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Adherence to Mediterranean diet is inversely associated with the consumption of ultra-processed foods among Spanish children: the SENDO project

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Abstract

Objective: To assess whether higher adherence to the traditional Mediterranean diet (MedDiet) was associated with lower consumption of ultra-processed foods (UPF) and lower free sugar intake.

Design: Cross-sectional analysis of baseline information among participants in the SENDO project, a Spanish paediatric cohort. Dietary information was collected through a semi-quantitative FFQ. Food items were classified according to the NOVA classification. Adherence to the MedDiet was evaluated through the KIDMED index.

Setting: Spain.

Participants: Three hundred eight-six children (52 % boys) with a mean age of 5·3 years old (SD 1·0) were included in the analysis.

Results: 74·4 % of the children had moderate adherence to the MedDiet (mean KIDMED score: 5·9 points; SD 1·7) and overall, 32·2 % of the total energy intake came from UPF. Each two additional points in the KIDMED score was associated with 3·1 % (95 % CI 2·1, 4·0) lower energy intake from UPF. Compared to those with low adherence to the MedDiet, children with medium and high adherence reported 5·0 % (95 % CI 2·2, 7·7) and 8·5 % (95 % CI 5·2, 11·9) lower energy intake from UPF, respectively. We also found that 71·6 % of the variability in free sugar intake was explained by the variability in UPF consumption.

Conclusions: Adherence to the traditional MedDiet was inversely associated with energy intake from UPF. Furthermore, most of the variability in free sugar intake was explained by the variability of UPF consumption. Public health strategies are needed to strengthen the adherence to the MedDiet in pre-schoolers while regulating the production, marketing and advertising of UPF.

Keywords
Mediterranean diet
Food processing
Ultra-processed foods
Free sugar

The Mediterranean diet (MedDiet) is a traditional dietary pattern based on a high consumption of plant-based foods (vegetables, fruits, nuts, legumes and minimally processed cereals); low consumption of meat and meat products; moderate-to-high consumption of fish and low consumption of dairy products (with the exception of yogurt and the long-preservable cheeses). The total fat intake may be high, but the ratio of the beneficial monounsaturated to the non-beneficial saturated lipids is high as well. This is due to the high monounsaturated content of liberally consumed olive oil, which represents a hallmark of the MedDiet as the main culinary fat(1).

The cultural heritage aspect of the (MedDiet) was officially recognised by UNESCO in 2010(2,3). However, in

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many Mediterranean countries the MedDiet is gradually being replaced by western dietary patterns, which are primarily based on animal products and ultra-processed foods (UPF), resulting in high intakes of refined carbohydrates, added sugar, saturated fats and Na[4]. Spain is one of those Mediterranean countries. Over the last two decades, the dietary pattern of Spanish children has shifted drastically, with an alarming substitution of fresh foods with UPF like snacks, sugar-sweetened beverages and ready-to-eat meals[5].

The transition from a traditional to a Western dietary pattern has been promoted by the sociocultural changes that accompanied industrialisation, which, together with the globalisation of food production, resulted in shared food behaviours worldwide[6]. Far from meeting the world's dietary needs, global food systems are determining the world's dietary pattern, with three-quarters of total sales coming from UPF in the food market worldwide[7].

UPF are formulations of ingredients, which are created from extracted isolated substances derived or not from food constituents and added additives whose function is to make the food product palatable or often hyper-palatable[8,9]. These substances are primarily used for exclusive industrial purposes and their production involves several industrial processes among different industries[9]. UPF also contain a wide variety of flavouring and colouring agents in order to imitate, intensify or improve the sensory qualities of the final product. Therefore, UPF are generally rich in free sugar, oils, fats, salt, synthetic antioxidants, stabilisers and chemical additives[8,9]. Previous studies have reported that higher consumption of UPF was associated with lower intakes of polyunsaturated fats, vitamins A, B_{12}, C and E, Ca, Zn and fibre, and higher intakes of Na, free sugar and trans fats[10–16].

Recent studies among Spanish populations found that 31·7 % of the daily energy household availability came from UPF[5] and a higher consumption of UPF was associated with a greater risk of overweight and obesity[17], hypertension[18] and all-cause mortality[19,20]. Within this context, we hypothesised that higher adherence to the MedDiet may lead to lower consumption of UPF. Therefore, the main objective of this study was to assess whether higher adherence to the traditional MedDiet was associated with lower consumption of UPF in Spanish pre-schoolers. As a secondary objective, we aimed at quantifying the reduction in free sugar intake associated with higher adherence to the traditional MedDiet.

Methods

Selection of participants

The SENDO project (Seguimiento del Niño para un Desarrollo Óptimo) is a prospective and dynamic paediatric cohort of Spanish children focused on assessing the impact of children's diet and lifestyle on their health during childhood and adolescence. This project started in 2015 as an initiative of the Department of Preventive Medicine and Public Health of the University of Navarra and the Public Health Service of Navarra. The recruitment in this cohort is permanently open. The inclusion criteria are: (1) age: 4 to less than 6 years old and (2) residence: Spain. The only exclusion criterion is inaccessibility to internet. All of the participants' parents signed an informed consent at recruitment. Sociodemographic, dietary and lifestyle information is gathered at baseline and updated every year through online questionnaires. Further information on this cohort study design has previously been reported in detail elsewhere[21].

Of the 485 children eligible for the analyses, 91 (18·7 %) were excluded due to missing data on dietary information and 8 (2·0 %) more due to reported energy intakes out of the predefined limits (below percentile 1 or above percentile 99). Thus, the final sample consisted of 386 participants with complete information.

Data collection

The participants' parents completed a self-administered online questionnaire on sociodemographic, lifestyle and dietary habits at baseline. For this study, we used information on participant's sex (male or female), age (quantitative), breast-feeding history (yes or no) and physical activity (quintiles of Metabolic Equivalent of Task (MET)-h/week). Physical activity was collected with a questionnaire that included fourteen activities and ten response categories, from never to eleven or more hours per week. MET-h/week for each activity were calculated by multiplying the number of MET of each activity[22] by the weekly frequency of participation in that activity, weighted according to the number of months dedicated to it. Total physical activity was quantified by summing the MET-h/week dedicated to all activities performed during leisure time. Regarding parental data, we used information on maternal age (quantitative), family history of obesity (yes or no) and parent's maximum education level (high school or lower, university graduate or university master/doctorate).

Dietary information was collected through a semi-quantitative FFQ which included 149 food items. For each food item, a portion size was specified. Parents reported how often their child had consumed each of the food items over the previous year by choosing one out of nine frequencies of consumption ranging from 'never or almost never' to '6 or more times per day'. Nutrient content of each food item was calculated by a team of specialised dietitians by multiplying the frequency of consumption, by the edible portion and the nutrient composition of the specified portion size, using data from updated Spanish food composition tables[23] and online databases. We considered free sugar as those added to foods and beverages by the industrial processing industrial or homemade preparation and those naturally present in honey, syrups and fruit juices[24].

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Box 1 Classification of foods in the SENDO food frequency questionnaire according to the degree of processing by NOVA

Unprocessed or minimally processed foods
- Apple, asparagus, eggplant, avocado, banana, beans, cabbage, carrot, chard, cherry, chicken, clam, curd, eggs, fig, fish, fruit juice, fruit smoothie, garbanzo beans, grapes, kiwi fruit, lamb, leek, lentils, lettuce, mango, meatball, melon, milk (skimmed or whole), nuts, octopus, onion, orange, pasta, peas, peach, pear, pepper, pineapple, plum, pork, potatoes, seafood, pumpkin, rabbit meat, rice, strawberry, string beans, tangerine, tomato, veal, viscera, watermelon

Processed culinary ingredients
- Sunflower oil, olive oil, sugar, butter, cream, salt.

Processed foods
- Olives, compote of fruit, cured ham, canned fish, jam, baguette, wholemeal bread, white cheese, cured cheese, bacon

Ultra-processed food and drink products
- Bakery products, blood sausage, bonbon, breakfast cereals, cake, candies, carbonated beverages, cereal bar, chocolate bar, chocolate powder, cookies, crab sticks, cream cheese, cream chocolate, croquet*, cruller or 'churro'*, custard*, dry soup, fish sticks, gelatine, ham, hamburger, ice cream, industrialised juices (sugar-sweetened juices), industrialised sliced cheese, industrialised sliced bread, ketchup, lasagne*, margarine, mayonnaise*, muffin*, nougat, nugget, pâté, petit suisse, pie*, pizza*, popcorn*, salami, sausage, pepperoni, snacks, soda, soft drinks, sweetened beverages, sweetened fermented milk, sweetened yogurt (skimmed or whole)

*There are foods that could have different ratings depending on the way they are prepared: homemade or industrialised. In these cases, we chose to classify them as ultra-processed foods because most traditional foods have been replaced by industrial food products in supermarkets

Box 2 KIDMED index to assess adherence to Mediterranean diet in children and adolescents scoring

Item 1	+1	Takes a fruit or fruit juice every day
Item 2	+1	Has a second fruit every day
Item 3	+1	Has fresh or cooked vegetables regularly once a day
Item 4	+1	Has fresh or cooked vegetables more than once a day
Item 5	+1	Consumes fish regularly (at least 2–3 times per week)
Item 6	–1	Goes more than 1 time per week to a fast food restaurant
Item 7	+1	Likes pulses and eats them more than once per week
Item 8	+1	Consumes pasta or rice almost every day (5 or more times per week)
Item 9	+1	Has cereals or grains (bread, etc.) for breakfast
Item 10	+1	Consumes nuts regularly (at least 2–3 times per week)
Item 11	+1	Uses olive oil at home
Item 12	–1	Skips breakfast
Item 13	+1	Has a dairy product for breakfast (yogurt, milk, etc.)
Item 14	–1	Has commercially baked goods or pastries for breakfast
Item 15	+1	Takes two yogurts and/or some cheese (40 g) every day
Item 16	–1	Takes sweets and candy several times per day

All food items were classified by their type of processing according to the NOVA classification (Box 1). Food processing, as identified by NOVA, involves physical, biological and chemical processes that occur after foods are separated from nature, and before they are acquired and submitted to culinary preparation or directly consumed as such[25]. The first group includes unprocessed or minimally processed foods (MPF): no processing or mostly physical processes used to make single whole foods more durable, accessible, convenient, palatable or safe. The second group contains processed culinary ingredients: refined substances obtained by extraction and purification of foods or other natural resources that are used, in combination with foods in group 1, in the preparation of meals in households or traditional restaurants. The third group comprises processed foods: relatively simple products made by adding sugar, oil, salt or other ingredients in group 2 to foods in group 1. Processing includes several preservations, cooking or fermentation methods. And the fourth group comprises UPF and drink products: typically industrial formulations made by adding sugar, oils, fats, salt, synthetic antioxidants and stabilisers to foods in group 1, which represent only a small proportion of the final product[9,25]. UPF are made from isolated substances, derived or not from foods constituents, which are primarily for exclusive industrial use and several chemical additives, resulting in a product with no (or almost no) identifiable intact food within it. Examples include sugar-sweetened beverages, fast food products (sausages, burgers), cookies, candy sweet or savoury packaged snacks, and sugared milk and fruit drinks[9].

Total energy intake (TEI) was obtained summing the energy content of each food item. To calculate the percentage of energy from each group of the NOVA classification, we divided the energy content of each group by TEI.

Adherence to the MedDiet was calculated with the KIDMED index (Box 2), a previously validated index[26] that assesses the adherence to the MedDiet by children and adolescents. The KIDMED consists of sixteen questions: negative connotations regarding MedDiet (items 6, 12, 14 and 16) were assigned a score of –1 and those with positive connotations (the rest of the items) scored +1. The score of the KIDMED index ranges from –4 to +12 points. According to their score, participants were classified as having low (≤3 points), medium (4–7 points) or high (≥8 points) adherence to the Mediterranean dietary pattern[26]. The KIDMED index in general and that classification, in particular, were consistently reported to be good predictors of diet quality[27,28], body composition[29,30] and health-related outcomes[31,32] in children and adolescent.

Information about physical activity was reported by the participants' parents at baseline. It was gathered using a validated questionnaire which consisted of fourteen activities, including sports and games, and nine response categories from 'never' to 'more than 11 hours per week'[22].

Statistical analysis

We described participants' main characteristics by sex. The results are presented as frequency (percentages) for categorical variables, and means and SD for continuous variables. χ^2 tests or Student's t tests were used to assess the statistical significance of the differences of proportions and means, respectively.

Linear trend tests by adherence to MedDiet were calculated to analyse the contribution of each food item and each group (according to NOVA classification) to TEI.

Generalised estimating equations with Gaussian distribution were used to evaluate the association between adherence to the MedDiet (as a continuous variable and categorised in three levels) and the energy intake from UPF (continuous), while accounting for intra-cluster correlation between siblings. We calculated crude and multivariable adjusted differences (95 % CI) in the percentage of energy intake from UPF associated with (1) two additional points in the KIDMED score and (2) medium and high adherence compared with low adherence to the MedDiet. The multivariable adjusted model was controlled for sex (male or female), participant's age (continuous), total dietary energy intake (quintiles), physical activity (quintiles of MET-h/week), breastfeeding (yes or no), maternal age (continuous), family history of obesity (yes or no) and parents' maximum education level (high school or lower, university graduate or university/doctorate). To assess the robustness of our findings, we repeated the analyses moving the food item 'yogurts' from the MPF group to the UPF group, considering most yogurt consumed by children is sweetened and artificially flavoured, which changes its classification according to NOVA.

Additional analyses were performed to further describe the importance of classifying yogurts as an UPF, considering their Ca and free sugar content. We assessed the correlation between Ca (mg/d) from UPF and the percentage of total energy from (1) energy from total free sugar and (2) free sugar from UPF. We also calculated the contribution of all foods to the variability in free sugar and Ca intakes using stepwise regression analyses.

In sensitivity analyses, we considered other potentially controversial items of the KIDMED index such as number 9, 13 and 15 (Box 2). We calculated the percentage of UPF included in those items and corrected the original score of each participant taking into account that percentage. Therefore, the higher the proportion of MPF or processed foods, the lower the modification of the original score. On the other hand, when the proportion of UPF included in those items of the KIDMED index was high, the original score of each participant was more severely penalised.

We considered P values lower than 0·05 to be statistically significant. Analyses were performed using STATA version 12.0 (StataCorp).

Results

We included in our analyses 386 participants, 52·0 % boys, with mean age 5·3 (SD 1·0) years old. Table 1 shows participants' main characteristics overall and by sex. Girls showed higher BMI z-score (0·2 (SD 1·1)) and lower physical activity (32·7 (SD 21·0)) than boys (–0·1 (SD 1·0) and 46·6 (SD 32·8), respectively). Although most participants had a normal weight status, we observed significant differences by sex, with a higher percentage of girls being overweight or obese (18·5 *v.* 9·7 %). Most participants (74·4 %) reported moderate adherence to the MedDiet (KIDMED: 4–7 points). Mean energy intake was 2216 (SD 489·6) [9272 kJ/d (SD 2048)] and mean percentages of energy from unprocessed food or MPF, processed culinary ingredients, processed foods and UPF were 47·5, 10·3, 10·0 and 32·2 %, respectively. Between-sex differences were neither observed for adherence to the MedDiet, TEI, nor the percentage of energy from food groups by NOVA classification.

The contribution of each food item and each food group to the TEI (%TEI), overall and by level of adherence to the MedDiet, is shown in Table 2. Higher adherence to the MedDiet was associated with higher energy intake from unprocessed food or MPF ($P < 0·01$) and lower energy intake from UPF ($P < 0·001$). Participants in the highest category of the KIDMED score reported higher consumption of fruit, yogurt, vegetable, rice, nuts, fruit juices, processed cheese and cured ham but a lower consumption of ultra-processed meat, chocolate, ready-to-eat meals, snacks and candies.

We found a significant inverse association between adherence to the MedDiet and the percentage of energy from UPF (Table 3). Two additional points in the KIDMED score were associated with a 2·8 % (95 % CI 1·9, 3·7) lower contribution of UPF to the TEI in the crude model. The difference was even higher after adjusting for potential confounders (difference 3·1 % (95 % CI 2·1, 4·0)). Furthermore, compared with children in the lowest category of adherence to the MedDiet, those in the highest category showed 6·6 % (95 % CI 3·2, 10·0) lower contribution of UPF to the TEI in the crude model and 8·5 % (95 % CI 5·2, 11·9) in the multivariable adjusted model. A significant linear trend was observed for the contribution of UPF to the TEI across the categories of adherence to the MedDiet ($P < 0·0001$). Similar results were found when yogurt was moved from the group of unprocessed food or MPF to the group of UPF.

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Table 1 Baseline main characteristics of the 386 participants in the SENDO project 2015–2018†

	Total (*n* 386)		Boys (*n* 200)		Girls (*n* 186)	
Variable	Mean	SD	Mean	SD	Mean	SD
Children's characteristics						
Age (years)	5·3	1·0	5·2	0·9	5·4	1·0
BMI (kg/m^2)*	15·7	1·6	15·5	1·4	15·9	1·8
z-Score BMI**	0·1	1·0	–0·1	1·0	0·2	1·1
Waist/Height ratio	0·5	0·1	0·5	0·1	0·5	0·0
Physical activity (MET-h/week)***	40·0	28·6	46·6	32·8	32·7	21·0
Nutritional status**						
Thinness	55	14·3	37	18·5	18	9·7
Normal	282	72·0	148	74·0	134	72·0
Overweight or obesity	49	12·7	15	7·5	34	18·3
Adherence to KIDMED						
Low						
n	31		18		13	
%	8·0		9·0		7·0	
Moderate						
n	287		143		144	
%	74·4		71·5		77·4	
High						
n	68		39		29	
%	17·6		19·5		15·6	
Processing food (kcal‡/%TEI)						
Energy intake	2216·0	100·0	2224·2	100·0	2207·0	100·0
Unprocessed or minimally processed foods	1044·6	47·5	1047·5	47·50	1041·5	47·6
Processed culinary ingredients	229·5	10·3	222·6	10·0	237·0	10·6
Processed foods	221·5	10·0	227·1	10·3	215·50	9·7
Ultra-processed food and drink products	720·2	32·2	727·0	32·3	713·0	32·0
Parents' characteristics						
Mother						
Age (years)	40·0	0·2	39·8	0·3	40·2	0·2
Level of studies*						
≤High school						
n	70		43		27	
%	18·2		21·5		14·6	
College						
n	221		118		103	
%	57·4		59·0		55·7	
Master or doctorate						
n	94		39		55	
%	24·4		19·5		29·7	
Father						
Age (years)	40·0	0·3	40·0	0·4	40	0·4
Level of studies						
≤High school						
n	135		68		67	
%	35·0		34·0		36·2	
College						
n	173		93		80	
%	45·0		46·5		43·2	
Master or doctorate						
n	77		39		38	
%	20·0		19·5		20·5	
Family obesity						
Yes	69	18·0	33	16·7	36	19·7
No	312	82·0	165	83·3	147	80·3

†*P*-values were obtained with Student's *t*-test for quantitative variables and χ^2 test for qualitative variables.
‡To convert energy values from kcal to kJ, multiply it by 4·183.*$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.

In sensitivity analyses, we found that the proportions of cereals, milk and cheese/yogurt that could be considered as UPF were 33, 36 and 99 % (considering yogurts as UPF). After the penalisation, the mean score in the KIDMED index decreased to 5·2 (SD 1·5; $P < 0·0001$) and the proportion of children with moderate and low adherence to the MedDiet increased to 76·30 and 21·10 %, respectively (data not shown in tables). In this scenario, considering the KIDMED index score as both a quantitative and categorical variable, higher adherence to the MedDiet resulted in a slightly lower contribution of UPF to TEI (online supplementary material, Supplemental Table 1).

In further analyses, considering yogurt as an UPF, we found that free sugar contribution to TEI was 11·0 %, with

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Table 2 Contribution to total energy intake (%) of each food group according to its processing degree by adherence to the Mediterranean dietary pattern of the participants in the SENDO project 2015–2018

	Score in the KIDMED index							
	Total (*n* 386)		Low (≤3, *n* 31)		Moderate (4–7, *n* 287)		High (≥8, *n* 68)	
Food groups	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total energy intake (TEI)***	2216·0	489·6	1852·4	403·9	2229·2	482·0	2326·0	488·4
Unprocessed or minimally processed foods (kcal†)***	1044·6	249·0	849·0	207·5	1036·2	230·0	1169·5	278·0
%TEI**	47·5	7·5	46·3	7·9	47·0	7·2	50·6	7·9
Milk**	10·6	5·6	12·9	6·7	10·7	5·5	9·1	4·9
Fruits***	6·7	3·4	4·7	1·8	6·5	3·1	8·5	4·2
Red meat**	5·6	2·7	6·7	3·2	5·6	2·5	5·1	2·8
Yogurt**	4·0	3·1	3·0	1·9	3·9	3·0	5·0	3·8
Legume	3·5	1·5	3·3	1·3	3·5	1·5	3·7	1·7
Potatoes**	3·0	2·2	2·9	2·3	3·0	2·3	2·8	2·1
Pasta	2·5	1·5	2·9	1·9	2·5	1·5	2·7	1·5
Vegetables***	2·1	1·2	1·2	0·7	2·1	1·2	2·8	1·0
Rice**	2·0	1·3	2·0	1·7	1·9	1·2	2·7	1·4
Lean meat	2·0	0·9	2·1	1·0	2·0	0·9	1·9	1·0
Fish	1·8	0·9	1·7	0·8	1·8	1·0	1·8	0·9
Eggs	1·4	0·8	1·4	0·8	1·4	0·9	1·4	0·6
Nuts*	1·2	1·5	1·1	2·0	1·1	1·2	1·7	2·2
Fruit juice**	0·9	1·4	0·3	0·3	0·8	1·2	1·2	2·2
Others MPF‡	0·1	0·2	0·1	0·1	0·1	0·2	0·1	0·1
Processed culinary ingredients (kcal†)	229·5	121·4	200·2	125·7	231·6	125·4	233·9	100·0
%TEI	10·3	4·8	10·6	5·8	10·3	4·9	10·1	4·1
Olive oil	9·0	4·5	7·9	4·4	9·0	4·7	9·4	4·1
Cream and butter	0·6	1·1	0·6	1·4	0·6	1·1	0·4	0·8
Vegetable oil***	0·5	1·5	2·0	3·5	0·5	1·2	0·1	0·2
Sugar	0·2	0·6	0·2	0·3	0·2	0·6	0·2	0·7
Processed foods (kcal†)***	221·5	133·9	138·5	93·4	223·5	134·4	251·0	133·6
%TEI**	10·0	5·5	7·3	3·9	10·1	5·6	10·9	5·3
Processed bread	6·6	5·1	5·2	4·1	6·6	5·2	6·8	5·0
Processed cheese**	1·3	1·4	0·8	0·8	1·3	1·5	1·6	1·4
Cured ham*	1·0	0·8	0·7	0·5	1·0	0·9	1·1	0·9
Olives*	0·3	0·4	0·2	0·1	0·3	0·4	0·37	0·4
Fruit in syrup	0·3	0·5	0·2	0·3	0·3	0·5	0·4	0·6
Bacon	0·2	0·5	0·1	0·3	0·3	0·5	0·2	0·5
Canned fish*	0·2	0·5	0·2	0·3	0·2	0·4	0·4	0·7
Ultra-processed food and drink products (kcal†)	720·3	265·0	664·6	211·9	737·9	268·7	671·3	264·6
%TEI***	32·2	8·0	35·8	7·5	32·6	7·6	28·4	8·7
Ultra-processed meat***	5·7	2·8	7·5	2·8	5·7	2·8	4·9	2·3
Bakery	5·6	3·5	5·9	4·0	5·7	3·6	5·1	2·7
Chocolate§*	4·8	3·0	4·9	3·1	5·0	3·0	3·9	2·3
Sweetened dairy products‖	4·4	3·6	4·1	3·0	4·6	3·5	3·7	3·9
Ready-to-eat meal*	3·8	1·7	4·3	1·5	3·9	1·7	3·4	2·1
Other products¶*	2·1	1·8	2·3	2·0	2·2	1·9	1·6	1·1
Ice cream	1·7	1·5	1·6	1·2	1·7	1·4	1·6	2·0
Ultra-processed cheese	1·5	1·7	1·3	1·2	1·6	1·8	1·5	1·6
Ultra-processed bread	1·1	1·6	1·6	1·9	0·9	1·5	1·3	1·8
Sugar-sweetened beverages	0·9	1·3	1·5	2·8	0·8	1·0	1·0	1·4
Candies***	0·4	0·4	0·6	0·6	0·4	0·4	0·2	0·2
Margarine and mayonnaise	0·2	0·4	0·2	0·4	0·2	0·4	0·2	0·4

†To convert to kJ/person, multiply kcal/person values by 4·184.
‡Viscera, seafood.
§Sugary chocolate drinks and products.
‖Sweetened petit suisse, fermented milk, custard.
¶Gelatine, popcorn and nougat.Linear trend test. *P*-values: $^{*}P < 0·05$, $^{**}P < 0·01$, $^{***}P < 0·001$.

9·4 % of it coming from UPF alone. In this context, we observed a direct and moderate correlation between Ca from UPF and both total free sugar ($r = 0·57$) and free sugar from UPF ($r = 0·68$) (Fig. 1). Furthermore, 71·6 % of the variability in free sugar intake was explained by the variability in the consumption of UPF, with sweetened dairy products being the most important contributor to that variability (24·3 %), closely followed by yogurts (16·3 % change in R^2). However, the variability in the consumption of sweetened dairy products and yogurt only explained the 5·2 and 8·6 %, respectively, of the variability in Ca intake from UPF (Table 4).

Table 3 Change (β coefficient and 95 % CI) in the percentage of total energy intake from ultra-processed foods associated with higher adherence to the Mediterranean dietary pattern of the participants in the SENDO project 2015–2018*

	Crude			Multivariable adjusted†		
	β	95 % CI	*P*-trend	β	95 % CI	*P*-trend
Model 1	−2·8	−3·7, −1·9		−3·1	−4·0, −2·1	
Model 2	−2·1	−3·1, −1·2		−3·0	−3·9, −2·0	
Model 3						
Low	Reference		<0·0001	Reference		<0·0001
Moderate	−3·6	−6·3, −0·9		−5·0	−7·7, −2·2	
High	−6·6	−10·0, −3·2		−8·5	−11·9, −5·2	
Model 4						
Low	Reference		<0·001	Reference		<0·0001
Moderate	−3·0	−5·7, −0·2		−4·7	−7·5, −2·0	
High	−5·5	−8·9, −2·2		−8·0	−11·5, −4·5	

*__Model 1__: Change associated with a two-point increase in the KIDMED score (continuous), with yogurts classified as minimally processed foods. **Model 2**: Change associated with a two-point increase in the KIDMED score (continuous), with yogurts classified as UPF. **Model 3**: Change associated with a higher adherence to the Mediterranean dietary pattern with KIDMED index as a categorical variable and yogurts classified as minimally processed foods. **Model 4**: Change associated with a higher adherence to the Mediterranean dietary pattern with KIDMED index as a categorical variable and yogurts classified as UPF.

†Generalised estimating equation adjusted for sex, age (continuous), total energy intake (quintile), physical activity (quintile), breast-feeding (dichotomous), mother's age (continuous), maternal education (categorical), paternal education (categorical), family history of obesity (dichotomous) and accounting for intra-cluster correlation between siblings.

Discussion

In the present study of 386 Spanish pre-schoolers, we found that children with higher adherence to the MedDiet reported a healthier dietary profile, with higher consumption of unprocessed food or MPF and processed culinary ingredients, which together made up 50·6 % of energy intake. This suggests that children with higher adherence to the traditional MedDiet obtained most of their energy content from handmade meals, in which the preparation of MPF is combined with culinary ingredients, such as salt, table sugar and oils or animal fats[8,33]. Our results showed that compared with low adherence, high adherence to the MedDiet was associated with an 8·5 % (95 % CI 5·2, 11·9) decrease in energy intake from UPF, after adjusting for potential confounders and accounting for intra-cluster correlations between siblings.

The industrialisation of dietary patterns has led to a higher intake of UPF and consequently a higher intake of free sugar, which has been associated with an increased risk of CVD, adiposity and dyslipidemia[34]. In our sample, free sugar accounted for 11·0 % of TEI, which is above the 5–10 % upper threshold recommended by the WHO[24]. 71·6 % of the free sugar intake in our sample came from UPF. These findings agree with the last Spanish Household Budget Survey, which estimated that 13·0 % of the TEI of Spanish households came from free sugar and of which 80·4 % came from UPF[5]. Furthermore, data from the USA indicated free sugar accounted for 13·7 % of TEI [35], with 89·7 % coming from UPF.

Yogurt represents an important food item in children's diet because many families consider it a main source of Ca in their diet. However, a recent study with Spanish schoolchildren found that the consumption of dairy products was insufficient to impact total Ca intake[36]. To further investigate the role of yogurts in children's diet, we presented two scenarios: (1) yogurts were classified as unprocessed food or MPF (unsweetened) or (2) yogurts were classified as UPF (sweetened). In the first scenario, we found high adherence to the MedDiet was associated with an 8·5 % lower energy intake from UPF. However, in the second scenario, the reduction was slightly lower (8·0 %). We favoured the second scenario and, based on the correlation and regression analyses (Fig. 1, Table 4), concluded that the contribution of sweetened dairy products (including yogurts) to the total variability in Ca intake should be confronted with their contribution to the variability in total and free sugar intake.

Regardless of the classification of yogurts, most of the children in our study reported moderate adherence to

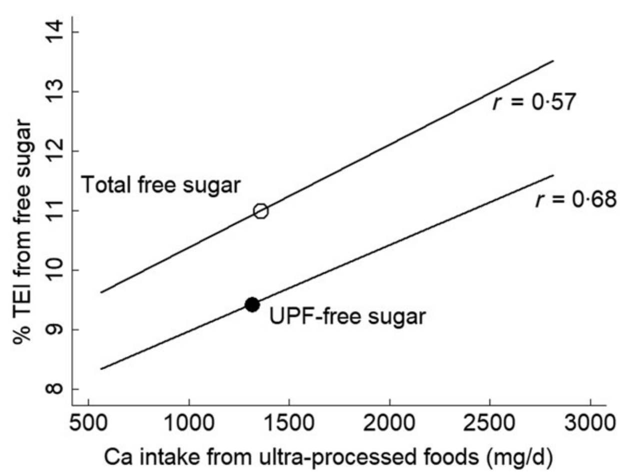

Fig. 1 Pearson's correlation (*r*) between Ca (mg/d) from UPF and percentage of total energy intake (%TEI) from total free sugar (mean 11 %) and free sugar from ultra-processed foods (mean = 9·4 %) in the SENDO project 2015–2018

Table 4 Contribution of the ultra-processed foods to the intake of total free sugar and Ca of the participants in the SENDO project 2015–2018*

	Free sugar (%TEI)		Ca (mg/d)†	
	Change in R^2	Cumulative R^2	Change in R^2	Cumulative R^2
Sweetened dairy products‡		24·3		5·2
All unprocessed or minimally processed foods	23·1	47·4	67·1	72·3
Yogurt§	16·3	63·7	8·6	80·9
Chocolate‖	17·0	80·7	0·4	81·3
Ice cream	5·1	85·8	–	–
All processed culinary ingredients and processed foods	5·2	91·0	5·7	87·0
Bakery	5·0	96·0	–	–
Sugar-sweetened beverages	3·1	99·1	2·0	89·0
Candies	0·8	99·9	–	–

*Cumulative R^2 values were determined with the use of nested regression analyses after a stepwise selection.
†The order of stepwise analysis of Ca: All unprocessed or minimally processed foods, yoghurt, UPF cheese (R^2 = 7·69), sweetened dairy products, all processed culinary ingredients and processed foods, sugar-sweetened beverages, chocolate.
‡Sweetened petit suisse, fermented milk, custard.
§Sweetened yogurts.
‖Sugary chocolate drinks and products.

the MedDiet, and the mean energy intake from UPF was 32·2 %. Previous studies in Spanish population found that, in the period between 1990 and 2010, the contribution of UPF to the total household food increased from 11·0 to 31·7 %[5], and adherence to the MedDiet decreased[37]. In Europe, outside the Mediterranean region, the contribution of UPF to household availability of food ranges from 10·2 % in Portugal to the alarming peak of 51 % in the United Kingdom[38], where it has also impacted the nutritional quality of the whole nation[10,11,39]. This change in the dietary pattern may be key to explaining the growing prevalence of childhood obesity and obesity-related complications[40,41]. The association between the consumption of UPF and obesity has been reported in a prospective cohort of Spanish adults[42], but the evidence in pediatric populations is still scarce. Nevertheless, the transformation of the food environment that followed industrialisation is becoming more and more evident as with UPF dominate the food market and replace, more and more, fresh and MPF. Since young generations will be exposed to this food environment for a longer period of time, it is logical to expect the impact on their health to be greater.

In the sensitivity analysis, we used a more conservative KIDMED index, since we penalised the score in those items that, under our consideration, included UPF (items 9, 13 and 15). Using that corrected score, we found that the magnitude of the association between the adherence to the MedDiet and the contribution of UPF to TEI was even higher (more negative). These results not only reinforce our hypothesis but also point out the need to update the KIDMED index to make it more suitable for capturing true adherence to the traditional MedDiet of children and adolescents.

We have previously published that higher adherence to the MedDiet in children was directly associated with parental healthy eating habits but not with parental nutritional knowledge[21]. These findings suggest that, beyond individual knowledge, several factors that impact an individual's food choices must be considered. The regulation of the production, marketing and advertising of UPF should be a priority for public health policies. Strategies such as front of package labelling with clear information on sugar content[43–45] or sweetened beverages taxation could be helpful in improving individual choices[46,47].

Our study has several strengths. First, to the best of our knowledge, no other study has associated the MedDiet with the consumption of UPF in children. Second, we have identified that the KIDMED, one of the most extensive indexes for assessing children's adherence to the MedDiet, might present some drawbacks related to insufficient information on the food processing type. Third, in all analyses, we accounted for intra-cluster correlation between siblings, which is a common limitation of cohort studies in children. Lastly, our results are consistent in a sensitivity analysis aimed at evaluating whether the classification of yogurts would impact the magnitude of the observed difference.

Nevertheless, we must acknowledge some limitations as well. First, a 24-h recall is better than a FFQ for estimating usual intake. As a consequence, food consumption in our study may be overestimated[48,49]. Nevertheless, previous studies have concluded that the information provided by FFQs is valid for use in epidemiological research[50] and that self-administration reduces cost and facilitates long-term follow-up. Second, we used self-reported information, which might lead to measurement errors. However, since it is unlikely that misclassification of UPF consumption was associated with the adherence to the MedDiet, the most probable classification bias is non-differential, which would bias the estimate towards the null. Third, FFQ are not expected to collect information about food processing; thus, misclassification of some food items cannot be discarded. However, to minimise misclassification

Public Health Nutrition

bias, food classification was performed by two independent researchers and disagreements were solved by consensus. We also acknowledge that our sample was homogeneous, with a large proportion of participants being highly educated and white families. Although this factor may hamper the generalisability of our results, it also has some benefits, such as higher validity of the self-reported information and the reduction of potential confounding by socio-economic variables. Finally, we used a cross-sectional design; therefore, prospective studies with large sample size and adequate retention rates are needed before causality can be inferred.

Conclusion

Our study provides evidence that higher adherence to MedDiet is associated with a significantly lower percentage of energy intake from UPF. The consumption of unprocessed food and MPF ('real foods') should be encouraged as a strategy to regain traditional dietary patterns. Moreover, Spain should promote public health strategies that have been successful in reducing the consumption of UPF such as the regulation of television advertising content during children's programmes, the implementation of a user-friendly nutritional front labelling, the taxation of sugar-sweetened beverages and the reduction of UPF vending machines in school areas.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020001524

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