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ORIGINAL RESEARCH

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Consumption of ultra-processed foods and its association with added sugar content in the diets of US children, NHANES 2009-2014

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Summary

Background: There is cumulative recognition that increases in the dietary share of ultra-processed foods result in deterioration of the nutritional quality of the overall diet and adverse health outcomes.

Objective: The purpose of this study was to assess the consumption of ultra-processed foods and to examine its association with added sugar content in the diet of US children aged 2 to 19 years.

Methods: We classified all food items according to the NOVA food classification system and looked at the consumption of ultra-processed foods, measured as percentage of total energy intake. We assessed dietary added sugar content by estimating its contribution to total energy intake and the proportion of individuals with diets exceeding the recommended limit of 10% of total energy intake from added sugars. We also examined the proportion of those who surpassed twice that limit. Gaussian and Poisson regressions estimated the association between consumption of ultra-processed foods and estimates of added sugar content.

Results: Ultra-processed foods contributed to 65% of total energy intake and to 92% of energy from added sugars in the diet of US children. The mean percent energy provided by added sugars in the observed period was 14.3%. Most individuals (70.9%) had diets exceeding the recommended limit of added sugar (<10% of total energy intake), and 18.4% of the population had diets surpassing twice the recommended level (20% of total energy intake). A 5.5% point increase in the dietary share of ultra-processed foods determined a 1 percentage point increase in the dietary content of added sugars, with stronger adjusted associations among younger children.

Conclusions: Public health efforts to reduce added sugars in the diet of US children must put greater emphasis on decreasing the consumption of ultra-processed foods.

KEYWORDS

added sugars, children, ultra-processed foods, United States

The conclusions and opinions in this article are those of the authors and do not necessarily reflect those of the FAPESP.

1 | INTRODUCTION

There is increasing recognition of the association between dietary patterns based on ultra-processed foods, as defined by the NOVA food classification system,[1] and adverse health outcomes, including weight gain,[2] obesity,[3-6] hypertension,[7] metabolic syndrome,[8,9] myocardial infarction and stroke,[10] gastrointestinal disorders,[11] total and breast cancer,[12] and all-cause mortality among adults[13]; and increased waist circumference,[14] dyslipidemia,[15] and metabolic syndrome[16] among children. National estimates have shown that ultra-processed foods provide on average 58% of daily energy in the US general population's diet,[17,18] and an increased trend in its consumption has been observed between 2007 to 2008 and 2011 to 2012, more specifically among adolescents.[18]

Ultra-processed foods are typically energy dense products, high in sugar, unhealthy fats, and salt, and low in dietary fiber, protein, vitamins, and minerals.[19-26] As a result, dietary patterns based on these food products are associated with diets of lower nutritional quality,[27-29] especially with regards to the added sugars content.[17,25,26]

The 2015-2020 Dietary Guidelines for Americans recommend limiting added sugars intake to less than 10% of daily calories,[30] and the World Health Organization (WHO) to less than 10% of total energy from "free sugars," which include both added and all sugars present in honey, syrups, and fruit juices.[31] Current added sugars intake in the United States far exceeds national and global guidelines. Young and older children consume on average 14% and 16%, respectively, of total energy intake from added sugars.[32-36] This is particularly worrying given that a number of studies have linked high consumption of added sugar in early childhood to an increased preference for sweet foods and beverages,[37] dental caries,[31,38] and excess weight in mid-childhood[37,39] and to an increased risk of cardiovascular disease,[40] insulin resistance,[41] type 2 diabetes,[40,42,43] and obesity later in life.[39]

Suboptimal diets are a major risk factor of malnutrition in all its forms, noncommunicable diseases (NCD), and death globally.[44,45] Children, especially young ones and adolescents, are nutritionally vulnerable populations due to their higher nutrient needs for growth and continued development of food preferences and dietary habits, and these preferences are key determinants of food choices, and therefore diet quality.[46]

In light of the previous findings on high consumption of ultra-processed foods among the general US population, accumulated evidence linking dietary patterns based on these food products with diets of lower nutritional quality and increased risk of NCDs, and the overweight epidemic in increasingly younger ages in the country, understanding the patterns of consumption of ultra-processed foods among this nutritionally vulnerable group can better help inform the nutrition response.

The current study examines the consumption of ultra-processed foods and its association with added sugars content in the diet of a large, nationally representative, cross-sectional sample of US children aged 2 to 19 years participating in the National Health and Nutrition Examination Surveys (NHANES) of 2009-2014.

2 | METHODS

2.1 | Data source and sample

We used nationally representative data from 2009-2014 NHANES (three 2-year cycles). NHANES is a cross-sectional, nationally representative survey of the US noninstitutionalized civilian population.[47] The survey has a complex, multistage, probability sampling. We selected all subjects from 2 to 19 years of age who had at least 1 day 24-hour dietary recall. The term "children" is used to refer to all participants aged 2 to 18 years rather than to specific age. The final sample of this study was 9469 participants.

2.2 | Dietary intake

Detailed methodology on NHANES has been reported elsewhere.[47] Dietary intake data are collected through two 24-hour dietary recall interviews. First-day recall interview is conducted in person and second-day recall is done by telephone. The survey uses the USDA multiple-pass format interview system,[47] with standardized probes, developed to estimate current dietary intake and to minimize misreporting.[48] Proxies provided the 24-hour dietary recalls for preschoolers aged 2 to 5 years; school-aged children (6-11 y) were assisted by an adult, and adolescents (12-19 y) provided their own recalls.

2.3 | Exposure

Our main exposure of interest was the consumption of ultra-processed foods, measured as percentage of total energy intake, categorized into quintiles of consumption. To calculate this measure, we classified all food items recorded in NHANES 2009-2014 according to the nature, extent, and purpose of industrial food processing established by the NOVA food classification system.[49]

The NOVA system considers all physical, biological, and chemical methods used during the food manufacturing process, including the use of additives, and divides foods into four groups. "Unprocessed or minimally processed foods" include grains (cereals), legumes (pulses), fresh, dry, or frozen fruits and vegetables, nuts, milk, meat, and other foods; "processed culinary ingredients" include oils and fats, sugar, honey, and salt used to prepare, cook, or season unprocessed or minimally processed foods; "processed foods" include foods such as canned fish and vegetables, commercially prepared baby foods, and artisanal cheeses and breads, which are manufactured by adding salt, sugar, oil, or other processed culinary ingredients to unprocessed or minimally processed foods; and "ultra-processed foods" include industrially manufactured breads; industrially manufactured cakes, cookies and pies; dry cake and pancake mixes; French fries and other premade potato products such as chips; sweet and savory snack foods; sweet breakfast cereals; frozen and shelf-stable plate meals; ice cream, frozen yogurt, and ice pops; meatless patties and fish sticks; reconstituted meat and fish products; ready-to-eat and dry-mix desserts such as pudding; confectionery; sugar-sweetened or artificially sweetened beverages including soda, fruit drinks, presweetened tea and coffee, energy drinks, and dairy-based drinks; flavored and/or sweetened yoghurt; and infant formula and toddler milks.

Food and Standard Reference (SR) codes from the USDA's Food and Nutrient Database for Dietary Studies[50] were used to code individual foods and preparations reported by participants in NHANES. We classified foods by taking into account the NHANES variables "Main Food Description," "Additional Food Description," which describes foods (food codes), and "SR Code Description," which describes the underlying ingredients of foods (SR codes). We also considered the NHANES variables "Combination Food Type" and "Source of Food." In consequence, most foods categorized as "Lunchables" or "Frozen meals," or sourced from a "Restaurant fast food/pizza" or "Vending machine," were classified as ultra-processed. When foods were judged to be a hand-made recipe, we applied the classification to the underlying ingredients (SR codes) in order to ensure a more accurate classification.[5,17] Two investigators reviewed the classification of each item.

2.4 | Outcomes

On the basis of the national and global target to limit added/free sugars intake to less than 10% of daily energy intake,[30,31] our outcome variables were (a) the mean percent total energy from added sugars, (b) the proportion of individuals with diet exceeding the recommended limit (10% cut-off), and, in addition, (c) the proportion with diets surpassing twice the recommended limit (20% cut-off).

The USDA defines added sugars as all sugars used as ingredients in processed and prepared foods and does not include naturally occurring sugars, such as fructose in fruit or lactose in milk, unless the sugar is added to the food item. A list of sugars included in the database as added sugars is publically available.[51]

Data on added sugars per Food Code were obtained by merging the Food Patterns Equivalents Database (FPED) 2009-2014.[51] In the FPED, quantities of added sugar are expressed in terms of teaspoons equivalents of table (granulated white) sugar per each 100 g of a food code. Teaspoons were converted into grams using the factor 4.2 g/teaspoon and into kcal using the factor 3.87 kcal/g.

2.5 | Statistical analysis

All analyses were stratified by age group (2-5, 6-11, and 12-19 y) and performed using the STATA statistical software package version 14.0. Appropriate sampling weights were applied in the analysis to obtain nationally representative estimates. Analyses were adjusted by sex, race/ethnicity (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and other race [including multiracial]), education, and income level, with family income being categorized in relation to the US poverty level. Thus, ratio of family income to poverty was categorized based on Supplemental Nutrition Assistance Program eligibility (low, 0.00-1.30; medium, greater than 1.30-3.50; and high, greater than 3.50). Education reflected the highest grade completed by the reference person and was categorized as less than 12 years (middle and elementary school), 12 years (high school), and greater than 12 years (college and graduate School).

Dietary intake data were assessed using means of both recall days when available and 1 day otherwise. Age-specific quintiles of ultra-processed foods contribution were used. The mean relative total energy and total energy from added sugars from each NOVA group and subgroup were estimated for all children and by age group. To obtain the overall percentage total energy from added sugars, we divided each individual's added sugars intake in calories by the total calories each consumed that day. We also determined the proportion (and 95% confidence interval) of individuals exceeding the recommended limits of energy from added sugars.

We used linear regression to estimate the association between the dietary contribution of ultra-processed foods and the dietary content of added sugars, each expressed as proportions of total energy. We assessed the linearity of the association using restricted cubic spline functions.

Linear regression analysis was used to compare the mean percentage total energy from added sugars across quintiles of the dietary share of ultra-processed foods. Poisson regression models were used to compare crude and adjusted proportion of individuals exceeding the recommended limits of energy from added sugars across quintiles of the dietary share of ultra-processed foods. Both the increase in the contribution and excessive added sugars intake across quintiles were evaluated using unadjusted and adjusted linear trend test. The significance level was defined as $P < .05$.

3 | RESULTS

3.1 | Energy from NOVA food groups and dietary sources of ultra-processed foods

The average US daily energy intake in 2009 to 2014 was 1513 kcal for preschoolers, 1907.4 kcal for school-aged children, and 2043.3 kcal for adolescents (data not shown). Table 1 shows the contribution of NOVA food groups to total energy intake and to the energy intake provided by added sugars. Among the three studied age groups, most calories came from ultra-processed foods: 58.2%, 66.2%, and 66.4% of total energy for preschoolers, school-aged children, and adolescents, respectively. Unprocessed or minimally processed foods contributed to 33.5%, 25.5%, and 25.2% of total energy for preschoolers, school-aged children, and adolescents, respectively, processed foods an additional 5.9%, 5.7%, and 5.9%, and processed culinary ingredients the remaining 2.4%, 2.6%, and 2.5%, respectively.

Within ultra-processed foods, the major contributors of energy among preschoolers were industrially manufactured breads, cakes and cookies, salty snacks, reconstituted meats, breakfast cereals, and milk-based drinks. By the age of 6 to 11 years, pizza and soft-and-fruit drinks are added to the list of most consumed products and, compared with their contribution to energy, pizza and soft-and-fruit drinks increased by 86% and 68%, respectively, from preschool to school age. The product pattern of choice among adolescents was similar to

TABLE 1 Mean contribution of NOVA food groups and subgroups to total energy intake and to energy intake from added sugars by age categories

NOVA Food Groups and Subgroups	Age Groups: All (2 to 19 y) (n = 9469) % of Total Energy Intake	All (2 to 19 y) (n = 9469) % of Energy Intake From Added Sugars	2 to 5 y (n = 2411) % of Total Energy Intake	2 to 5 y (n = 2411) % of Energy Intake From Added Sugars	6 to 11 y (n = 3335) % of Total Energy Intake	6 to 11 y (n = 3335) % of Energy Intake From Added Sugars	12 to 19 y (n = 3723) % of Total Energy Intake	12 to 19 y (n = 3723) % of Energy Intake From Added Sugars
Unprocessed or minimally processed foods	27.1	0.0	33.5	0.0	25.5	0.0	25.2	0.0
Meat (includes poultry)	5.9	0.0	4.0	0.0	5.2	0.0	7.4	0.0
Fruit and freshly squeezed fruit juices	5.4	0.0	8.8	0.0	5.1	0.0	3.9	0.0
Milk and plain yoghurt	7.0	0.0	11.4	0.0	6.8	0.0	5.2	0.0
Grains	2.3	0.0	2.7	0.0	2.2	0.0	2.1	0.0
Roots and tubers	1.0	0.0	0.9	0.0	0.9	0.0	1.1	0.0
Eggs	1.1	0.0	1.3	0.0	1.0	0.0	1.1	0.0
Pasta	1.5	0.0	1.6	0.0	1.6	0.0	1.8	0.0
Legumes	0.6	0.0	0.7	0.0	0.7	0.0	0.6	0.0
Fish and sea food	0.3	0.0	0.3	0.0	0.4	0.0	0.4	0.0
Vegetables	0.5	0.0	0.5	0.0	0.5	0.0	0.5	0.0
Other unprocessed or minimally processed foods[a]	1.2	0.0	1.2	0.0	1.1	0.0	1.2	0.0
Processed culinary ingredients	2.5	4.2	2.4	4.1	2.6	3.9	2.5	4.6
Table sugar[b]	0.6	4.2	0.5	4.1	0.6	3.9	0.6	4.6
Plant oils	1.1	0.0	1.1	0.0	1.2	0.0	1.1	0.0
Animal fats[c]	0.8	0.0	0.8	0.0	0.8	0.0	0.7	0.0
Other processed culinary ingredients[d]	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Processed foods	5.8	3.5	5.9	4.6	5.7	3.5	5.9	3.0
Cheese	2.9	0.0	2.8	0.0	2.8	0.0	3.0	0.0
Ham and other salted, smoked or canned meat or fish	0.6	0.0	0.5	0.0	0.6	0.0	0.7	0.0
Vegetables and other plant foods preserved in brine	0.6	0.8	0.6	1.0	0.6	0.9	0.5	0.7
Commercial baby foods: legumes, vegetables, meats and/or entrees	0.0	0.0	0.0	0.0	0	0		0
Commercial baby food: fruits	0.0	0.0	0.1	0.0	0	0		0
Other processed foods[e]	1.7	2.6	1.9	3.5	1.7	2.6	1.7	2.2
Ultra-processed foods	64.6	92.2	58.2	91.4	66.2	92.6	66.4	92.4
Breads	9.5	6.4	8.1	6.2	10.0	6.0	9.8	6.7
Soft and Fruit drinks[f]	6.6	30.4	3.9	19.5	5.7	27.4	8.6	37.8
Cakes, cookies, and pies	6.6	11.7	6.8	13.9	7.7	13.3	5.6	9.6
Salty-snacks	5.7	1.0	5.8	1.6	5.7	0.8	5.6	0.8
Frozen and shelf-stable plate meals	3.8	0.9	3.9	1.2	3.7	0.8	3.8	0.8
Pizza (ready-to-eat/heat)	5.0	1.4	2.9	0.8	5.4	1.4	5.8	1.7
Breakfast cereals	3.7	9.1	4.0	10.8	3.9	9.5	3.4	8.1
Sauces, dressings and gravies	2.0	3.2	1.2	2.4	1.6	2.7	2.6	3.9

(Continues)

TABLE 1 (Continued)

NOVA Food Groups and Subgroups	Age Groups: All (2 to 19 y) (n = 9469) % of Total Energy Intake	All (2 to 19 y) % of Energy Intake From Added Sugars	2 to 5 y (n = 2411) % of Total Energy Intake	2 to 5 y % of Energy Intake From Added Sugars	6 to 11 y (n = 3335) % of Total Energy Intake	6 to 11 y % of Energy Intake From Added Sugars	12 to 19 y (n = 3723) % of Total Energy Intake	12 to 19 y % of Energy Intake From Added Sugars
Reconstituted meat or fish products	4.9	0.7	5.5	0.9	5.0	0.5	4.5	0.7
Ice cream and ice pops	2.5	6.3	2.2	6.7	2.9	7.5	2.3	5.2
Sweet-snacks	3.0	8.1	3.3	9.7	3.2	8.2	2.8	7.1
Milk-based drinks	3.1	8.1	4.0	12.3	4.0	9.7	2.1	4.9
Desserts[g]	0.6	1.5	0.6	1.9	0.7	1.6	0.6	1.2
French fries and other potato products	2.0	0.0	1.6	0.0	1.7	0.0	2.4	0.0
Sandwiches and hamburgers on bun (ready-to-eat/heat)	2.0	0.9	0.9	0.4	1.6	0.6	2.9	1.2
Instant and canned soups	0.9	0.1	0.7	0.1	0.8	0.1	1.0	0.0
Infant formula	0.1	0.1	0.3	0.2				0
Other ultra-processed foods[h]	2.7	2.6	2.6	2.8	2.6	2.4	2.8	2.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note. US population aged 2 to 19 y (NHANES 2009-2014) (N = 9469).

[a]Including nuts and seeds (unsalted); yeast; dried fruits (without added sugars) and vegetables; non-presweetened, nonwhitened, nonflavored coffee and tea; coconut water and meat; homemade soup and sauces; flours; tapioca.

[b]Including honey, molasses, maple syrup (100%).

[c]Including butter, lard, and cream.

[d]Including starches; coconut and milk cream; unsweetened baking chocolate, cocoa powder and gelatin powder; vinegar; baking powder and baking soda.

[e]Including salted or sugared nuts and seeds; peanut, sesame, cashew and almond butter or spread; beer and wine.

[f]Including energy drinks, sports drinks, nonalcoholic wine.

[g]Including ready-to-eat and dry-mix desserts such as pudding.

[h]Including soy products such as meatless patties and fish sticks; dips, spreads, mustard and catsup; margarine; sugar substitutes, sweeteners and all syrups (excluding 100% maple syrup); distilled alcoholic drinks.

that of school-aged children, except for a 50% decrease in milk-based drinks, 30% decrease in cakes and cookies, and 50% increase in soft-and-fruit drinks (Table 1).

3.2 | Energy contribution and dietary sources of added sugars

In all age groups, approximately 92% of energy from added sugars came from ultra-processed foods. The top five food subgroup sources of added sugars for all children were “soft and fruit drinks” (30.4%) followed by “cakes, cookies, and pies” (11.7%), “breakfast cereals” (9.1%), “sweet snacks” (8.1%), and “milk-based drinks” (8.1%) (Table 1). “Soft and fruit drinks” were the leading source of added sugars in all age groups, providing the highest contribution among adolescents (19.5% preschoolers vs. 37.8% of energy among adolescents).

The mean percent energy provided by added sugars was 12.1% for preschoolers, 14.4% for school-aged children, and 15.3% for adolescents (Table 2). Most children (58.5%) had diets exceeding the recommended limits, and 10.6% surpassed twice the recommended level (20% cut-off) before they reached school age. Three-quarters of

TABLE 2 Indicators of dietary added sugar content by age groups

Indicators of Dietary Added Sugar Content	Age Groups: All (2-19 y) (n = 9469)	2 to 5 y (n = 2411)	6 to 11 y (n = 3335)	12 to 19 y (n = 3723)
Dietary added sugar content (% of total energy) (mean (SE))	14.3 (0.1)	12.1 (0.2)	14.4 (0.2)	15.3 (0.2)
Diets with >10% of energy from added sugars (% (95% CI))	70.9 (69.7; 72.1)	58.5 (55.2; 61.7)	74.2 (72.2; 76.1)	74.5 (73.9; 75.1)
Diets with >20% of energy from added sugars (% (95% CI))	18.4 (16.4; 20.6)	10.6 (9.2; 12.1)	16.0 (13.6; 18.9)	23.9 (21.7; 26.2)

Note. US population aged 2 to 19 y (NHANES 2009-2014) (N = 9469).

school-aged children and adolescents had diets exceeding the recommended added sugar limit, and 16% of school-aged children and 24% of adolescents surpassed twice the recommended level.

3.3 | Association between consumption of ultra-processed food and added sugars

In unadjusted restricted cubic spline Gaussian regression analysis, a strong linear association was found between the dietary share of ultra-processed foods (percentage of calories) and the dietary content of added sugars for the entire studied population (coefficient for linear term = 0.19; 95% CI, 0.15-0.23) and for each age group separately (Figure 1). There was little evidence of nonlinearity in the restricted cubic spline model for the entire studied population (Wald test for linear term $P < .0001$; Wald test for all nonlinear terms .21) and for each age group.

The strength of the association remained essentially the same after adjusting for age, sex, race/ethnicity, family income, and educational attainment for the entire studied population (coefficient for linear term = 0.18; 95% CI, 0.14-0.22) and for each age group: preschoolers (coefficient for linear term = 0.14; 95% CI, 0.08-0.20), school-aged children (coefficient for linear term = 0.17; 95% CI, 0.10-0.23), and adolescents (coefficient for linear term = 0.20; 95% CI, 0.13-0.27). Thus, each 5.5 percentage point increase in the dietary share of ultra-processed foods determined a one percentage point increase in the dietary content of added sugars for the entire studied population. For preschoolers, school-aged children, and adolescents, each 7%, 6%, and 5% point increase in the dietary share of ultra-processed foods determined a one percentage point increase in the dietary content of added sugars, respectively.

Across all age groups, the mean contribution of total energy from added sugars was 7.6% of total energy in the first quintile of ultra-processed foods consumption, whereas in the highest quintile, it was 18% (Table 3). The consumption of ultra-processed food in all age groups was significantly associated with both mean percentage total energy from added sugars intake and excessive added sugars intake

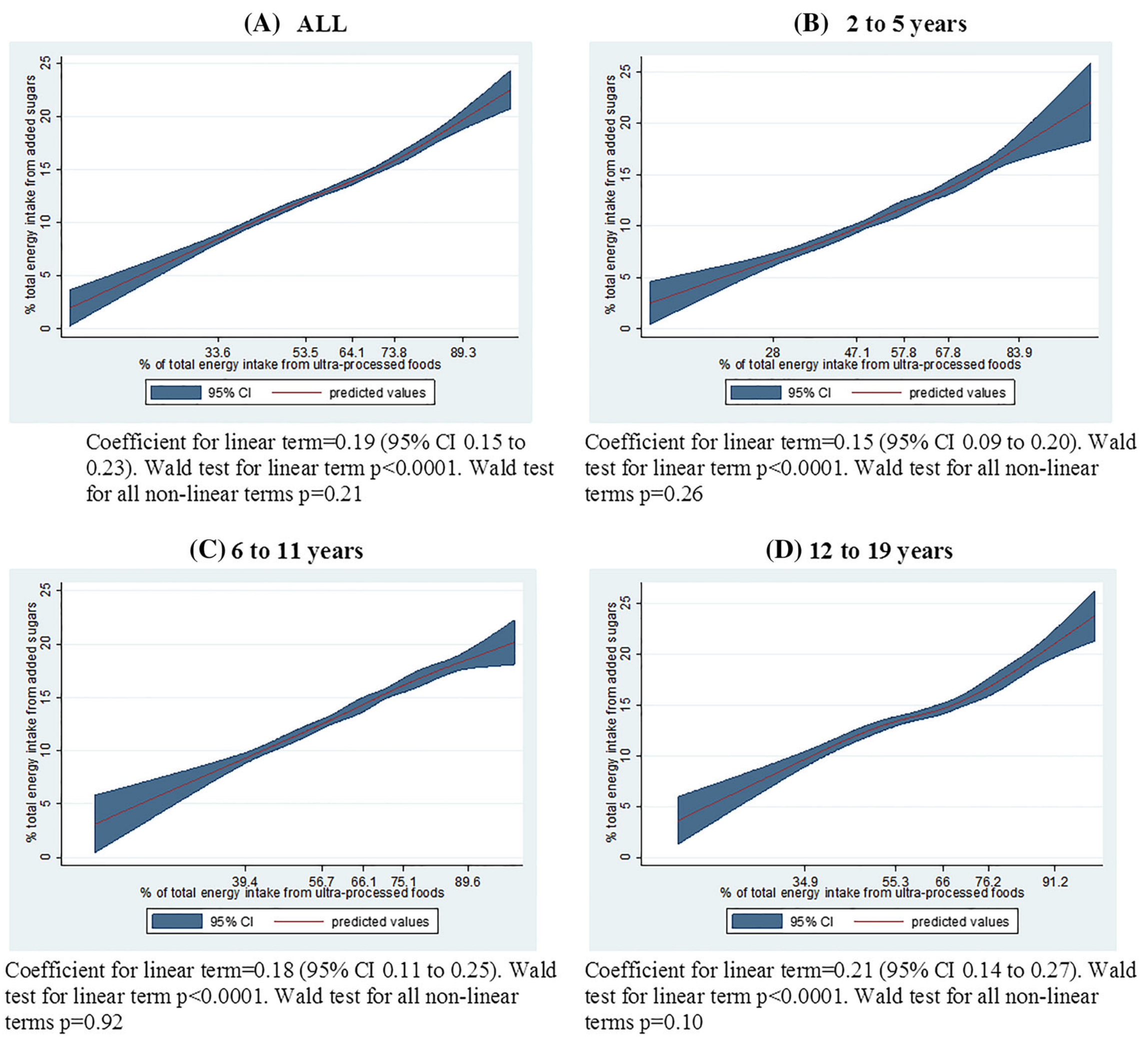

FIGURE 1 The dietary content in added sugars regressed on the dietary contribution of ultra-processed foods evaluated by restricted cubic splines. US population. All children (n = 9469) (A), 2 to 5 y (n = 2411) (B), 6 to 11 y (n = 3335) (C), 12 to 19 y (n = 3723) (D). (NHANES 2009-2014). The values shown on the x-axis correspond to the 5th, 27.5th, 50th, 72.5th, and 95th centiles for percentage of total energy from ultra-processed foods (knots)

TABLE 3 Indicators of the dietary content in added sugars according to the dietary contribution of ultra-processed foods

	All (n = 9469)							2 to 5 y (n = 2411)						
	Dietary added sugar content (% of total energy)	Diets with >10% of energy from added sugars			Diets with >20% of energy from added sugars			Dietary added sugar content (% of total energy)	Diets with >10% of energy from added sugars			Diets with >20% of energy from added sugars		
Quintiles UPP	Mean	%	PR	PRadj	%	PR	PRadj	Mean	%	PR	PRadj	%	PR	PRadj
1st	7.6	29	1	1	2	1	1	7.7	27	1	1	1	1	1
2nd	11.3	56	2.0	1.9	5	2.5	2.1	10.3	47	1.7	1.6	2	3.5	3.1
3rd	12.9	66	2.3	2.2	12	5.9	4.8	12.2	64	2.4	2.2	9	12.8	10.8
4th	14.9	78	2.7	2.6	18	8.9	6.8	13.8	71	2.7	2.4	16	21.8	17.5
5th	18*	86	3*	2.8*	34	16.5*	11.9*	16.5*	84	3.1*	2.8*	25	34.7*	27.0*
All	14.3	71	_	_	18	_	_	12.1	59	_	_	11	_	_

Note. US population aged 2 to 19 y (NHANES 2009-2014) (N = 9,469) (using day 1 and 2). Mean (range) dietary share of ultra-processed foods per quintile - 2 to 5 y: 1st = 35.0 (0-43.8), 2nd = 50.3 (43.8-54.9), 3rd = 58.9 (54.9-62.8), 4th = 67.1 (62.8-71.8), 5th = 80.1 (71.9-100); 6 to 11 y: 1st = 44.7 (5.5-53.2), 2nd = 58.8 (53.-63.3), 3rd = 66.9 (63.3-70.4), 4th = 74.6 (70.4-79.3), 5th = 86.2 (79.3-100); 12 to 19 y: 1st = 42.3 (6.2-52.7), 2nd = 58.1 (52.7-63.3), 3rd = 67.3 (63.3-71.5), 4th = 76.2 (71.5-81.0), 5th = 88.2 (81.0-100).

Abbreviation: UPP, ultra-processed foods.

*Significant linear trend across all quintiles ($P \leq .001$), both in unadjusted and models adjusted for sex, age (months), race/ethnicity (Mexican-American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black and Other Race – Including Multi-Racial-), ratio of family income to poverty (SNAP 0.00-1.30, >1.30-3.50, and >3.50 and over) and educational attainment (<12, 12 y and >12 y).

[a]PR = Prevalence ratios estimated using Poisson regression.

[b]PRadj = Prevalence ratios adjusted for sex, age groups, race/ethnicity, ratio of family income to poverty and educational attainment, as above.

(10% and 20% cut-offs) in both unadjusted and adjusted models. After adjusting for potential sociodemographic confounders, preschoolers in the highest quintile of dietary share of ultra-processed foods (71.9%-100% energy) were three times (PR_{adj} = 2.8; 95% CI, 2.31-3.57) more likely to exceed the 10% cut-off compared with those children in the lowest quintile (0-43.8% energy) and almost thirty times (PR_{adj} = 27; 95% CI, 9.01-81.01) more likely to exceed the 20% cut-off compared with those children in the lowest quintile. School-aged children in the highest quintile of dietary share of ultra-processed foods (79.3%-100% energy) were almost two times (PR_{adj} = 1.7; 95% CI, 1.52-1.95) more likely to exceed the 10% cut-off compared with those children in the lowest quintile (5.5%-53.2% energy) and almost 10 times (PR_{adj} = 9.6; 95% CI, 5.64-16.39) more likely to exceed the 20% cut-off compared with those children in the lowest quintile; and among adolescents, those in the highest quintile of dietary share of ultra-processed foods (81.0%-100% energy) had a 50% greater probability (PR_{adj} = 1.5; 95% CI, 1.36-1.69) of exceeding the 10% cut-off compared with those individuals in the lowest quintile (6.2% to 52.7% energy) and almost six times (PR_{adj} = 5.6; 95% CI, 3.59-8.63) more likely to exceed the 20% cut-off compared with those children in the lowest quintile.

4 | DISCUSSION

Our analysis of nationally representative US dietary data found that ultra-processed foods contribute to 65% of all calories in this pediatric population's diet and contribute to 92% of all calories from added sugars in the observed period. We also found a large proportion of children whose intake exceeds national and global recommendations to limit the intake of added sugars. Even among the lowest quintiles of ultra-processed foods consumption, the average added sugars intake exceeds the recommended limit for school-aged children and adolescents. Notably, a strong dose-response association was found between the consumption of these products and the dietary content of added sugars, and the increase of inadequacy across quintiles was more evident among younger children.

The mean dietary share of ultra-processed foods observed for all age groups (65%) in this analysis is higher than that reported for the general US population (58%).[17,18] It is also far higher than that observed among children in Chile (39%)[26] and the general population of other middle-income countries.[29,52] Previous evaluations using national dietary intake surveys have found that ultra-processed foods

TABLE 3 Indicators of the dietary content in added sugars according to the dietary contribution of ultra-processed foods

	6 to 11 y (n = 3335)							12 to 19 y (n = 3723)						
	Dietary added sugar content (% of total energy)	Diets with >10% of energy from added sugars			Diets with >20% of energy from added sugars			Dietary added sugar content (% of total energy)	Diets with >10% of energy from added sugars			Diets with >20% of energy from added sugars		
Quintiles UPP	Mean	%	PR	PRadj	%	PR	PRadj	Mean	%	PR	PRadj	%	PR	PRadj
1st	10.4	50	1	1	3	1	1	11.2	57	1	1	8	1	1
2nd	12.7	67	1.3	1.3	8	2.5	2.0	13.6	70	1.2	1.2	17	2.2	2.3
3rd	14.8	81	1.6	1.6	14	4.6	4.1	14.8	76	1.3	1.3	20	2.6	2.6
4th	15.8	84	1.7	1.6	20	6.4	5.5	16.9	81	1.4	1.4	30	3.9	3.7
5th	18.2*	90	1.8*	1.7*	35	11.3*	9.6*	20.2*	89	1.6*	1.5*	46	6.0*	5.6*
All	14.4	74.2	_	_	16	_	_	15.3	75	_	_	24	_	_

Note. US population aged 2 to 19 y (NHANES 2009-2014) (N = 9,469) (using day 1 and 2). Mean (range) dietary share of ultra-processed foods per quintile - 2 to 5 y: 1st = 35.0 (0-43.8), 2nd = 50.3 (43.8-54.9), 3rd = 58.9 (54.9-62.8), 4th = 67.1 (62.8-71.8), 5th = 80.1 (71.9-100); 6 to 11 y: 1st = 44.7 (5.5-53.2), 2nd = 58.8 (53.-63.3), 3rd = 66.9 (63.3-70.4), 4th = 74.6 (70.4-79.3), 5th = 86.2 (79.3-100); 12 to 19 y: 1st = 42.3 (6.2-52.7), 2nd = 58.1 (52.7-63.3), 3rd = 67.3 (63.3-71.5), 4th = 76.2 (71.5-81.0), 5th = 88.2 (81.0-100).

Abbreviation: UPP, ultra-processed foods.

*Significant linear trend across all quintiles ($P \leq .001$), both in unadjusted and models adjusted for sex, age (months), race/ethnicity (Mexican-American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black and Other Race – Including Multi-Racial-), ratio of family income to poverty (SNAP 0.00-1.30, >1.30-3.50, and >3.50 and over) and educational attainment (<12, 12 y and >12 y).

[a]PR = Prevalence ratios estimated using Poisson regression.

[b]PRadj = Prevalence ratios adjusted for sex, age groups, race/ethnicity, ratio of family income to poverty and educational attainment, as above.

contributed to more than half of the total calories consumed in other high-income countries such as Canada[24] and the United Kingdom[25].

The contribution of ultra-processed foods among preschoolers (58%) was as high as that observed in the US general population.[17,18] Consumption rose sharply from preschool to school age (66.2%) and remained stable, among adolescents (66.4%). Children as young as 6 years of age showed an ultra-processed food subgroup consumption pattern similar to adolescents, but with lower sodas and higher milk-based drinks. What draws attention is how ultra-processed foods consumption can be so high among the youngest children (2 to 5 y of age) and the wide range of ready-to-eat foods that characterize an "obesogenic" environment readily available since the early years. By contrast, the consumption of unprocessed or minimally processed foods, especially fruits and milk, decreased sharply with age. This suggests an overall replacement of fresh foods and meals by ultra-processed products, which has a devastating impact on the quality of diets.

Results from this analysis can be used as a springboard to discuss implications for developing food habits. There are reasons to believe that ultra-processed foods are habit forming,[53] which is consistent with our data showing that ultra-processed foods comprise more than 50% of total energy since the first years of life and its consumption increases with age. It is well known that learned taste preference is self-developed based on prior exposure to certain foods.[54] There is also a conditioned preference for low-nutrient, high-energy density foods compared with high-nutrient density foods among school-aged children and adolescents. Other factors that might explain the increased consumption of ultra-processed foods with age are the individual characteristics of the child (expected eating patterns for age and level of autonomy) and social-environmental influencers. School-aged children and adolescents interact directly with their food environments. They more often eat away from home, the role of the caregiver/parent controlling foods and supervising meals is reduced, and a transition from caregiver- or school-prepared meals to more purchased meals/snacks or more meals outside of the home are expected.[55] Longitudinal dietary data are necessary to understand the factors leading to changes in consumption with aging.

In our study, most food sources of added sugars consumed by young children (2-5 y) were similar to those eaten by school-aged children and adolescents, including "soft and fruit drinks" followed by "cakes, cookies, and pies," "breakfast cereals," "sweet snacks," and "milk-based drinks," all of them considered ultra-processed foods. Just as we observed, others have demonstrated that "soft and fruit drinks" consumption is high[56] and is a leading source of added sugars, contributing to approximately one-third of the added sugars consumed by all children.[32,36] Due to their substantial contribution to total added sugars intake, previous policy efforts have focused on added sugars from beverages. However, our findings indicate other important sources of added sugars: the ultra-processed food group as a whole. Therefore, policy measures for improving food literacy, informing consumer food purchasing practices, targeting the identification of ultra-processed foods, and increasing consumption of minimally processed foods while enhancing cooking skills, would be more effective strategies to promote healthy eating for families and consequently their children.

Although decreases in intakes of added sugars have been documented among US children[32,33] and adults[57] in some studies, our analysis shows that its mean energy contribution is higher than recommended from early in life and increases as children age. Seventy-one percent of children and adolescents exceeded the Dietary Guidelines for Americans recommendation to limit added sugar to less than 10% of total dietary energy and more than 18% surpassed twice the recommended level. These findings carry implications for child current and future health as high contribution of added sugars has been clearly associated with increased risk of developing caries,[31,38] cardiovascular disease,[40] type 2 diabetes,[40,42,43] and obesity.[39]

This research adds to the growing body of literature that identifies consumption of ultra-processed foods as being highly associated with added sugars intake.[17,21,25-27,58] The increase of inadequacy across quintiles was more evident among younger children most likely because as children grow older, they become more exposed to foods rich in added sugars, even the lowest consumers of ultra-processed foods.[26,58] Older children and adolescents become more autonomous and exposed to the obesogenic marketing environment that surrounds them.[59] Similar to our findings, NHANES analyses of the general population has shown that those in the highest quintile of ultra-processed food consumption were three times more likely to exceed the 10% added sugars cut-off than those in the lowest quintile.[17] Cediel et al[26] observed that Chilean children from 2 to 19 years in the highest quintile of consumption were four times more likely to exceed the 10% limit of the recommendation than those in the lowest quintile (PR_{adj} = 3.9).[26] Recent evidence from the British population examining the relationship between free sugars intake and ultra-processed foods consumption across the life cycle suggested similar patterns, showing that teens in the highest quintile of dietary share of ultra-processed foods had a 56% greater probability of exceeding the 10% cut-off compared with those individuals in the lowest quintile (PR_{adj} = 1.56).

The high consumption of ultra-processed foods observed in our study are cause for concern because of the evidence linking increases in the dietary share of ultra-processed foods to deterioration of the nutritional quality of the overall diet[25,27-29]. Particularly concerning for this population is the fact that beyond carrying more than 90% of all added sugars in the diet, ultra-processed foods as a whole are typically attractively packaged, aggressively marketed, and appealing to children[59]; they promote food addiction[60] and overconsumption,[1] and they take the place of healthy homemade dishes, increasing energy density of diets and potentially promoting micronutrient deficiencies[1]—all of which could have adverse health-related consequences to children.

This study has several strengths. It is the first to our knowledge to describe the patterns of consumption of ultra-processed foods among US children and to investigate the effects of food processing in relation to dietary intake of added sugars with detailed analysis using specific age groups. The availability of dietary and demographic data on a large national sample of children, and the use of food groups and subgroups defined by NOVA[49] are other important strengths. This study also has some important limitations. First, the extent to which parents can accurately report the dietary intake of their young children is unknown. They may also be subject to reporting bias if they believe that the foods they provide their children are not aligned with societal norms or guidelines. This risk may be greater for parents/guardians of children who are overweight or obese. If so, these biases may lead to an underestimation of the dietary contribution of ultra-processed foods and the overall intake of added sugars but should have much less effect on the association between these. However, the standardized methods and approach of NHANES minimize potential error and bias, particularly for assessing population averages as focused on in the present study. Also, although NHANES collects some information indicative of food processing (ie, place of meals and product brands), these data are not consistently determined for all food items, which could lead to misclassification of food items and potentially modest overestimation or underestimation of the consumption of ultra-processed foods.

In conclusion, ultra-processed foods contribute to two-thirds of the caloric intake and 92% of added sugars in the diets of US children aged 2 to 19 years. Higher dietary share of ultra-processed foods result in increased probabilities of exceeding national and global recommendations to limit added sugars intake. Public health efforts to reduce intake of added sugars in the US must put greater emphasis on decreasing the consumption of ultra-processed foods and in nurturing lifelong healthful eating patterns.

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CONFLICTS OF INTEREST

No conflict of interest was declared.

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