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Short Communication

Processed and ultra-processed foods are associated with lower-quality nutrient profiles in children from Colombia

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Abstract

Objective: To determine if processed and ultra-processed foods consumed by children in Colombia are associated with lower-quality nutrition profiles than less processed foods.

Design: We obtained information on sociodemographic and anthropometric variables and dietary information through dietary records and 24 h recalls from a convenience sample of the Bogotá School Children Cohort. Foods were classified into three categories: (i) unprocessed and minimally processed foods, (ii) processed culinary ingredients and (iii) processed and ultra-processed foods. We also examined the combination of unprocessed foods and processed culinary ingredients.

Setting: Representative sample of children from low- to middle-income families in Bogotá, Colombia.

Subjects: Children aged 5–12 years in 2011 Bogotá School Children Cohort.

Results: We found that processed and ultra-processed foods are of lower dietary quality in general. Nutrients that were lower in processed and ultra-processed foods following adjustment for total energy intake included: *n*-3 PUFA, vitamins A, B_{12}, C and E, Ca and Zn. Nutrients that were higher in energy-adjusted processed and ultra-processed foods compared with unprocessed foods included: Na, sugar and *trans*-fatty acids, although we also found that some healthy nutrients, including folate and Fe, were higher in processed and ultra-processed foods compared with unprocessed and minimally processed foods.

Conclusions: Processed and ultra-processed foods generally have unhealthy nutrition profiles. Our findings suggest the categorization of foods based on processing characteristics is promising for understanding the influence of food processing on children's dietary quality. More studies accounting for the type and degree of food processing are needed.

Keywords
Processed and ultra-processed foods
Nutrients
Children

Many countries in Latin America have recently experienced significant economic and social advancement[1,2] leading to a nutrition transition. There is a decline in the consumption of whole grains, fruits and vegetables, and a rise in the consumption of animal food products and processed foods high in fats and sugars[2], accompanied by a rising prevalence of overweight and sedentary lifestyles[3,4].

Studies in developed countries have shown that diets composed of white bread, sweets, red meat and other low-quality processed foods are positively associated with overweight risk among children aged 6–11 years[5,6]. A previous study involving the Bogotá School Children Cohort found a positive correlation between child overweight and a snacking dietary pattern[7].

Many studies have examined the association between poor-quality dietary patterns and overweight. However, examinations of food intake using categorization methods classifying foodstuffs based on type, intensity and purpose

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of processing are now critical to informing nutrition public health policy, as food processing becomes increasingly prevalent[2,8,9]. A few studies conducted in Brazil using such methods have been published in the past 2 years[10–12] showing that micronutrient content was lower in ultra-processed foods[10] while energy density and fat were higher[11,12]. Furthermore, Rauber *et al.* found that intake of ultra-processed products was a predictor of a higher increase in total cholesterol and LDL cholesterol levels from pre-school to school age[13].

Our aim was to compare the quality of nutrient profiles by food processing categories, and among tertiles of processed and ultra-processed food intake, in our sample of children from the Bogotá School Children Cohort.

Methods

The present study was conducted using a convenience sub-sample from the Bogotá School Children Cohort, a representative study population from low- and middle-income families in Bogotá[14]. Information on this cohort study design has been reported previously in detail[14].

In February 2006, 3202 public primary-school children aged 5–12 years were recruited in Bogotá using cluster sampling, with classrooms as the sampling units. Information on sociodemographic and lifestyle variables was collected at the time of enrolment with a self-administered questionnaire completed by the parents. Food security was measured using a version of the Spanish-language US Department of Agriculture Household Food Security Survey Module and the Community Childhood Hunger Identification Project[14]. In the weeks following enrolment, teams of trained research assistants visited the public schools. After obtaining confirmed participation consent from the parents of the children, anthropometric measurements were collected using standard techniques[15].

For the present study we used a convenience sub-sample of 223 children from the Bogotá School Children Cohort from a few selected schools to guarantee 100 % participation. Baseline characteristics of children with dietary data are not different from those of the rest of the cohort, and therefore the sample is still representative of low- to middle-income families in Bogotá. Dietary intake was collected using two different methods (24 h recalls and dietary records which were administered to the mothers by trained dietitians) because it was difficult for some families to find the time to be interviewed. It was decided to collect at least one 24 h recall and one dietary record, and whenever possible we collected more than 2 d. In the end, the number of dietary records and 24 h recalls varies from one to six with an average of three per child. Each food from the dietary records and 24 h recalls was coded according to guidelines from Monteiro *et al.* and the nutrient composition of these foods was found using US Department of Agriculture food composition tables complemented with local food tables and chromatography analysis of fatty acids in cooking oils[8,9,16]. The three processed food categories are (i) unprocessed and minimally processed foods, (ii) processed culinary ingredients and (iii) processed and ultra-processed food products, according to the original classification of Monteiro *et al.*[9]. Two independent research assistants carried out categorization with high reliability ($\kappa = 0{\cdot}80$). Disagreements were resolved by a third independent reviewer.

Data analysis

We calculated the total energy intake and percentage of total energy by food processing group. We also calculated the percentage of total energy from fats, protein, carbohydrates and sugars, by food processing group. Then, for these nutrients as well as for fibre, cholesterol, vitamins, folate, Ca, Fe, K, Na and Zn, we adjusted for total energy intake using the residual method[17]. Differences by food processing group were tested with a one-way ANOVA and a t test. We also present average nutrient levels, adjusted for total energy intake and stratified by tertiles of intake of processed and ultra-processed foods. ANOVA was used to test differences across tertiles.

P values were considered significant at the $P < 0{\cdot}05$ level. All analyses were conducted using the statistical software package SAS version 9.3.

Results

Table 1 shows characteristics of the 223 children from the Bogotá School Children Cohort overall and stratified by child's sex (Table 1).

Table 2 shows that foods from group 1 (unprocessed and minimally processed) represented 45·2 % of total daily energy intake, foods from group 2 (processed culinary ingredients) represented 20·4 % and foods from group 3 (processed and ultra-processed) represented 34·4 % (Table 2). Diets high in processed and ultra-processed foods were in general of lower quality than diets high in unprocessed and minimally processed foods, although not all nutrients followed this expected distribution. Nutrient indicators known to be beneficial for health that were lower in the processed and ultra-processed category compared with unprocessed and minimally processed foods and processed culinary ingredients included: n-3 PUFA ($P < 0{\cdot}001$), fibre ($P < 0{\cdot}001$), vitamin A ($P < 0{\cdot}001$), vitamin B_{12} ($P < 0{\cdot}001$), vitamin C ($P < 0{\cdot}001$), vitamin E ($P < 0{\cdot}001$), Ca ($P = 0{\cdot}019$), K ($P < 0{\cdot}001$) and Zn ($P < 0{\cdot}001$). Nutrient indicators known to be detrimental to health that were higher in processed and ultra-processed foods compared with unprocessed and minimally processed foods and processed culinary ingredients included Na ($P < 0{\cdot}001$; Table 2). Some nutrients known to be detrimental, including sugar and *trans*-fatty acids, though lower in processed

Table 1 Baseline characteristics of children aged 5–12 years (*n* 223) from low- to middle-income families in Bogotá, Colombia

	Whole sample (*n* 223)		Males (*n* 119)		Females (*n* 104)	
	Mean or %	SD	Mean or %	SD	Mean or %	SD
Child's BMIZ (WHO)	0·2	1·1	0·3	1·2	0·1	0·9
Child's age (years)	8·5	1·9	8·6	1·8	8·4	1·9
Child's HAZ (WHO)	–0·6	0·9	–0·6	0·9	–0·7	0·8
Child's subscapular-to-triceps skinfold thickness ratio	0·7	0·2	0·7	0·2	0·7	0·2
Child was born in Bogotá (% yes)	89·5	–	90·5	–	88·2	–
Time watching TV/video games per week (h)	16·5	13·8	15·9	14·0	17·1	13·6
Time playing outside last week (h)	6·3	7·5	6·6	7·2	6·0	7·9
Mother's age (years)	35·4	6·8	36·2	7·2	34·6	6·4
Mother is single parent (% yes)	21·2	–	21·6	–	20·8	–
Mother's education (years)	9·2	3·3	9·1	3·5	9·3	3·1
Home ownership (% yes)	30·5	–	31·5	–	29·3	–
Number of home assets	4·3	1·4	4·4	1·5	4·2	1·4
Mother's height (cm)	157·8	6·2	157·2	5·6	158·4	6·7
Mother's BMI (kg/m^2)	23·8	3·8	24·0	4·0	23·7	3·6
Food security (% yes)	28·6	–	31·3	–	25·7	–
SES stratum (% 1 or 2, i.e. lowest)	16·1	–	13·5	–	19·2	–

BMIZ, BMI-for-age *Z*-score; HAZ, height-for-age *Z*-score; TV, television; SES, socio-economic status.

and ultra-processed foods compared with the combination of unprocessed and minimally processed foods and processed culinary ingredients, were higher in processed and ultra-processed foods compared with unprocessed and minimally processed foods alone ($P<0·001$ and $P=0·007$, respectively; Table 2). However, some nutrients known to be beneficial to health, including folate and Fe, were higher in processed and ultra-processed foods compared with unprocessed and minimally processed foods ($P=0·015$ and $P=0·008$, respectively; Table 2).

Results from Table 3 allow us to directly assess the association between the contribution of processed and ultra-processed foods to dietary intake and the nutrient quality of the overall diet. We observed a significant increase in the mean daily intakes of the following unhealthy nutrients with increasing tertiles of processed and ultra-processed food consumption: saturated fat ($P<0·001$), sugar ($P<0·001$) and Na ($P<0·001$); and a significant decrease in mean daily intakes of the following health-promoting nutrients with each increasing tertile: protein ($P<0·001$), fibre ($P<0·001$), vitamin C ($P=0·025$) and Zn ($P<0·001$).

Discussion

Our results support our hypothesis that diets consisting of greater consumption of energy from processed and ultra-processed foods and less from unprocessed and minimally processed foods are of lower quality. These diets are composed overall of lower amounts of beneficial nutrients and higher amounts of detrimental nutrients. Particularly, compared with unprocessed and minimally processed foods, we observed higher levels in processed and ultra-processed foods of Na, sugar and *trans*-fatty acids and lower levels of fibre, K, many vitamins and Zn. Additionally, with increasing processed and ultra-processed food consumption we observed greater mean daily intake of saturated fat. These findings suggest that reducing processed and ultra-processed food consumption is an important method of promoting healthy eating among Colombian children.

We saw higher Fe and folate in the processed and ultra-processed group compared with the unprocessed and minimally processed foods because of flour fortification. However, high exposure to synthetic folate from ultra-processed foods may result in high amounts of unmetabolized folic acid that may lead to increased risk of cancer[18,19].

We also found that the low-dietary-quality processed and ultra-processed foods made up over a third of our Bogotá School Children Cohort sample's average total daily energy intake. These findings support the evidence of a transition to a dietary pattern composed of greater amounts of significantly lower-quality processed foods among children in Colombia. This shift should be combated to address the rising health problems among Colombian children that are known to be associated with a poor-quality diet largely composed of high-energy-density processed foods.

Our study sample is a representative sample of children from low- to middle-income families in Bogotá. In some transitioning countries, there is evidence that lower income groups are more susceptible to the convergence towards cheaper high-energy-density foods, whereas more educated higher income groups converge towards 'healthy market niches'[20]. However, as developing countries such as Colombia urbanize, they become part of a global culture. This globalization westernizes diets in Latin America, and those with higher incomes often live in more urban areas with better access to processed foods[21]. Thus, the relationship between

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Table 2 Distribution of nutrients by group of processed foods, adjusted for total energy intake, among children aged 5–12 years (*n* 223) from low- to middle-income families in Bogotá, Colombia

	Unprocessed and minimally processed foods		Processed culinary ingredients		Combination: unprocessed and minimally processed foods and processed culinary ingredients		Processed and ultra-processed foods		Total*			
	Mean or %	SD	Mean or %	SD	Mean or %	SD	Mean or %	SD	Mean	SD	*P*†	*P*‡
Energy (kJ/d)	3415	1115	1515	422	4931	1243	2610	937	7541	1442	<0·001	<0·001
Energy (kcal/d)	816·3	266·5	362·2	100·9	1178·5	297·2	623·8	223·9	1802·3	344·6	<0·001	<0·001
Percentage of total energy (%)	45·2	–	20·4	–	65·6	–	34·4	–	–	–	–	–
Percentage of energy from total fat (%)	38·9	–	33·6	–	72·5	–	27·5	–	–	–	–	–
Total fat adjusted for total energy intake (g/d)	23·0	6·4	20·0	5·6	42·9	8·7	16·8	7·5	59·4	8·7	<0·001	<0·001
Percentage of energy from saturated fat (%)	50·3	–	15·7	–	65·9	–	34·1	–	–	–	–	–
Saturated fat adjusted for total energy intake (g/d)	9·4	2·6	2·9	1·0	12·3	2·7	6·9	3·8	19·0	3·7	<0·001	<0·001
Percentage of energy from monounsaturated fat (%)	51·4	–	30·6	–	82·0	–	18·0	–	–	–	–	–
Monounsaturated fat adjusted for total energy intake (g/d)	7·8	2·6	4·7	1·7	12·5	3·1	2·8	2·1	15·3	3·4	<0·001	<0·001
Percentage of energy from polyunsaturated fat (%)	14·5	–	68·2	–	82·7	–	17·3	–	–	–	–	–
Polyunsaturated fat adjusted for total energy intake (g/d)	2·5	1·0	12·4	4·2	14·8	3·8	3·0	1·7	17·7	3·7	<0·001	0·120
Percentage of energy from *n*-3 PUFA (%)	63·7	–	0·8	–	64·5	–	35·5	–	–	–	–	–
n-3 PUFA adjusted for total energy intake (g/d)	0·04	0·01	0·00	0·00	0·04	0·01	0·02	0·01	0·10	0·02	<0·001	<0·001
Percentage of energy from *n*-6 PUFA (%)	41·8	–	5·0	–	46·9	–	53·4	–	–	–	–	–
n-6 PUFA adjusted for total energy intake (g/d)	0·2	0·1	0·03	0·1	0·2	0·1	0·2	0·1	0·5	0·1	<0·001	0·995
Percentage of energy from *trans*-fatty acids (%)	1·2	–	94·4	–	95·2	–	4·8	–	–	–	–	–
Trans-fatty acids adjusted for total energy intake (g/d)	0·01	0·02	0·9	0·5	0·9	0·5	0·1	0·2	1·0	0·6	<0·001	0·007
Percentage of energy from protein (%)	63·4	–	6·2	–	69·6	–	30·4	–	–	–	–	–
Protein adjusted for total energy intake (g/d)	39·8	9·6	3·8	2·7	43·6	9·3	19·1	6·8	62·3	7·5	<0·001	<0·001
Percentage of energy from carbohydrates (%)	43·5	–	17·6	–	61·1	–	38·9	–	–	–	–	–
Carbohydrates adjusted for total energy intake (g/d)	111·2	27·7	45·4	17·7	222·4	55·5	101·3	31·7	256·1	22	<0·001	<0·001
Percentage of energy from sugar (%)	30·8	–	29·8	–	60·5	–	39·5	–	–	–	–	–
Sugar adjusted for total energy intake (g/d)	29·3	10·5	28·8	12·5	58·1	16·9	39·7	18·9	97·2	19·6	<0·001	<0·001
Fibre adjusted for total energy intake (g/d)	11·1	3·9	1·5	1·3	12·7	4·0	3·8	2·0	16·5	3·9	<0·001	<0·001
Cholesterol adjusted for total energy intake (mg/d)	225·9	106·1	0·3	1·2	226·1	106·1	40·9	29·4	268·4	104·6	<0·001	<0·001
Vitamin A adjusted for total energy intake (μg/d)	1153	886	45	49	1198	886	522	2439	1738	2888	<0·001	<0·001
Vitamin A adjusted for total energy intake (IU/d)	3843·8	2953·2	150·1	163·6	3993·6	2953·1	1739·0	8129·4	5792·4	9627·0	<0·001	<0·001
Vitamin B_{12} adjusted for total energy intake (μg/d)	3·2	4·7	0·1	0·1	3·1	2·4	1·8	5·6	5·1	7·0	<0·001	0·001
Vitamin C adjusted for total energy intake (mg/d)	106·0	121·6	2·8	2·8	108·9	121·9	15·2	80·2	124·9	154·1	<0·001	<0·001
Vitamin D adjusted for total energy intake (μg/d)	2·63	1·01	0·00	0·00	2·63	1·01	3·69	20·26	5·84	17·28	0·003	0·604
Vitamin D adjusted for total energy intake (IU/d)	105·2	40·4	0·0	0·0	105·2	40·4	147·7	810·2	233·6	691·1	0·003	0·604
Vitamin E adjusted for total energy intake (mg/d)	1·2	0·6	8·6	2·2	9·8	2·3	0·5	0·3	10·2	2·4	<0·001	<0·001
Folate adjusted for total energy intake (μg/d)	102·6	43·0	14·0	8·2	114·4	40·7	113·5	56·6	226·5	63·9	<0·001	0·015
Ca adjusted for total energy intake (mg/d)	371·7	115·6	57·2	50·9	428·6	133·1	310·0	395·8	736·1	394·6	<0·001	0·019
Fe adjusted for total energy intake (mg/d)	5·3	1·6	1·8	1·3	7·0	1·8	6·9	9·6	14·0	9·4	<0·001	0·008
K adjusted for total energy intake (mg/d)	1728·1	449·1	56·8	85·1	1724·1	493·0	584·4	509·9	2332·9	577·0	<0·001	<0·001
Na adjusted for total energy intake (mg/d)	552·5	283·8	11·3	31·1	563·3	274·7	865·2	314·2	1426·6	321·2	<0·001	<0·001
Zn adjusted for total energy intake (mg/d)	4·9	1·6	0·8	0·5	5·6	1·6	1·7	0·9	7·3	1·6	<0·001	<0·001

*The total is the mean of the combination of the unprocessed and minimally processed foods, processed culinary ingredients, and processed and ultra-processed foods columns.
†One-way ANOVA comparing three groups: (i) unprocessed and minimally processed foods, (ii) processed culinary ingredients and (iii) processed and ultra-processed foods.
‡*t* Test comparing two groups: (i) unprocessed and minimally processed foods and (ii) processed and ultra-processed foods.

Table 3 Average nutrient levels, adjusted by total energy intake and stratified by tertiles of intake of processed and ultra-processed foods, among children aged 5–12 years (*n* 223) from low- to middle-income families in Bogotá, Colombia

	Tertiles (T) of consumption of processed and ultra-processed foods			
	T1 (*n* 74)	T2 (*n* 75)	T3 (*n* 74)	*P**
Mean percentage of energy from total fat (%)	29·4	30·8	30·1	0·129
Mean percentage of energy from protein (%)	14·3	14·4	13·5	<0·001
Mean percentage of energy from carbohydrates (%)	58·3	56·8	58·3	0·127
Total fat adjusted for total energy intake (g/d)	57·3	60·8	60·1	0·037
Saturated fat adjusted for total energy intake (g/d)	17·3	19·6	20·2	<0·001
Monounsaturated fat adjusted for total energy intake (g/d)	15·6	15·6	14·6	0·105
Polyunsaturated fat adjusted for total energy intake (g/d)	18·0	18·3	16·9	0·039
n-3 PUFA adjusted for total energy intake (g/d)	0·1	0·1	0·1	0·860
n-6 PUFA adjusted for total energy intake (g/d)	0·4	0·4	0·5	0·033
Trans-fatty acids adjusted for total energy intake (g/d)	1·0	1·1	0·8	0·021
Protein adjusted for total energy intake (g/d)	62·6	64·0	60·4	0·011
Carbohydrates adjusted for total energy intake (g/d)	255·7	252·8	259·8	0·149
Sugar adjusted for total energy intake (g/d)	89·5	97·6	104·6	<0·001
Fibre adjusted for total energy intake (g/d)	18·1	16·3	15·0	<0·001
Cholesterol adjusted for total energy intake (mg/d)	260·6	305·1	239·2	<0·001
Vitamin A adjusted for total energy intake (μg/d)	1626	2248	1332	<0·001
Vitamin A adjusted for total energy intake (IU/d)	5419·8	7494·3	4439·9	0·141
Vitamin B_{12} adjusted for total energy intake (μg/d)	5·0	6·0	4·4	0·343
Vitamin C adjusted for total energy intake (mg/d)	146·8	142·4	85·3	0·025
Vitamin D adjusted for total energy intake (μg/d)	4·05	8·16	5·31	0·336
Vitamin D adjusted for total energy intake (IU/d)	161·9	325·4	212·3	0·336
Vitamin E adjusted for total energy intake (mg/d)	10·8	10·6	9·0	<0·001
Folate adjusted for total energy intake (μg/d)	227·1	221·2	231·1	0·635
Ca adjusted for total energy intake (mg/d)	633·9	768·5	805·4	0·020
Fe adjusted for total energy intake (mg/d)	13·1	14·9	13·9	0·495
K adjusted for total energy intake (mg/d)	2401·7	2362·0	2234·8	0·185
Na adjusted for total energy intake (mg/d)	1299·3	1405·3	1575·5	<0·001
Zn adjusted for total energy intake (mg/d)	7·7	7·5	6·7	<0·001

*One-way ANOVA.

socio-economic factors and diet is multifaceted in transitioning countries. Future investigations should examine populations in Latin American countries that represent a wide range of socio-economic statuses in order to assess the associations between these variables and dietary quality in these transitioning countries. This will direct policy to improve dietary quality.

Our study has some limitations. Our results cannot be generalized to children from high-income families. The dietary records and 24 h recalls measuring dietary information in the children were administered to the children's mothers with consequent potential for misclassification. Some nutrients like Na are likely to be estimated with more error because added salt intake is not recalled accurately. *Trans*-fatty acids are higher for the processed culinary ingredients group because we had information on the type of oil that each family was consuming and we analysed the fatty acid composition by GC[16]. On the other hand, many of the snacks consumed in Colombia are made with palm oil that is not partially hydrogenated. However, we cannot rule out the possibility that a lower amount of *trans*-fatty acids in the processed/ultra-processed group is due to lack of accurate food composition tables. Similarly, sugar intake was calculated as total sugar since the available food composition tables did not allow us to distinguish between sugars naturally found in foods and added sugars.

A final limitation is that, within the last 2 years, the classification criteria for food processing have improved such that a distinction has been made between processed and ultra-processed foods[22]. Studies using this updated classification have demonstrated a global rise in production and consumption of ultra-processed foods and a substantial negative impact of these foods on dietary quality and conditions such as obesity and metabolic syndrome[22]. Due to the timing of the present work, we analysed processed and ultra-processed foods together. We uncovered valuable findings that these foods together have unhealthy nutrition profiles when compared with less processed foods and should be avoided by children. However, we acknowledge that distinction between processed and ultra-processed foods would have been useful to better inform dietary guidelines. In future studies, the updated version of the processing classification system should be used to examine the association between the shift towards an ultra-processed dietary pattern and children's dietary quality in Latin America[22].

Consumption of processed and ultra-processed foods is rising in Colombia[2]. This transition poses a serious public health threat in this country. Despite the aforementioned study limitations, we did find that, generally, Monteiro *et al.*'s three-group classification shows that diets high in processed and ultra-processed foods are of poorer quality.

This suggests that studies classifying foods by type, intensity and purpose of processing will be useful for understanding how the nutrition transition in Colombia and other developing countries is affecting children's health in future studies. Longitudinal studies examining these associations over time that are generalizable to children of varying socioeconomic status are also necessary.

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