	17.0 ± 23	19.1 ± 18	22.5 ± 20	26.1 ± 23	21.7 ± 27	18.0 ± 18	20.2 ± 18	28.4 ± 27	29.9 ± 27
Snacking between meals (%)	32	30	28	31	37	38	41	42	46	50

¹ MET, metabolic equivalent; MUFA, monounsaturated fatty acids; SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids; HPS, hamburger, pizza and sausages. *P* for interaction (product-term) between consumption of SSSD and weight gain in the previous 5 y = 0.006 in the linear multivariate-adjusted model (outcome: prospective weight gain) and *P* = 0.07 in the nonconditional logistic regression-adjusted model (outcome: prospective weight gain). There was no significant interaction between consumption of SSSD and weight gain in the previous 5 y for any of the variables reported in the table.

² $\bar{x} \pm SD$ (all such values).

consumption of HPS and weight gain in the period before our study (*P* for interaction = 0.41).

When we assessed the association between quintiles of HPS consumption and the magnitude of weight change during follow-up, we also observed that the participants in the 2 upper quintiles of HPS consumption exhibited a significantly greater weight gain during follow-up than did the participants in the lowest quintile (mean weight change during follow-up: 0.78 and 0.77 kg compared with 0.47 kg for the first quintile; *P* for trend = 0.014). When we used linear regression modeling to assess the independent association between consumption of HPS and the magnitude of weight change during follow-up, these differences were attenuated after a multivariate adjustment (mean weight changes for quintiles 4 and 5 were 0.71 and 0.64 kg, respectively) and they did not remain statistically significant. When we repeated the analyses after excluding underreporters (ie, those participants with a basal metabolic rate ratio <1.2) (33), we did not find any substantial difference with respect to the main results shown in our tables.

When we analyzed all food items that were included in our food-frequency questionnaire after classifying them into 24 groups (legumes, pasta, cereals, biscuits, whole-meal bread, commercial bakery bread, chocolate, nuts, fruits and vegetables, sweetened fruit juices, SSSD, diet sodas, dairy products, alcohol beverages, eggs, fish, lean meats, red meats, HPS, cold or cured meats, precooked meals, sauces, animal fats, and vegetable oils), we found that, apart from SSSD and HPS, only 2 other food groups (red meats and sweetened fruit juices) were significantly dose-response associated with a higher risk of weight gain; nevertheless, these associations were weaker, and the odds ratio did not reach statistical significance even for fruit juice consumption, although the *P* for trend was 0.04 (Table 4 and Table 5). The crude OR for the 5th compared with the 1st quintile of red meat consumption was 1.16 (95% CI: 1.00, 1.36). Nevertheless, the OR for the 5th quintile did not remain statistically significant after multivariate adjustment, but the *P* for trend was 0.004 (Table 4). These 2 groups did not confound our estimates for SSSD or HPS consumption.



TABLE 2

Odds ratios (ORs) for any weight gain during follow-up according to increasing quintiles (Q) of sugar-sweetened soft drink (SSSD) consumption¹

	Baseline consumption of SSSD					<i>P</i> for trend ²
	Q1	Q2	Q3	Q4	Q5	
Weight gain ≥3 kg in the previous 5 y						
Participants (<i>n</i>)	464	464	464	464	464	
Consumption of SSSD (mL/d)	<5.5	5.5–17.6	17.7–33.3	33.4–87.4	≥87.5	
Weight gain during follow-up (%)	41	46	43	46	50	
Crude OR (95% CI) ³	1.00 (ref)	1.21 (0.94, 1.57)	1.07 (0.83, 1.39)	1.20 (0.93, 1.56)	1.39 (1.07, 1.81)	0.019
Age- and sex-adjusted OR (95% CI) ⁴	1.00 (ref)	1.23 (0.95, 1.59)	1.09 (0.84, 1.41)	1.23 (0.94, 1.60)	1.43 (1.09, 1.87)	0.017
Multivariate-adjusted OR (95% CI) ⁵	1.00 (ref)	1.37 (1.04, 1.81)	1.24 (0.93, 1.65)	1.35 (1.01, 1.79)	1.56 (1.17, 2.09)	0.015
Additionally adjusted for HPS consumption (95% CI) ⁶	1.00 (ref)	1.37 (1.04, 1.81)	1.24 (0.93, 1.64)	1.34 (1.01, 1.78)	1.55 (1.16, 2.07)	0.018
Weight gain <3 kg in the previous 5 y						
Participants (<i>n</i>)	974	975	975	975	975	
Consumption of SSSD (mL/d)	<4.0	4.0–14.8	14.9–27.8	27.9–80.2	≥80.3	
Weight gain during follow-up (%)	48	54	53	49	53	
Crude OR (95% CI) ³	1.00 (ref)	1.26 (1.05, 1.50)	1.23 (1.03, 1.46)	1.05 (0.88, 1.26)	1.20 (1.01, 1.43)	0.377
Age- and sex-adjusted OR (95% CI) ⁴	1.00 (ref)	1.24 (1.04, 1.48)	1.18 (0.99, 1.42)	0.99 (0.83, 1.19)	1.11 (0.92, 1.33)	0.996
Multivariate-adjusted OR (95% CI) ⁵	1.00 (ref)	1.25 (1.03, 1.51)	1.23 (1.01, 1.50)	1.01 (0.83, 1.23)	1.10 (0.91, 1.34)	0.724
Additionally adjusted for HPS consumption (95% CI) ⁶	1.00 (ref)	1.24 (1.02, 1.50)	1.21 (1.00, 1.48)	0.99 (0.82, 1.21)	1.08 (0.89, 1.32)	0.611

¹ HPS, hamburgers, pizza, and sausages. The cutoff for weight gain during the followup period was ≥1 kg.² Nonconditional logistic regression.³ *P* for interaction (product-term) between consumption of SSSD and weight gain in the previous 5 y = 0.14.⁴ *P* for interaction (product-term) between consumption of SSSD and weight gain in the previous 5 y = 0.05.⁵ Adjusted for age (y), sex, total energy intake from non-SSSD sources (kcal/d), fiber intake (g/d), alcohol intake (g/d), milk consumption (mL/d), leisure-time physical activity (metabolic activity h/wk), smoking status (never smoker, smoker, or former smoker), snacking (yes or no), television watching (h/wk), and baseline weight (kg). An interaction term (age × sex, *P* < 0.001) was also added. *P* for interaction (product-term) between consumption of SSSD and weight gain in the previous 5 y = 0.07⁶ *P* for interaction (product-term) between consumption of SSSD and weight gain in the previous 5 y = 0.06.

DISCUSSION

We observed that an increase in the consumption of SSSDs was associated with weight gain after a 28.5-mo follow-up in 7194 participants of a Mediterranean cohort. This association was only apparent in the participants who had reported a previous weight gain (≥3 kg; during the 5 y before baseline) at our baseline assessment. This differential effect in the participants who had not recently gained weight could be attributed to other lifestyle or genetic factors that render them less susceptible to subsequent weight gain associated with the consumption of SSSDs. Moreover, the consumption of SSSDs, in absolute terms, was higher in the participants who had gained weight in the 5 y before the baseline assessment than in the participants who had not gained weight, which supports this interpretation. The consumption of HPS (as a proxy for fast-food consumption) was also associated with higher weight gain, independent of the consumption of SSSDs and of previous weight gain.

Our findings are a reason for concern with regard to the global epidemic of obesity because they suggest that the adverse association between SSSDs (or fast food) and weight gain reported in the United States (6, 11, 23) is beginning to appear in educated young adults in a Mediterranean country. Apparently, calories that are consumed as liquid carbohydrates do not fully displace those that are consumed from solid sources and may, in fact, lead to an increase in the consumption of other foods (12, 34). A meta-analysis of studies conducted during a 25-y period showed that humans compensate poorly for calories that are consumed in a liquid form (35). Thus, the overconsumption of SSSDs could be a particular problem because it could represent an extra source of energy ingested in liquid form. Similar effects can be expected with sweetened fruit juice consumption. On the other hand, the similar estimates reported in Table 2 before and after a multivariate adjustment suggest that a higher total energy intake from other sources is not necessarily the single mechanism by which



TABLE 3

Odds ratios (ORs) for any weight gain during follow-up according to increasing quintiles (Q) of consumption of hamburgers, pizza, and sausages (HPS)¹

	Baseline consumption of HPS					<i>P</i> for trend ²
	Q1	Q2	Q3	Q4	Q5	
Participants (<i>n</i>)	1438	1439	1439	1439	1439	
Fast food consumption (g/d)	<3.3	3.3–13.2	13.3–23.2	23.3–34.7	≥34.8	
Weight gain during follow-up (%)	47	49	51	50	52	
Crude OR (95% CI)	1.00 (ref)	1.12 (0.96, 1.29)	1.19 (1.03, 1.38)	1.18 (1.02, 1.37)	1.24 (1.08, 1.44)	0.004
Age- and sex-adjusted OR (95% CI)	1.00 (ref)	1.11 (0.96, 1.29)	1.17 (1.00, 1.35)	1.15 (0.99, 1.33)	1.20 (1.03, 1.40)	0.030
Multivariate-adjusted OR (95% CI) ³	1.00 (ref)	1.13 (0.97, 1.32)	1.19 (1.02, 1.39)	1.17 (1.00, 1.37)	1.21 (1.03, 1.42)	0.040
Additionally adjusted for SSSD (95% CI)	1.00 (ref)	1.15 (0.98, 1.33)	1.20 (1.03, 1.40)	1.18 (1.01, 1.38)	1.20 (1.02, 1.41)	0.053

¹ SSSD, sugar-sweetened soft drinks. The cutoff for weight gain during the follow-up period was ≥1 kg.² Nonconditional logistic regression.³ Adjusted for age (y), sex, total energy intake from non-fast-food sources (kcal/d), fiber intake (g/d), alcohol intake (g/d), leisure-time physical activity (metabolic equivalent-h/wk), smoking status (never smoker, smoker, or former smoker), snacking (yes or no), television watching (h/wk), baseline weight (kg), and weight gain ≥3 kg in the past 5 y (yes or no). An interaction term (age × sex, *P* < 0.001) was also added.

the overconsumption of SSSDs leads to overweight. In fact, the similarity between the crude and adjusted estimates may indicate that the main associations we report here are independent of the influence of the other foods that we took into account in the multivariate models. Nonetheless, we also acknowledge that our estimates of total energy intake or of the consumption of some foods, as measured by the food-frequency questionnaire, may present some degree of measurement error, which is to be expected in nutritional epidemiology (26, 29). In any case, it is important not to forget that, independent of the additional increase in energy intake that they represent, SSSDs and many fast foods are basically fiber-free foods and, therefore, they lose the ability that a fiber-rich diet (such as the traditional Mediterranean diet) has to prevent weight gain. A wide array of evidence suggests that fiber may exert this beneficial role through several mechanisms, which include effects on satiety, glucose metabolism, energy density, and the rates of ingestion and gastric emptying (24, 36–42). In fact, we found a strong inverse correlation between the consumption of SSSDs and fiber intake, which supports these mechanistic explanations.

Besides the mechanisms related to a poorer fiber intake, the quality of sugar in SSSDs should also be taken into account. High-fructose corn syrup was reported to represent >40% of the caloric sweeteners that are added to foods and beverages, and it is the sole caloric sweetener in SSSDs (9). The digestion, absorption, and metabolism of fructose differ from those of glucose. The hepatic metabolism of fructose favors de novo lipogenesis. In addition, unlike glucose, fructose does not stimulate insulin secretion nor enhance leptin production, whereas it may promote insulin resistance (9, 10). However, disagreement exists as to whether fructose has an adverse effect on body weight relative to glucose, and some authors have reported that fructose intake may actually induce a reduction in total food intake (43, 44).

Other mechanisms that could explain the association between SSSDs and weight gain are related to the inverse correlation between SSSDs and dairy products. We observed this inverse trend in our study (*P* < 0.001; see Table 1). This finding is consistent with the concurrent observed decrease in the intake of dairy products and an increase in the trend of soda consumption

TABLE 4

Odds ratios (ORs) for any weight gain during follow-up according to increasing quintiles (Q) of red meat consumption¹

	Baseline consumption of red meat					<i>P</i> for trend ²
	Q1	Q2	Q3	Q4	Q5	
Participants (<i>n</i>)	1438	1439	1439	1439	1439	
Red meat consumption (g/d)	<42.9	43.0–64.3	64.4–92.4	92.3–128.6	≥128.7	
Weight gain during follow-up (%)	49	46	49	52	53	
Crude OR (95% CI)	1.00 (ref)	0.88 (0.76, 1.03)	1.01 (0.87, 1.18)	1.12 (0.96, 1.30)	1.16 (1.00, 1.36)	0.002
Age- and sex-adjusted OR (95% CI)	1.00 (ref)	0.88 (0.75, 1.03)	1.01 (0.86, 1.18)	1.11 (0.96, 1.30)	1.16 (0.99, 1.35)	0.003
Multivariate-adjusted OR (95% CI) ³	1.00 (ref)	0.88 (0.75, 1.03)	1.01 (0.86, 1.18)	1.12 (0.95, 1.31)	1.16 (0.99, 1.36)	0.004

¹ The cutoff for weight gain during the follow-up period was ≥1 kg.² Nonconditional logistic regression.³ Adjusted for age (y), sex, total energy intake from non-fast-food sources (kcal/d), fiber intake (g/d), alcohol intake (g/d), leisure-time physical activity (metabolic equivalent-h/wk), smoking status (never smoker, smoker, or former smoker), snacking (yes or no), television watching (h/wk), baseline weight (kg), and weight gain ≥3 kg during the past 5 y (yes or no). An interaction term (age × sex, *P* < 0.001) was also added.

TABLE 5

Odds ratios (ORs) for any weight gain during follow-up according to increasing quintiles (Q) of sweetened fruit juice consumption¹

	Baseline consumption of sweetened fruit juice					<i>P</i> for trend ²
	Q1	Q2	Q3	Q4	Q5	
Participants (n)	1438	1439	1439	1439	1439	
Fruit juice consumption (g/d)	<13.3	13.3–26.7	26.8–57.1	57.2–185.7	≥185.8	
Weight gain during follow-up (%)	48	48	50	50	52	
Crude OR (95% CI)	1.00 (ref.)	0.98 (0.84, 1.14)	1.07 (0.92, 1.24)	1.06 (0.91, 1.24)	1.15 (0.98, 1.34)	0.042
Age- and sex-adjusted OR (95% CI)	1.00 (ref.)	0.98 (0.84, 1.14)	1.06 (0.91, 1.24)	1.05 (0.90, 1.23)	1.14 (0.98, 1.33)	0.049
Multivariate-adjusted OR (95% CI) ³	1.00 (ref.)	0.99 (0.84, 1.17)	1.08 (0.91, 1.28)	1.08 (0.92, 1.27)	1.16 (0.99, 1.36)	0.039

¹ The cutoff for weight gain during the follow-up period was ≥ 1 kg.

² Nonconditional logistic regression.

³ Adjusted for age (y), sex, total energy intake from non-fast-food sources (kcal/d), fiber intake (g/d), alcohol intake (g/d), leisure-time physical activity (metabolic equivalent-h/wk), smoking status (never smoker, smoker, or former smoker), snacking (yes or no), television watching (h/wk), baseline weight (kg), and weight gain ≥ 3 kg in the past 5 y (yes or no). An interaction term (age \times sex, $P < 0.001$) was also added.

that has been repeatedly reported, especially in children and adolescents (45–47). Also, an inverse association between total milk consumption and weight gain was found in our cohort (data not shown). An inverse association between dairy products (or total calcium intake) and overweight and obesity has also been reported in several other studies, which have claimed dairy product consumption as a possible protective mechanism against obesity (48, 49). Although residual confounding cannot be completely ruled out, the association of SSSDs with weight gain did not materially change after adjustment for milk consumption.


When we explored all food categories in our questionnaire and classified the food items into 24 groups, we found a significantly higher risk of weight gain for only 4 food groups: HPS, red meats, SSSDs, and sweetened fruit juices. The available scientific literature on the relation between red meat or sweetened fruit juices and weight gain is not abundant. However, our data are consistent with other studies (50, 51, 11). In the ongoing Baltimore Longitudinal Study of Aging, Newby et al (50) found that a diet low in red and processed meat, fast food, and soft drinks was associated with smaller gains in body mass index and waist circumference. In a cross-sectional study, Dennison et al (51) reported that obesity was more common in children who drank 12 fl oz juice/d than in those who drank less juice. In the Nurses' Health Study II, Schulze et al (11) found that an increase in fruit punch consumption was associated with greater weight gain. The fact that only 2 other food categories were associated with weight gain supports that HPS and SSSD consumption play an important role as predictors of weight gain in our cohort. Similar to SSSDs, sweetened juices contain a high content of refined sugars, including fructose, and provide no fiber. Red meats are similar to HPS because they are products of animal origin that are rich in saturated fatty acids. Thus, the association of sweetened juice and red meat consumption with a higher likelihood of weight gain is consistent with our similar findings regarding SSSD and HPS consumption.

The strengths of our study include the prospective design, which avoids the possible effect of inverse causation in the reported associations, the previous validation of the methods used for the measurement of the main variables that were considered in the analyses, the use of a highly educated cohort in a different culture and dietary environment that had been previously studied (6, 11, 23, 24), the large sample size, and control for an important

number of potential confounders. Although we cannot rule out the existence of unmeasured confounders, we included the main important known risk factors for weight gain in our analysis. Imprecise dietary measurements could have influenced our observed associations and left room for residual confounding and imprecise adjustment of our estimates. However, random errors of classification or residual confounding in our analyses might have accounted for a lack of association, but not for the reverse situation.

Our indicator for fast-food consumption (HPS) was the sum of 3 food items (hamburgers, pizza, and sausages). We used this sum as a proxy variable for categorizing exposure. We acknowledge this limitation of our assessment, and it could be possible that the hamburgers, pizza, and sausages consumed at home may have a healthier composition than the same food items consumed in cafeterias, snack-bars, or fast-food restaurants. This fact may hinder our ability to find stronger associations. However, in a previous study of our cohort in which we used factor analysis, we identified the sum of these 3 food items as one of the groups that better explained the total variance in the adherence to a westernized dietary pattern (19).

We did not control for socioeconomic status (SES) confounding, but we are confident that the SES of the participants was not a major confounder in our analyses because our cohort is homogeneous with regard to SES. A recommended procedure to adjust for SES is adjustment for educational level, but all our participants had attained the same educational level (ie, we used restriction instead of multivariate adjustment to control for confounding by SES).

Even if an absolute proof of causality cannot be firmly established when it comes from an observational design, it seems clear from our results, in any case, that SSSD or fast-food consumption are at least markers of an unhealthy dietary pattern that promotes overweight or obesity in the participants. The optimistic side of our findings is that this dietary pattern has the potential of being used as a quick screening test for an increased risk of overweight or obesity (52). 

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