Prospective association between added sugars and frailty in older adults

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ABSTRACT

Background: Sugar-sweetened beverages and added sugars (monosaccharides and disaccharides) in the diet are associated with obesity, diabetes, and cardiovascular disease, which are all risk factors for decline in physical function among older adults.

Objective: The aim of this study was to examine the association between added sugars in the diet and incidence of frailty in older people.

Methods: Data were taken from 1973 Spanish adults ≥60 y old from the Seniors-ENRICA cohort. In 2008–2010 (baseline), consumption of added sugars (including those in fruit juices) was obtained using a validated diet history. Study participants were followed up until 2012–2013 to assess frailty based on Fried's criteria. Statistical analyses were performed with logistic regression adjusted for age, sex, education, smoking status, body mass index, energy intake, self-reported comorbidities, Mediterranean Diet Adherence Score (excluding sweetened drinks and pastries), TV watching time, and leisure-time physical activity.

Results: Compared with participants consuming <15 g/d added sugars (lowest tertile), those consuming ≥36 g/d (highest tertile) were more likely to develop frailty (OR: 2.27; 95% CI: 1.34, 3.90; *P*-trend = 0.003). The frailty components "low physical activity" and "unintentional weight loss" increased dose dependently with added sugars. Association with frailty was strongest for sugars added during food production. Intake of sugars naturally appearing in foods was not associated with frailty.

Conclusions: The consumption of added sugars in the diet of older people was associated with frailty, mainly when present in processed foods. The frailty components that were most closely associated with added sugars were low level of physical activity and unintentional weight loss. Future research should determine whether there is a causal relation between added sugars and frailty. *Am J Clin Nutr* 2018;107:772–779.

INTRODUCTION

Evidence has accumulated indicating that consuming sugar-sweetened beverages contributes to worsening of cardiometabolic risk markers (1) and weight gain (2), and increases the risk of diabetes (3), coronary heart disease (4), and other chronic diseases (5, 6) that hinder healthy aging. The unhealthy effects of sugar sweetening beyond beverages have also been studied, and such studies have shown that the amount of added sugars in the whole diet is associated with cardiovascular mortality in US adults (7). Dietary sugars raise triglycerides, total cholesterol, LDL cholesterol, and HDL cholesterol concentrations, and blood pressure even within isocaloric replacement and in the absence of weight gain (8).

Many older people suffer a progressive loss of strength, agility, and mobility over time, which leads to disability. The frailty syndrome (9, 10), characterized by increased vulnerability to even minor stressors, forecasts this process and is associated with greater risk of falls, institutionalization, and death (11). Cardiovascular risk factors are associated with prevalent (12) and incident (13) frailty, which implies that either they are on the causal pathway to frailty or they share common lifestyle and socioeconomic causal factors (14). In particular, diet is well known to influence the risk of frailty and disability in older adults (15–22). However, the specific role of added sugars in this process has not been addressed.

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Supplemental Figure 1 is available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

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Thus, we hypothesized that higher amounts of added sugars in the diet are associated with the development of frailty in older people.

METHODS

Study design and participants

Data were taken from the Seniors-ENRICA cohort; the methods of the investigators have been reported elsewhere (23). In brief, the cohort was derived from the ENRICA study, a survey conducted in 2008–2010 among individuals representative of the noninstitutionalized adult population of Spain. The study participants, aged ≥60 y (n = 3289), were targeted to be followed up as the Seniors-ENRICA cohort. At baseline, information on sociodemographic variables, lifestyle, health status, and morbidity was collected via a telephone interview; details of food consumption were also obtained, and physical examination was performed by trained staff at the home of the participants. Another round of data collection was performed in 2012 to update the information of the cohort. In total, 675 participants were lost during follow-up and 95 deaths were identified. Among survivors (n = 2519), we excluded participants with dementia or Alzheimer disease at baseline (n = 9), with frailty at baseline (n = 52), with missing data on diet (n = 12), or with missing questionnaires or function tests (n = 473). Thus, the analytical sample comprised 1973 participants (**Supplemental Figure 1**). Informed written consent was obtained from all participants, and the study was approved by the Clinical Research Ethics Committee of La Paz University Hospital in Madrid.

Diet and added sugar

A validated (24) computer-based diet history was used to ascertain the participant's habitual consumption of 880 different foods. Taking into account weekly frequency of consumption of each food, this diet history provides an estimate in daily grams of foods that represents the average intake during the preceding year.

Carbohydrates present in the diet can be chemically classified as simple—also known as sugars (monosaccharides and disaccharides), which have a marked sweet taste—and complex, which have a higher degree of polymerization. Sugars are naturally present in fruits, vegetables, and milk, but they are also added to foods, primarily to sweeten them. Foods with sugars have higher glycemic indexes and produce stronger endocrine responses for glucose regulation than foods without them.

Standard food composition tables allowed calculation of the amount of sugars that each food contributed to the participants' diet. The amounts were summed for foods belonging to the following groups: table sugar, honey, and syrups; special breads; baked goods and cookies; pastries; breakfast cereals; flavored milks; whole yogurt and fermented milk; dairy desserts; sweetened cheeses; cooked and canned fruits and vegetables; jam and jelly; candy; chocolate; soft drinks; and fruits juices and nectars. All sugars in these food groups were deemed added sugars, which correspond to the concept of "free sugars" elaborated by WHO because they include sugars in fruit juices (25). The variable total sugars included sugars from all foods with sugars in their composition, irrespective of whether they were added or not. We considered the amount of sugars naturally appearing in food (also known as intrinsic sugars) to be the difference between total sugars and added sugars calculated as described above.

Frailty assessment

Frailty was defined as the presence of 3 of the following 5 Fried criteria (26): *1*) exhaustion, identified by an affirmative response to either of the 2 following statements from the Center for Epidemiologic Studies Depression Scale (27): "I feel that anything I do is a big effort" or "I feel that I cannot keep on doing things" ≥3–4 d/wk; *2*) low physical activity, identified when self-reported walking was ≤2.5 h/wk in men and ≤2 h/wk in women (28); *3*) slow gait speed, considered as the lowest cohort-specific quintile in a 2.44-m walking speed test, which was performed as part of the Short Physical Performance Battery, adjusted for sex and height (29); *4*) unintentional weight loss, when ≥4.5 kg of body weight was lost in the preceding year; and *5*) muscle weakness, when grip strength, measured with a Jamar dynamometer (highest of 2 consecutive measurements in the dominant hand) and adjusted for sex and BMI, was in the cohort-specific lowest quintile (30).

Other variables

At baseline, we collected data on age, sex, education, smoking status, measured weight and height, self-reported physician-diagnosed diseases, time spent watching TV, and leisure-time physical activity [with the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort questionnaire]. The Mediterranean Diet Adherence Score (MEDAS) was used to assess accordance with the Mediterranean dietary pattern (31). Because of the score overlap with intake of some sources of added sugar, we calculated a modified MEDAS that excluded sweetened drinks and pastries so that we could adjust for adherence to a healthy diet. The new score has a range 0–12, with higher values indicating closer adherence to the Mediterranean pattern. BMI was calculated as weight (in kilograms) divided by height squared (in meters).

Statistical analyses

Participants were classified in tertiles of the amount of added sugars in their diet. The cutoff values used for classification were 14.952 and 35.795 g/d; however, for the sake of readability, these are rounded up to 15 and 36 g/d in the text and tables. The intertertile ORs and 95% CIs were calculated by logistic regression, with the first tertile as the reference. Trend significance was calculated with the use of tertile ordinals. Regression models were built with 4 levels of adjustment: model 1 was adjusted for age, sex, and education; model 2 was additionally adjusted for smoking status, BMI, energy intake, and self-reported comorbidities (listed in **Table 1**); model 3 was further adjusted for the modified MEDAS; and model 4 was also adjusted for time spent watching TV and leisure-time physical activity. Models 3 and 4 were segregated to determine whether added sugars have an intrinsic effect or are indicators of an unhealthy diet (as captured by MEDAS) or unhealthy physical activity habits. Frail

TABLE 1
Characteristics of the study participants across tertiles of daily intake of added sugars[1]

	Overall	Added sugars, g: Tertile 1 <15	Tertile 2 ≥15 and <36	Tertile 3 ≥36	*P*-trend
n	1973	659	656	658	
Men	49.0 [966]	48.0 [316]	47.3 [310]	51.7 [340]	0.177
Age, y	68.5 ± 6.3	68.8 ± 6.3	68.7 ± 6.4	68.1 ± 6.3	0.048
Education					
Primary or less	52.8 [1041]	52.5 [346]	53.2 [349]	52.6 [346]	0.977
Secondary	25.0 [494]	23.7 [156]	26.5 [174]	24.9 [164]	0.600
University	22.2 [438]	23.8 [157]	20.3 [133]	22.5 [148]	0.561
BMI, kg/m^2	28.4 ± 4.3	28.6 ± 4.5	28.3 ± 4.4	28.3 ± 3.9	0.132
Energy intake, kcal/d	2037.8 ± 570.3	1814.1 ± 541.1	2005.0 ± 493.7	2294.5 ± 568.1	<0.001
Time spent watching TV, h/wk	17.7 ± 10.9	17.8 ± 11.0	17.8 ± 10.4	17.5 ± 11.1	0.594
Leisure-time physical activity, MET-h/wk	22.0 ± 15.3	22.5 ± 15.4	22.3 ± 15.8	21.4 ± 14.6	0.176
Modified MEDAS	5.7 ± 1.6	6.0 ± 1.6	5.8 ± 1.6	5.3 ± 1.7	<0.001
Smoking status					
Current smoker	11.4 [225]	11.4 [75]	11.0 [72]	11.9 [78]	0.787
Former smoker	30.9 [610]	32.8 [216]	27.1 [178]	32.8 [216]	0.985
Never smoker	57.7 [1138]	55.8 [368]	61.9 [406]	55.3 [364]	0.849
Comorbidities					
Diabetes mellitus	15.0 [295]	22.5 [148]	11.6 [76]	10.8 [71]	<0.001
Bronchitis or asthma	7.1 [140]	8.2 [54]	5.8 [38]	7.3 [48]	0.525
Cardiovascular disease	5.0 [99]	6.1 [40]	4.0 [26]	5.0 [33]	0.381
Osteo-muscular disease	47.0 [928]	49.3 [325]	47.0 [308]	44.8 [295]	0.103
Depression	7.3 [145]	6.5 [43]	7.6 [50]	7.9 [52]	0.338
Cancer	1.8 [36]	2.0 [13]	1.2 [8]	2.3 [15]	0.678

[1]Data are shown as % [*n*] or mean ± SD. *P*-trend values were calculated from linear and logistic regressions using the tertile ordinal as the predictor variable. MET, metabolic equivalent; modified MEDAS, MEditerranean Diet Adherence Score excluding sweetened drinks and pastries.

participants at baseline were excluded from the analytic sample and only robust participants at baseline were considered for the specific analysis estimating the association between added sugars and incidence of each frailty trait. In order to understand better whether the association is with the whole syndrome or with a particular trait, sensitivity analyses were performed with modified definitions of frailty requiring 3 criteria, but excluding those frailty criteria that show more intense association with added sugars.

Subanalyses were performed by the same methods, with the predictors being the amounts of added sugars from particular food groups: table sugar, honey, and syrups; foods with sugars added during food production (all other foods containing non-naturally present sugars); pastries and cookies; and sweetened beverages. In these cases, we compared participants that did not consume these foods with those consuming above the median amount among those that consumed. We also analyzed tertiles of sugars naturally appearing in foods. Lastly, we performed a stratified analysis by diabetes and by BMI (nonobese compared to obese), and also interaction models for these variables. Regression analyses were performed on R version 3.0.2.

RESULTS

Among the 1973 participants (mean age 68.5 y, 49.0% men), higher added sugars intake at baseline was associated with lower age, higher energy intake, lower adherence to the Mediterranean diet, and lower frequency of diabetes (Table 1). During follow-up, 140 individuals developed frailty (**Table 2**).

In adjusted analyses (model 2), those participants consuming ≥36 g added sugars/d (highest tertile) showed significantly increased odds for frailty (OR: 2.48; 95% CI: 1.49, 4.19) when compared with those consuming <15 g/d (lowest tertile). After additionally adjusting for adherence to the Mediterranean diet and for physical activity (model 4), the OR decreased, but only by a small amount, to 2.27 (95% CI: 1.34, 3.90). Interestingly, the latter additional adjustment for physical activity (model 4) did not materially change the estimates compared with the previous adjustment for MEDAS (model 3). Lastly, there was a statistically significant dose-response trend (Table 2). The specific frailty components that were associated with added sugars consumption in the fully adjusted model (model 4) were low physical activity (OR: 1.50; 95% CI: 1.00, 2.26) and unintentional weight loss (OR: 1.93; 95% CI: 1.10, 3.49), which were also associated with a statistically significant dose-response trend (Table 2). The association between added sugars and frailty was robust to criteria used to define the latter, as excluding either or both of the 2 aforementioned criteria from the frailty definition did not substantially change the association magnitude or its statistical significance (data not shown).

Among this cohort of older people, one-third of added sugars was in the form of table sugar (or honey or syrups). The remaining two-thirds were sugars added during food processing, including pastries and cookies (15% of the total) and sugar-sweetened

TABLE 2
ORs (95% CIs) for the association of daily intake of added sugars with frailty and its components[1]

	Added sugars, g			
	Tertile 1 <15	Tertile 2 ≥15 and <36	Tertile 3 ≥36	*P*-trend
Frailty, *n*/*N*	34/659	54/656	52/658	140/1973
Model 1	1.00 (Ref)	1.64 (1.04, 2.61)	1.75 (1.11, 2.81)	0.019
Model 2	1.00 (Ref)	2.19 (1.35, 3.60)	2.48 (1.49, 4.19)	0.001
Model 3	1.00 (Ref)	2.12 (1.30, 3.49)	2.29 (1.37, 3.90)	0.002
Model 4	1.00 (Ref)	2.10 (1.28, 3.50)	2.27 (1.34, 3.90)	0.003
Exhaustion, *n*/*N*	47/529	51/535	44/535	142/1599
Model 2	1.00 (Ref)	1.11 (0.72, 1.73)	1.07 (0.66, 1.73)	0.770
Model 4	1.00 (Ref)	1.10 (0.71, 1.71)	1.04 (0.64, 1.70)	0.863
Low levels of activity, *n*/*N*	58/529	69/535	93/535	220/1599
Model 2	1.00 (Ref)	1.12 (0.77, 1.64)	1.54 (1.05, 2.27)	0.026
Model 4	1.00 (Ref)	1.13 (0.76, 1.68)	1.50 (1.00, 2.26)	0.047
Slowness while walking, *n*/*N*	65/529	63/535	75/535	203/1599
Model 2	1.00 (Ref)	1.01 (0.69, 1.49)	1.30 (0.87, 1.94)	0.195
Model 4	1.00 (Ref)	0.97 (0.66, 1.43)	1.10 (0.73, 1.66)	0.665
Unintentional weight loss, *n*/*N*	24/529	36/535	50/535	110/1599
Model 2	1.00 (Ref)	1.57 (0.91, 2.75)	2.10 (1.21, 3.71)	0.009
Model 4	1.00 (Ref)	1.54 (0.89, 2.70)	1.93 (1.10, 3.46)	0.024
Muscle weakness, *n*/*N*	166/529	167/535	143/535	476/1599
Model 2	1.00 (Ref)	1.14 (0.85, 1.52)	1.05 (0.76, 1.43)	0.763
Model 4	1.00 (Ref)	1.12 (0.83, 1.49)	1.00 (0.72, 1.38)	0.987

[1]ORs and 95% CI were estimated with logistic regression models with different levels of adjustment. For frailty, participants without it were considered at risk; for frailty components, only robust participants were considered at risk. *P*-trend was calculated with the tertile ordinal as a continuous variable. *n*/*N*, number of cases/number at risk. Model 1 was adjusted for age, sex, and education; model 2 was additionally adjusted for smoking status, BMI, energy intake, and comorbidities; model 3 was further adjusted for MEDAS (excluding sweetened drinks and pastries); model 4 was also adjusted for time spent watching TV and leisure-time physical activity. MEDAS, MEditerranean Diet Adherence Score; Ref, reference.

beverages (6%). When considering specific sources of added sugars, those coming from foods that add sugars during food production (any food with added sugars except the table sugar group) showed the strongest association, although most of these specific-source analyses did not reach statistical significance (**Figure 1**). Increased intake of added sugars seems to be associated with frailty more strongly among obese participants (Figure 1).

Interestingly, the intake of sugars naturally appearing in foods was not statistically associated with worse outcomes. On the contrary, intake of such sugars showed a statistically significant protective association with frailty (OR: 0.53; 95% CI: 0.32, 0.88). However, when adherence to the Mediterranean diet was taken into account, the statistical significance was lost, although the OR was still in the protective direction (OR: 0.66; 95% CI: 0.38, 1.13) (**Table 3**).

When tertiles of grams of foods containing added sugars were analyzed, we found deleterious associations for frailty of similar scale to those found when considering only the grams of sugars contributed by those foods (Table 3).

DISCUSSION

After 3 y of follow-up, in this cohort of community-dwelling older people from Spain, a higher amount of added sugars consumed in the diet was associated with increased risk of frailty. This association was only partially explained by the co-occurrence of worse adherence to the Mediterranean diet and lower physical activity. Among the foods with added sugars, those with sugars added during production were more closely associated with frailty. Interestingly, the association could be

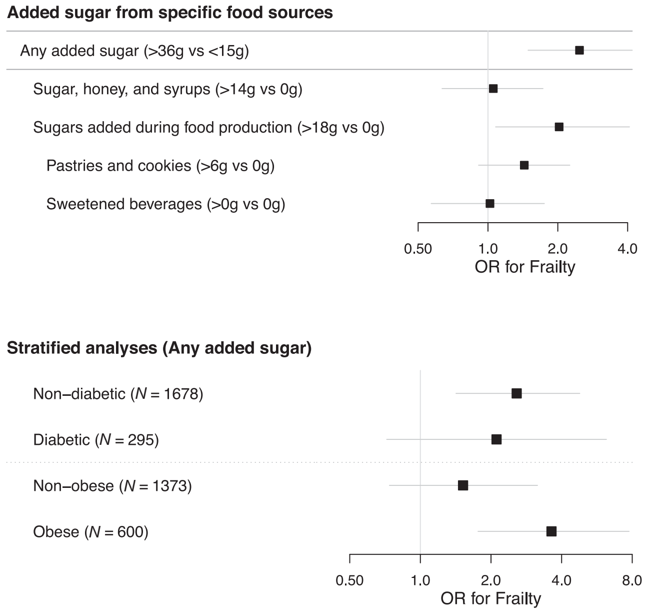

FIGURE 1 ORs for frailty of participants in the highest compared with the lowest consumption group of added sugars from specific food sources and for participants in the highest compared with the lowest added sugars consumption group stratified by diabetes and by BMI. Models were adjusted for age, sex, education, smoking status, BMI, energy intake, and comorbidities, except diabetes in the stratified analyses. The lines depict the 95% CIs. An interaction model for obesity showed that the association differed with statistical significance between obese and nonobese participants ($P = 0.028$).

asserted by simply considering the amount of food containing added sugars consumed and disregarding the contribution of their particular sugars. In contrast, this adverse association was not seen for sugars naturally present in foods. Although some frailty components were more strongly associated with added sugars than others, the association with the frailty syndrome was robust even when excluding them from its definition, reinforcing that our findings apply to frailty, rather than only to particular traits thereof.

To our knowledge, this is the first attempt to study specifically the association between added sugars in the diet and frailty among older people. We previously reported that total carbohydrates or total sugars in the diet were not associated with incident frailty (32). In the current study, we observed that naturally present sugars tended to be associated in a protective way with frailty, whereas added sugars were associated with increased risk, which may explain the null net association between total sugars present in the diet and frailty.

The effect of carbohydrates on physical function has received limited attention and research has focused only within the context of particular diseases: among older diabetic patients, exposure to higher glycemic levels, as ascertained with glycosylated hemoglobin, was associated with worse physical function measured through the Short Physical Performance Battery, although it was mostly explained by diabetes mellitus comorbidities (33). Besides physical function, most other studies on carbohydrates have focused on cognitive decline (34); for instance, Hosking et al. (35) showed that a dietary pattern that included a high sugar intake predicted a decline in several cognitive parameters.

The mechanisms of an adverse health effect of sugar-sweetened beverages, and by extension of added sugars in the diet, include increased energy intake, which is followed by a greater BMI. It is hypothesized that sugars in liquids do not suppress solid food intake enough to maintain an energy balance (36), although this insufficient inhibition could also occur for any high intake of sugars, regardless of whether they are ingested in liquid or solid form, or could be attributed to the different endocrine response to fructose (37). Fructose is one of the components of sucrose, the most common sugar consumed. Because fructose is sweeter than glucose or sucrose, the latter is usually partially broken down into its components, and is used in food preparation in the forms of inverted sugar or high-fructose corn syrup. Weight gain does not explain all the effects

TABLE 3
Additional analyses: ORs (95% CIs) for the association with frailty of daily intake of sugars naturally appearing in foods and of daily intake of foods (total amount) classified as having added sugars[1]

	Naturally appearing sugars, g				Food containing added sugars, g			
	Tertile 1 [lowest, 51.62]	Tertile 2 [51.65, 68.13]	Tertile 3 [68.14, highest]	*P*-trend	Tertile 1 [0, 46.4]	Tertile 2 [46.5, 146.9]	Tertile 3 [147.0, highest]	*P*-trend
Frailty, *n*/*N*	58/658	54/657	28/658	140/1973	32/658	47/657	61/658	140/1973
Model 1	1.00	1.01	0.54	0.016	1.00	1.59	2.07	0.002
	(Ref)	(0.67, 1.52)	(0.33, 0.86)		(Ref)	(0.99, 2.59)	(1.31, 3.31)	
Model 2	1.00	1.02	0.53	0.021	1.00	1.71	2.36	0.001
	(Ref)	(0.66, 1.56)	(0.32, 0.88)		(Ref)	(1.04, 2.83)	(1.45, 3.91)	
Model 3	1.00	1.07	0.63	0.128	1.00	1.69	2.18	0.003
	(Ref)	(0.69, 1.66)	(0.36, 1.06)		(Ref)	(1.03, 2.80)	(1.32, 3.63)	
Model 4	1.00	1.10	0.66	0.180	1.00	1.70	2.19	0.003
	(Ref)	(0.70, 1.71)	(0.38, 1.13)		(Ref)	(1.02, 2.84)	(1.32, 3.69)	

[1]Naturally appearing sugars were calculated as the difference between total sugars and added sugars. Food containing added sugars summed the grams of foods belonging to the food groups specified in the Methods section as containing added sugars. ORs and 95% CIs were estimated with logistic regression models with different levels of adjustment. *P*-trend was calculated with the tertile ordinal as a continuous variable. *n*/*N*, number of cases/number at risk. Model 1 was adjusted for age, sex, and education; model 2 was additionally adjusted for smoking status, BMI, energy intake, and comorbidities; model 3 was further adjusted for MEDAS (excluding sweetened drinks and pastries); model 4 was also adjusted for time spent watching TV and leisure-time physical activity. MEDAS, MEditerranean Diet Adherence Score, Ref, reference.

associated with added sugars; in fact, fructose is metabolized differently in the liver than glucose, promoting hepatic lipid synthesis and increasing postprandial circulating triglycerides (37) and atherosclerotic lipids (38). Other effects attributed to fructose are increased uric acid levels (39) and hepatic ATP depletion (40). Sugars have a high glycemic index, which can stress and degrade the insulin axis for glucose control. All these mechanisms have been proposed to link sugar-sweetened beverages consumed in large quantities with increased obesity, diabetes mellitus, cardiovascular risk factors, coronary heart disease, other chronic diseases, and cardiovascular mortality.

It is possible that some of these mechanisms could contribute to the physical decline associated with added sugars intake, including the increase in frailty, whose mechanisms are still being elicited. Sarcopenia, which includes a loss of muscle mass and weakness, is one of the mechanisms associated with frailty. In addition, insulin resistance and low-grade inflammation, favored by added sugars intake, impair muscle glucose handling and intracellular energy production, and reduce protein synthesis, disbalancing muscles towards a proteolytic state and thus compromising efficient muscle contraction (41, 42). Insulin resistance may also produce macro- and microvascular complications and promotes cognitive impairment in the elderly, mechanisms which also contribute to frailty (43, 44). With respect to obesity, our estimates were adjusted for baseline BMI and total energy intake, and one of the frailty components associated with added sugars intake was unintentional weight loss, so there must be some other mechanism or mechanisms that go beyond weight differences associated with diet. Higher carbohydrate intake and, in particular, higher added sugars intake are associated with worse diet quality (45). Older people may find it difficult to include enough proteins in their diet to prevent sarcopenia while maintaining a caloric content that is low enough to match the reduced energy requirement in old age. Diets with added sugars may thus draw them further away from this goal. Also, micronutrient dilution has been reported to occur among older people with diets high in added sugars (46, 47). Micronutrient deficiencies are related to functional decline in older people (48), vitamin D deficiency (49) and lower antioxidant vitamins C and E (50) are associated with frailty, and lower vitamin B is associated with impaired mobility (51), all of which point towards another possible explanation for the association that we describe.

Higher consumption of foods with added sugars could be a marker of poor lifestyle and dietary patterns, which are associated with physical decline and frailty (16, 17). We observed that the association is not with the quantity of sugars consumed per se, but with the quantity of sugars consumed from foods that we assumed to have sugars as an addition. Furthermore, the amount of those foods consumed was associated with frailty. Our results were adjusted for a modified MEDAS and remained practically unchanged, indicating that in the case that the association is due to a potential harmful dietary pattern, that pattern is not a lack of adherence to a Mediterranean diet. Because the association with table sugar was not the same as that with sugars added during food production, we conjecture that a dietary pattern with predominantly processed foods might be the underlying problem captured by the added sugars variable. Based on this evidence, targeting an improvement in diet healthiness might be more beneficial than focusing exclusively on sugars (52).

This study's strengths include a prospective design, a detailed measurement of food consumption with a validated diet history, and a relatively large sample size. Trained staff within a retraining schedule collected both exposure and outcome data with high precision, and nutrient intake is based on Spanish tables of food composition. However, there are some limitations as well. We assumed that all the sugars in the composition of foods that have added sugars were from the external addition. There are no means for discriminating between the amount of sugars naturally present and those that were added. This lack of discrimination can only dilute the effect and make the observable association weaker; nonetheless, we still found relatively strong associations. In our analyses, we adjusted for the main confounders; however, we cannot rule out some residual confounding. Finally, given that the mean age of the participants at baseline was 68.5 y, caution should be applied in trying to extrapolate these results to the very old. Those excluded for the absence of clinical or functional variables ate the same amount of added sugars, although they were more likely to be women with a lower level of education, less energy intake, who watched TV for longer and had a higher prevalence of osteomuscular disease. This might decrease the generalizability but, because the absence of data was not associated with the exposure variable but only with the adjustment variables, it is likely to have only a minor effect on internal validity.

The amount of added sugars present in the diet of older people was associated with the risk of frailty. The frailty components that were most closely associated with added sugars were low level of physical activity and unintentional weight loss. This was not explained by a lack of adherence to the Mediterranean diet or by worse physical activity habits, but it could be related to dietary patterns that include higher amounts of processed foods.

The authors' responsibilities were as follows—ML and EL-G: performed the statistical analyses; ML, FR-A, and EL-G: drafted the manuscript; EL-G and FR-A: supervised the conduct of research; ML: had primary responsibility for the final content; and all authors: designed the research, contributed to the interpretation of the results, reviewed the manuscript for important intellectual content, and read and approved the final manuscript. None of the authors have any conflicts of interest related to this study.

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