Ultraprocessed food consumption and dietary nutrient profiles associated with obesity: A multicountry study of children and adolescents

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SUPPLEMENT ARTICLE

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Ultraprocessed food consumption and dietary nutrient profiles associated with obesity: A multicountry study of children and adolescents

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Summary

This study assessed associations between ultraprocessed food consumption and dietary nutrient profile linked to obesity in children and adolescents in Argentina, Australia, Brazil, Chile, Colombia, Mexico, the United Kingdom, and the United States using nationally representative data collected between 2004 and 2014. Linear regression models were used to evaluate associations between dietary share of ultraprocessed foods (country and age group-specific quintiles and a 10% share increase) and the energy density of diets and their content of free sugars and fiber. Ultraprocessed foods, defined by the NOVA system, ranged from 18% of total energy intake among preschool children in Colombia to 68% among adolescents in the United Kingdom. In almost all countries and age groups, increases in the dietary share of ultraprocessed foods were associated with increases in energy density and free sugars and decreases in fiber, suggesting that ultraprocessed food consumption is a potential determinant of obesity in children and adolescents. Effective global policy action to address growing ultraprocessed food consumption and childhood obesity is urgently needed.

KEYWORDS
childhood obesity, nutrient profile, ultraprocessed foods

1 | INTRODUCTION

The penetration of ultraprocessed foods within food systems have been hypothesized as a major contributor to the rise in overweight and obesity globally.[1] As defined by the NOVA food classification system,[2] ultraprocessed foods are formulations of food substances with little if any whole food and which typically contain added flavors, colors, and other cosmetic additives. Analyses of data from nationally representative dietary surveys conducted in several countries have shown that ultraprocessed food consumption is systematically associated with dietary nutrient profiles that increase the risk of obesity and noncommunicable diseases (NCDs) in adult populations.[3–11] Three carefully conducted cohort studies and one randomized controlled trial have shown evidence linking ultraprocessed food consumption with obesity and weight gain in adults,[12–15] while there seems to be fairly consistent evidence suggesting ultraprocessed foods may be involved in the etiology of childhood obesity,[16] affecting body composition over time,[17–20] and in the development of cardiometabolic disease risk factors.[21–23] Consumption of ultraprocessed foods may contribute to weight gain and obesity through their unfavorable dietary nutrient profile, particularly high in energy density and free sugars and low in dietary fiber—nutrients of public health concern covered by international guidelines.[24–31]

Recent data have reported that children and adolescents are the leading consumers of ultraprocessed in some high-income countries, including the United Kingdom, Australia, the United States, and Canada.[5, 32–34] These food products provide on average 65% of daily energy intake among children in the United Kingdom.[35] Nationally representative studies from the United States, Australia, and Canada also show major contributions of ultraprocessed foods to children's and adolescents' energy intake (>55%).[10, 32, 36] In low- and middle-income countries (LMICs), the consumption of ultraprocessed foods is lower (<38%),[6, 37, 38] but young children are the largest consumers of these products in Chile, Colombia, and Mexico.[4, 6, 37]

Limited studies have examined associations between ultraprocessed foods and obesity among children and adolescents, precluding a systematic review. This evidence gap is important as it may constrain effective policy action to address growing ultraprocessed food consumption. Monitoring children's food consumption patterns while paying special attention to food processing and its nutritional profile is essential to support realistic food and nutrition policies that effectively address childhood obesity. This study assessed consumption of ultraprocessed foods among children and adolescents in eight countries and its association with dietary nutrient profiles linked to an increased risk of obesity.

2 | METHODS

2.1 | Data source

We used data from nationally representative dietary surveys conducted between 2004 and 2014 in Argentina, Australia, Brazil, Chile, Colombia, Mexico, the United Kingdom, and the United States. Detailed information pertaining to each survey including sampling design is described elsewhere.[39–46] Analyses were conducted separately in three age groups: preschool children (2–5 years), school-aged children (6–11 years), and adolescents (12–19 years). In Brazil, where data on young children were not collected, the analyses considered only adolescents whereas in Argentina, data were not collected on school-aged children and only collected among female adolescents. Table 1 summarizes the characteristics of the surveys in each country.

2.2 | Assessment of dietary intake

Surveys collected dietary data using either 24-h recalls or food diaries (Table 1). In most countries, proxies (parent/caregiver) provided dietary recalls for preschoolers, school-aged children were assisted by an adult, and adolescents (12–19 years) provided their own recalls when permission was granted. Dietary intake data were previously processed in each country using its correspondent food composition database (by itself or in combination with the USDA Food and Nutrient Database for Dietary Studies)[47] and energy and nutrient intakes were estimated.

2.3 | Exposure variable

The dietary share of ultraprocessed foods or their relative contribution to total energy intake was our main exposure of interest. It has been shown to be a robust indicator of the overall quality of national diets.[48–50] In this study, the dietary share of ultraprocessed foods was evaluated as continuous variable and also categorized into age specific quintiles of consumption. To calculate this measure, one or two investigators per country working independently systematically categorized all food items recorded in each dataset according to NOVA, a food classification system based on the nature, extent, and purpose of industrial food processing.[2] This classification includes four major food groups: G1, unprocessed foods or minimally processed foods; G2, processed culinary ingredients; G3, processed foods; and G4, ultraprocessed foods. Individual foods were classified by taking into

TABLE 1 Characteristics of surveys in the eight countries

Country	Survey/year	Age groups included (years)	Sample size	Dietary data collection method/number of recalls/records per participant	Available measures of socioeconomic status: Income	Education level	Race/ethnicity	Rural/urban area	Geographical region
Latin America countries									
Argentina	ENNYS 2005	2–5 and 10–19 (female)	9187	24-h recall 1 day	Household income per capita (fifths of income per capita)	Years of schooling of the head of the family: ≤7, 8–11, and ≥12 years	-	-	Great Buenos Aires, Cuyo, North East, North West, Pampeana, and Patagonia
Brazil	POF 2008–2009	12–19	5268	Food diary 2 days	Household income per capita (fifths of income per capita)	Years of schooling of the head of the family: ≤8, 9–11, and ≥12 years	White, Black, and other	Rural/urban	North, Northeast, Southeast, South, and Central-West
Chile	ENCA 2010	2–5, 6–11, and 12–19	1371	24-h recall 1 day	Family income: 1, 2, 3–5, and ≥6 minimum wages	Years of schooling of the head of the family: ≤8, 9–11, and ≥12 years	-	Rural/urban	North, Center, South, South (Austral), and Metropolitan
Colombia	ENDS/ENSIN 2004–2005	2–5, 6–11, and 12–19	26,988	24-h recall 1 day	Composite SES scale (housing, material possession, education, and income): Levels 1–4	-	-	-	Atlantic, Oriental, Central, Pacific, Amazonia, Orinoco, and Bogota
Mexico	ENSANUT	2–5, 6–11, and 12–19	6469	24-h recall 1 day	Composite SES scale (housing, material possession): low, medium, and high	Without education, elementary, middle school, high school, and college graduate education	-	Rural/urban	South, Central, and North regions
Non-Latin America countries									
Australia	NNPAS	2–5, 6–11, and 12–19	2915	24-h recall 1 day	SES (Index of Relative Socio-economic Disadvantage)	Years of schooling of the reference person of the family (up to 9 and 10–12 years, with no graduate degree, 12+ years with graduate degree)	-	Major cities of Australia, inner regional, and other, which includes outer regional, remote, and very remote Australia	-
United Kingdom	NDNS	2–5, 6–11, and 12–19	4635	Food diary 4 days	Equalized household income (equalized for different	-	White, mixed ethnic group, Black or Black British, Asian	-	England North, England Central/Midlands, England

(Continues)

TABLE 1 (Continued)

Country	Survey/year	Age groups included (years)	Sample size	Dietary data collection method/number of recalls/records per participant	Available measures of socioeconomic status: Income	Education level	Race/ethnicity	Rural/urban area	Geographical region
					household sizes and composition using the McClements equivalence scale)		or Asian British, and other race		South (including London), Scotland, Wales, and Northern Ireland
United States	NHANES	2–5, 6–11, and 12–19	9469	24-h recall 2 days	Ratio of family income to poverty (SNAP 0.00–1.30, >1.30–3.50, and >3.50 and over)	Years of schooling of the reference person of the family: <12, 12, and >12 years	Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, and other Race—including multiracial	-	-

account variables related to food and preparation codes, food names, and additional food description when available. Detailed information regarding how to identify ultraprocessed foods and the application of the NOVA system to each dataset can be found elsewhere.[3–6, 9, 11, 51]

2.4 | Outcome variables

Our outcome measures were dietary energy density (kcal/g) and dietary content of free sugars (% of total energy intake) and fiber (g/1000 kcal). Dietary energy density was calculated by dividing the energy content (in kilocalories) by weight of foods (in grams) consumed, excluding all beverages. The following items were identified as beverages: coffee, tea, and herbal teas; soda, soft drinks, sports drinks, and energy drinks; fruit and/or vegetable juices; alcoholic beverages; and bottled and flavored water. Liquids consumed as part of solid preparations (e.g., milk as part of a cake) were not excluded. Dietary energy density calculation was not possible for Argentina due to the lack of detailed information needed to identify if a liquid was consumed as a beverage or an ingredient in solid recipes.

Most countries estimated dietary content of free sugars based on their correspondent food and nutrient database, which contain information for several foods and beverages consumed during the surveys. Free sugars are those added to foods and beverages as part of processing or preparation, and sugars naturally present in honey, syrups, and fruit juices.[25] A few countries, including the United States, Chile, and Argentina, estimated the dietary content of added sugars based on the USDA Food Patterns Equivalents Database 2009–2014[52] and USDA National Nutrient Database.[47] Added sugars in these databases include all free sugars but exclude naturally occurring sugars. The term "free sugars" was adopted in this article to refer to both free and added sugars. Each research team calculated all measures and reviewed one another's calculations to ensure quality control.

2.5 | Data analysis

All analyses were stratified by age group (2–5, 6–11, and 12–19 years) and performed using Stata statistical software. Dietary intake data were assessed using means of all available dietary recalls or records in each country. We calculated for each country and age group the mean caloric contribution of the NOVA groups and subgroups of ultraprocessed foods to total daily energy. The mean dietary content of each nutrient of interest was evaluated according to age group-specific quintiles of caloric contribution of ultraprocessed foods.

We used linear regression models to estimate the association between country and age group-specific quintiles of the dietary share of ultraprocessed foods and dietary energy density and the content of free sugars and fiber for each country. Tests of linear trend were performed by treating quintiles of the dietary share of ultraprocessed food as an ordinal variable. When a significant linear trend was demonstrated across quintiles, we evaluated the effects of a 10% increase in the dietary share of ultraprocessed foods (as a continuous variable) on dietary energy density and content of free sugars and fiber using linear regression models. All analyses were adjusted for sociodemographic covariates listed in Table 1.

3 | RESULTS

3.1 | Distribution of total energy intake according to NOVA food groups

Figure 1 shows the contribution of the NOVA food groups to total energy intake by country and age groups. We found two different patterns of consumption of ultraprocessed foods among countries of the Latin America (LA) region: ultraprocessed foods accounted for 18% and 25% of all calories consumed by children and adolescents in Brazil and Colombia and 27% to 44% of those in Argentina, Mexico, and Chile. In non-LA countries (Australia, the United Kingdom, and the United States), 47% to 68% of all calories came from ultraprocessed foods.

Unprocessed or minimally processed foods contributed to most calories consumed by children and adolescents in Brazil (51%) and Colombia (approximately 60%), 50% of calories in Mexico, and between 24% and 37% in Chile, Argentina, and all non-LA countries. Processed culinary ingredients contributed to an average of 15% to 18% of all calories in Brazil, Colombia, and Argentina; an average of 9% and 10% in Mexico and Chile; and to 5% or less in Australia, the United Kingdom, and the United States. Processed foods contributed to an average of 11% and 25% of all calories in Argentina and Chile; 10% and 13% in Brazil and Australia; and to an average of 4% to 6% of all calories in Colombia, Mexico, the United Kingdom, and the United States.

The mean dietary contribution of ultraprocessed foods (% of total energy) across quintiles of the dietary contribution of ultraprocessed foods by country in each age group (2 to 5, 6 to 11, and 12 to 19 years) are shown in Tables S1–S3, respectively.

3.2 | Quintiles of the dietary share of ultraprocessed food consumption and dietary nutrient profile

The mean dietary energy density and content of free sugars and fiber across quintiles of the dietary share of ultraprocessed foods for each country and within the three age groups is shown in Figure 2. In most countries and age groups, as the contribution of ultraprocessed foods to total energy intake increased, the mean dietary energy density and the mean content of free sugars also increased whereas the mean content of fiber decreased, with significant linear trends ($p < 0.001$) observed before and after adjustment for sociodemographic covariates. No significant associations with quintiles of ultraprocessed food consumption were observed for preschool children from Colombia regarding free sugars and for preschool children from the United Kingdom regarding fiber.

3.3 | Effect of a 10% increase in the dietary share of ultraprocessed foods on the dietary nutrient profile

Figures 3 to 5 show the effect of a 10% increase in the dietary share of ultraprocessed foods on the dietary energy density and content of free sugars and fiber for each country and age group when a significant linear trend was observed in the analysis across quintiles.

Among preschoolers (Figure 3), the effects range from +0.09 kcal/g in Colombia to +0.15 kcal/g in Chile for energy density, from +1.05% of total energy in the United Kingdom to +2.80% of total energy in Chile for the content of free sugars, and from −0.20 g/1000 kcal in Argentina to −0.90 g/1000 kcal in Mexico for the fiber content.

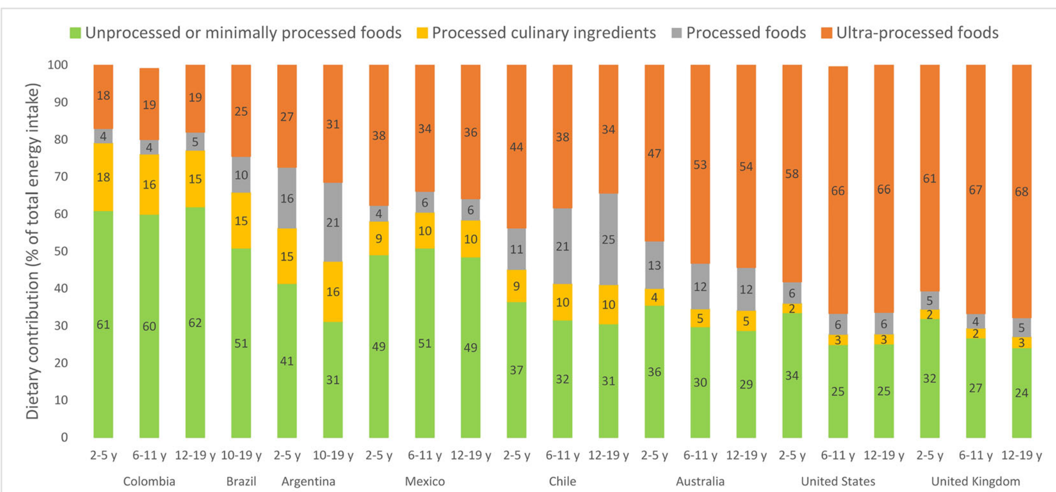


FIGURE 1 The contribution of the NOVA food groups to total energy intake by country and age group

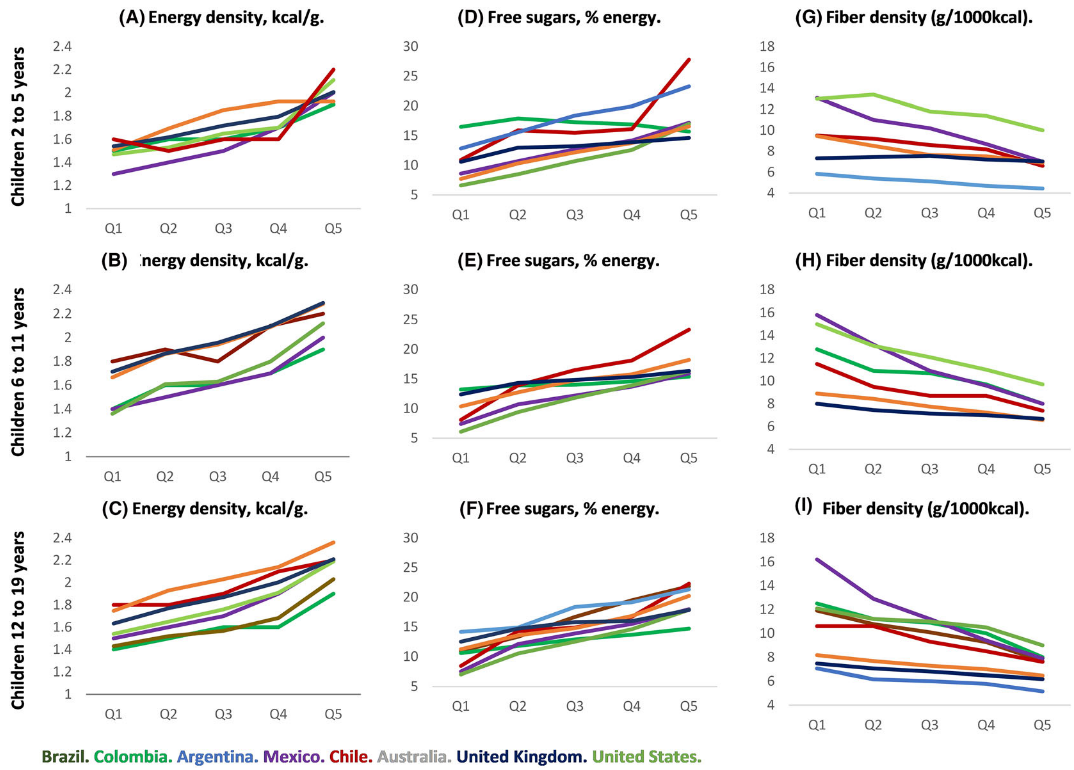


FIGURE 2 (A) Mean dietary energy density, (B) mean content of free sugars, and (C) mean content of fiber across quintiles of the dietary share of ultraprocessed foods for each country and within the three age groups

For school-aged children (Figure 4), the effects range from +0.08 kcal/g in Colombia to +0.15 kcal/g in the United States for energy density, from +0.57% of total energy in Colombia to +2.50% of total energy in Chile for the content of free sugars, and from −0.34 g/1000 kcal in the United Kingdom to −1.2 g/1000 kcal in Mexico for the fiber content.

Among adolescents (Figure 5), the effects range from +0.03 kcal/g in Brazil to +0.15 kcal/g in the United Kingdom for energy density, from +0.94% of total energy in Colombia and by 2.20% of total energy in Chile for the content of free sugars, and from −0.20 g/1000 kcal in Argentina to -1.2 g/1000 kcal in Mexico for fiber content.

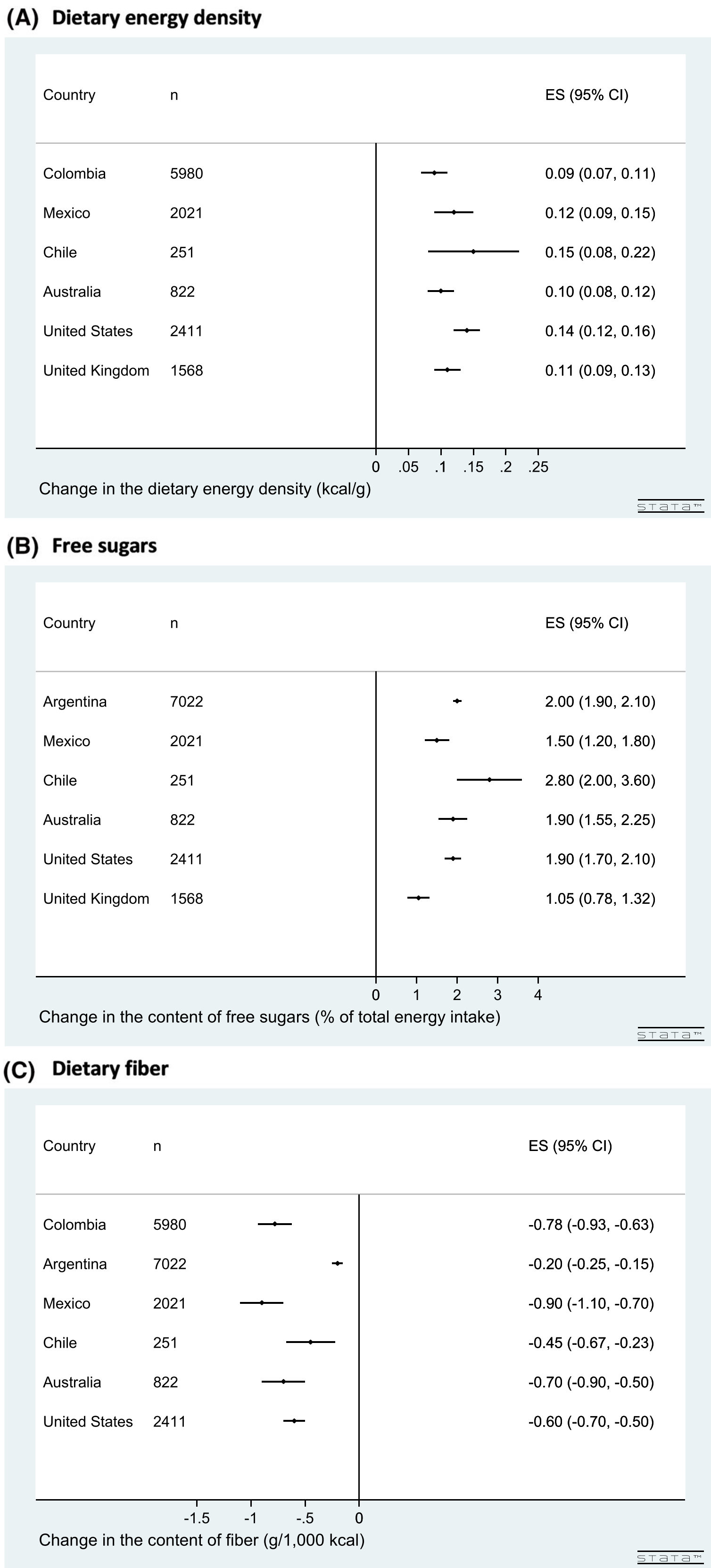
4 | DISCUSSION

To our knowledge, this is the first study analyzing the relationship between ultraprocessed food consumption and dietary nutrient profiles linked to obesity in children and adolescents using nationally representative data from different countries in diverse regions. Applying a common study design and statistical framework, we found in most countries and age groups positive dose–response associations between dietary share of ultraprocessed foods and dietary energy density and dietary content of free sugars and negative dose–response associations with dietary fiber content.

Compared with evidence from previous population-based studies,[6, 8, 10, 11, 26, 33, 36–38, 53] our findings show that the share of ultraprocessed foods in children and adolescents' diets (from 18% to 68% of all calories) is higher than that reported in the adult population (16% to 59% of all calories) of all countries included in this analysis. With the exception of Chile and Mexico, where preschool children are the highest consumers, we found that school-aged children and adolescents are the greatest consumers of ultraprocessed foods.

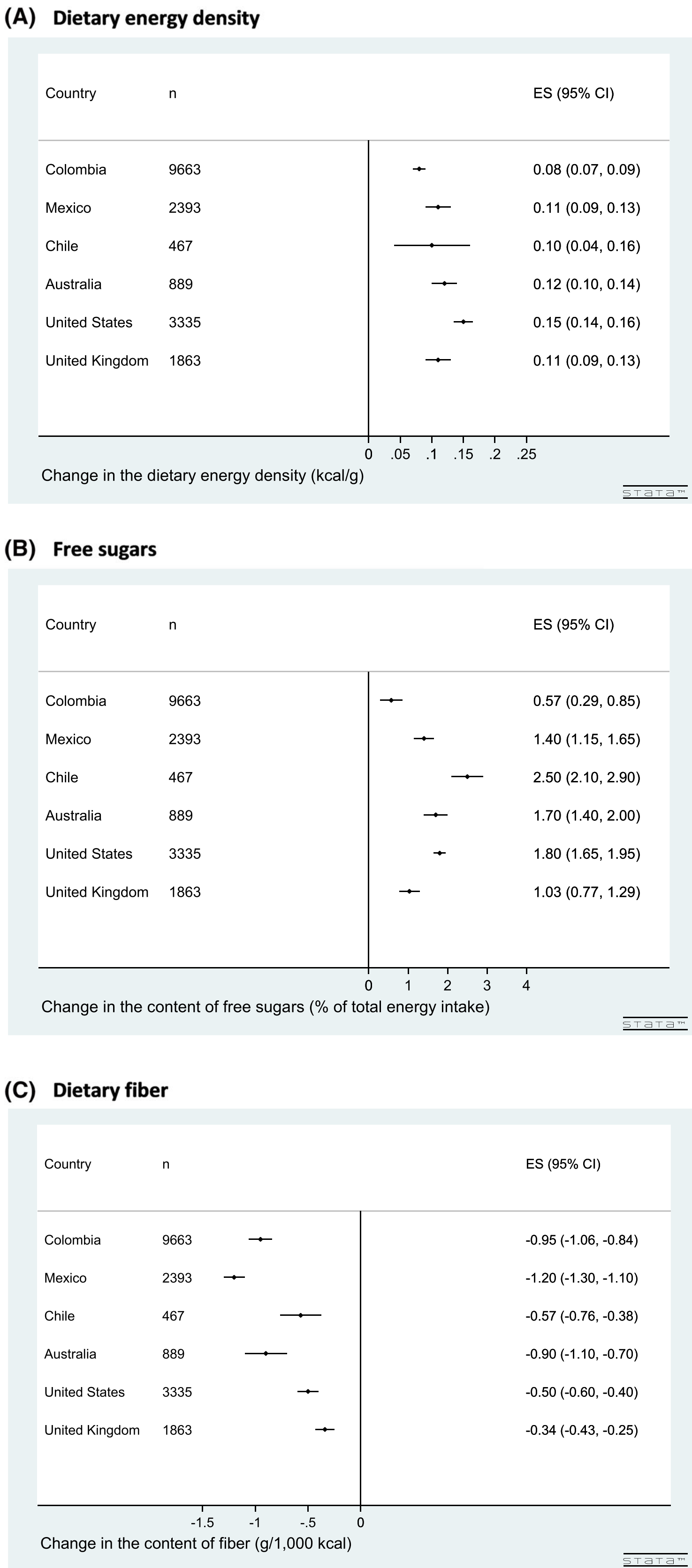
Dietary intake in school-aged children and adolescents is driven by their immediate needs, and they are susceptible to unhealthy food marketing due to developmental vulnerabilities and peer-group influence.[54] Added to this is the concern that aggressive marketing of ultraprocessed foods can shape their taste, immediate and future consumption, food brand preferences, and their families' purchasing decisions which is considered an important risk factor for childhood obesity.[1, 55] These critical aspects of children and adolescents' interpersonal/social-environmental characteristics and consequent dietary patterns are associated with decreased diet quality,[56, 57] making these life stages critical times for the preventive reduction of risk factors for obesity.

We identified a negative impact of ultraprocessed foods on children and adolescents' diets in all countries studied, irrespective of the extent of the dietary share of ultraprocessed foods, population groups, region, culture, food access pattern, and underlying food system. Our findings are similar to those from previous studies conducted in adults



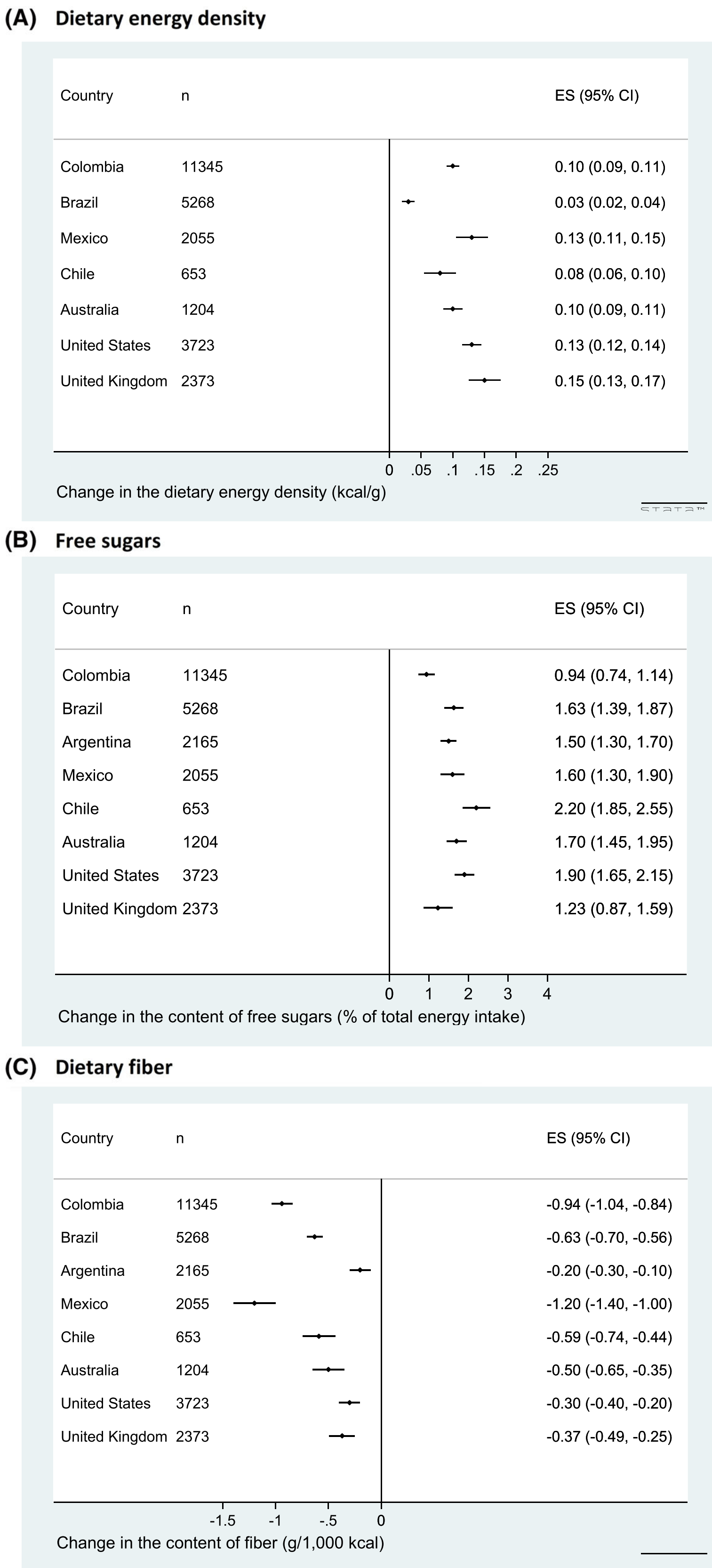
*Adjusted for sociodemographic factors listed in Table 1

FIGURE 3 Effect of a 10% increase in the dietary share of ultraprocessed foods among 2- to 5-year-old children on (A) the dietary energy density, (B) content of free sugars, and (C) content of fiber for each country. These analyses were performed when a significant linear trend was demonstrated across quintiles



*Adjusted for sociodemographic factors listed in Table 1

FIGURE 4 Effect of a 10% increase in the dietary share of ultraprocessed foods among 6- to 11-year-old children on (A) the dietary energy density, (B) content of free sugars, and (C) content of fiber for each country. These analyses were performed when a significant linear trend was demonstrated across quintiles



*Adjusted for sociodemographic factors listed in Table 1

FIGURE 5 Effect of a 10% increase in the dietary share of ultraprocessed foods among 12- to 19-year-old children on (A) the dietary energy density, (B) content of free sugars, and (C) content of fiber for each country. These analyses were performed when a significant linear trend was demonstrated across quintiles

from high- and middle-income countries, which have shown strong associations between consumption of ultraprocessed foods and diets with higher dietary content of free sugars,[4–6, 9, 32] higher energy density,[3, 4, 11] and lower fiber content.[3, 4, 9–11]

Processes and ingredients used to manufacture ultraprocessed foods are designed to create highly profitable, convenient, extremely palatable products that dislocate freshly prepared dishes and meals made from unprocessed or minimally processed foods and processed culinary ingredients.[2] The ingredients of ultraprocessed foods, generally unhealthy types of fats, starches, free sugars, and salt, plus food substances of no or rare culinary use and additives, make them energy dense, sugary, fatty, salty, and depleted in fiber, micronutrients, and bioactive compounds.[2]

Our findings add to evidence that the unfavorable dietary nutrient profile of ultraprocessed foods may be an important driver of the childhood obesity epidemic.[28, 58–62] However, the actual mechanisms by which ultraprocessed foods increase the risk of obesity are yet to be fully identified. There are indications that dietary patterns based on ultraprocessed foods influence health through a diversity of biological pathways. The greater deconstruction of the original food matrix related to the degree of processing,[63] the protein leverage hypothesis (reduction in dietary protein density to drive energy overconsumption),[64] higher energy intake rate (kcal/min),[65] and the presence of cosmetic food additives have all been implicated in less satiation and increased energy intake,[63, 64] low-grade gut inflammation,[66] and weight gain.[12]

Our study findings have important implications for strategies to prevent childhood overweight and obesity globally and provide a baseline to measure future progress of included countries. They reinforce the importance of promoting the consumption of minimally processed foods and limiting ultraprocessed foods, especially among children and adolescents. Much can be learnt from strategies recently implemented in the LA countries included in this analysis. These include food-based dietary guidelines that contain clear advice that young children[67] and adults[68] should avoid ultraprocessed foods, taxation of sugar sweetened beverages and high sugar snacks, and Food-Labeling and Advertising Law to protect the food environment for children and adolescents.[69, 70] The accumulation of consistent findings on the link between ultraprocessed foods and health is leading national public health authorities in Belgium and France to recommend privileging the consumption of unprocessed/minimally processed foods and limiting the consumption of ultraprocessed foods.[71, 72] The recently released food-based dietary guidelines from Belgium[71] and the target of a 20% reduction of consumption of ultraprocessed foods in France by 2022 set by the French National Programme for Nutrition and Health (PNNS) are good examples of this.[72] However, further research is needed to evaluate the impact of these measures on ultraprocessed food consumption and overweight and obesity, in both children and adults.

This study has several strengths. It is the first to our knowledge to examine the relationship between ultraprocessed food consumption and nutrients related to an increased risk of obesity among children and adolescents from multiple countries through a common study design and statistical framework, allowing comparability and increasing generalizability. The availability of individual-level consumption data and demographic data on large national samples of children and adolescents, and the use of the NOVA system for classifying foods and drinks according to level and purpose of processing, recognized as a relevant approach to investigate the link between nutrition and incidence of obesity,[12–15, 19, 20] are other important strengths. However, there are potential limitations to consider. Though analyses were controlled for several sociodemographic variables, residual confounding might remain. The data are based on a limited number of days of dietary recall or food record. Such as with any self-reported data, there are inherent limitations to this method of dietary assessment. Although most surveys collected information indicating food processing (i.e., combination food codes, places of meals, and product brands), these data are not consistently determined for all food items in all datasets, which can lead to misclassification of foods or inaccurate calculation of dietary energy density. Potential misclassification errors may lead to underestimation or overestimation of ultraprocessed food consumption. However, to reduce misclassification errors, each research team reviewed one another's classification and discussed inconsistencies until consensus was achieved. Cases of classification uncertainty were solved using a conservative approach, opting for the lesser degree of processing or assuming a homemade recipe, which could have led to underestimation of ultraprocessed food consumption. Finally, some of the survey data used in this study is quite old. Even though these may be the most recent data available for each country, it is unlikely that our findings reflect current dietary patterns, especially in LA where there has been rapid growth in sales of ultraprocessed food over the past 20 years.[73]

In conclusion, our findings show that ultraprocessed foods contribute substantially to children and adolescents' diets of many nations and represent a dietary nutrient profile consistent with an increased risk of obesity. These findings should be applied to create effective policy action to address growing ultraprocessed food consumption and childhood obesity across the globe. As such, framing the adoption of a clear and universal avoidance of ultraprocessed foods in children's everyday environments may be an effective strategy for improving diet and nutrition, managing body weight, and reducing childhood obesity.

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CONFLICT OF INTEREST

No conflict of interest statement.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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