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Association between the price of ultra-processed foods and obesity in Brazil

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Abstract *Background and aims:* To estimate the relationship between the price of ultra-processed foods and prevalence of obesity in Brazil and examine whether the relationship differed according to socioeconomic status.
Methods and results: Data from the national Household Budget Survey from 2008/09 (n = 55 570 households, divided in 550 strata) were used. Weight and height of all individuals were used. Weight was measured by using portable electronic scales (maximum capacity of 150 kg). Height (or length) was measured using portable stadiometers (maximum capacity: 200 cm long) or infant anthropometers (maximum capacity: 105 cm long). Multivariate regression models (log-log) were used to estimate price elasticity. An inverse association was found between the price of ultra-processed foods (per kg) and the prevalence of overweight (Body mass index (BMI) $\geq$25 kg/m^2) and obesity (BMI $\geq$30 kg/m^2) in Brazil. The price elasticity for ultra-processed foods was −0.33 (95% CI: −0.46; −0.20) for overweight and −0.59 (95% CI: −0.83; −0.36) for obesity. This indicated that a 1.00% increase in the price of ultra-processed foods would lead to a decrease in the prevalence of overweight and obesity of 0.33% and 0.59%, respectively. For the lower income group, the price elasticity for price of ultra-processed foods was −0.34 (95% CI: −0.50; −0.18) for overweight and −0.63 (95% CI: −0.91; −0.36) for obesity.
Conclusion: The price of ultra-processed foods was inversely associated with the prevalence of overweight and obesity in Brazil, mainly in the lowest socioeconomic status population. Therefore, the taxation of ultra-processed foods emerges as a prominent tool in the control of obesity.

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Introduction

Obesity is a major public health issue worldwide. Over 12.0% of the adult population (≥20 years) are obese [1]. The increase in obesity rates is expected to continue, affecting 19.5% of the global adult population by 2025 [2]. In Brazil, 56.9% of adults (≥18 years) are overweight, while 20.8% are obese [3]. Obesity is characterized both as a disease and as a risk factor for other noncommunicable diseases (NCDs), such as cardiovascular diseases, diabetes, and certain types of cancer [4]. In the year 2016, NCDs were responsible for 71.0% of all deaths worldwide and for 76.4% of all deaths in Brazil [5].

Increased consumption of ultra-processed foods has been associated with obesity [6–8] and with NCDs [9], hypertension [10], and some types of cancer [11]. Ultra-processed foods are industrial formulations, which in addition to salt, sugar, oils, and fats include substances (in particular additives) used to imitate the sensorial qualities of minimally processed foods and their culinary preparations [12]. Diets with high amount of ultra-processed foods tend to be nutritionally unbalanced, promote passive and excessive consumption of food and beverages and, thus, are harmful to health [13–15]. In Brazil, the household acquisition of ultra-processed foods increased from 20.8% to 25.4% of the total calories from 2003 to 2009 [16]. Regarding energy dairy intake per adults (from 20 to 64 years) in Brazil, there is greater consumption of ultra-processed foods among women and among those with higher levels of income [17].

Food choices are influenced by individual aspects and by environmental aspects, especially price [18]. Ultra-processed foods tend to have a lower price than unprocessed foods [19]. These results have fomented the discussion about the adoption of economic measures (such as taxes on unhealthy foods and beverages) to curb the obesity epidemic in the country [20,21]. Since 2016, the World Health Organization (WHO) has advocated taxation that would increase the price of sweetened beverages by 20% [22].

Previous studies suggest an inverse association between unhealthy food prices and nutritional status [23–26]. However, generally this association is based on studies with specific food groups recognized as unhealthy [23–25], in a restricted population (such as children, adolescents, or adults) from developed countries [23,24,26]. Prior to the present investigation, no study has focused on the relationship between the price of ultra-processed foods group and nutritional status of the population using a nationally representative sample from a developing country. Therefore, the aim of the present study was to estimate the relationship between the price of ultra-processed foods and prevalence of overweight and obesity in Brazil and examine whether the relationship differed according to socioeconomic status.

Methods

Design and sample

Data from the national Household Budget Survey (HBS) conducted by the Brazilian Institute of Geography and Statistics (IBGE) between May 2008 and May 2009 were used [27,28]. The HBS 2008/9 employed a probabilistic sample, with a complex clustered sampling procedure, based on the random selection of census sectors during the first stage and of households in the second stage.

Initially, the census tracts of the country were organized into strata with high geographic and socioeconomic homogeneity. For this, the location of the sectors (region, federation unit, capital or interior, urban, or rural area) and the spectrum of variation of the socioeconomic level of the families were considered. Census tracts in each stratum and households belonging to each census tract were selected. Then, the tracts and their households were distributed uniformly throughout the four quarters of the year of the research, to reproduce the seasonal variations in expenditures and family income in each stratum. The final sample consisted of 550 household strata and 55570 households. A detailed description of the sampling process is available elsewhere [27]. The short reference period used by HBS 2008/9 to record food expenditures in each household (7 days) does not allow the identification of the usual food purchase patterns of each household studied. Thus, the unit of analysis of the present study was the set of households visited within each of the 550 strata in the survey sample. This approach ensures units of analysis with great amplitude of geographic and socioeconomic variation, in which annual food purchase pattern can be identified with great precision [27].

Data collection and organization

Household purchases of foods and beverages for household consumption, along with anthropometric (weight and height) and sociodemographic data comprised the main information of interest from the HBS 2008/9.

Household food acquisition data

Purchases of foods and beverages for household consumption were recorded over 7 consecutive days (prospectively), by one of the household members or by the interviewer. For each purchase the quantity acquired, the unit of measurement (with its equivalent by weight or volume), the expenditure value, the acquisition modes (monetary or nonmonetary), and the place of acquisition were recorded [27].

Data on the acquisition of about 1500 items were available. Initially, multiple records of acquisition of the same food item by households belonging to the same stratum were added (specifically, the total quantity (per kg) and the value of the expenditure (in R$)).

Items were then classified according to the NOVA system and organized into 4 groups: unprocessed or minimally processed foods; processed culinary ingredients; processed foods; and ultra-processed foods and drinks (with "ultra-processed foods" alone being used) [12]. Unprocessed or minimally processed foods are those obtained directly from plants or animals, which have not undergone any change, as well as those subjected to minimal changes. Processed culinary ingredients are products used to add flavor, cook, and assemble culinary preparations and are extracted from natural foods or directly from nature. Processed foods are those with added salt or sugar in their manufacture. Finally, products in which their manufacture involves several steps or processing techniques, mainly industrial, and various ingredients are ultra-processed foods [12]. For analytical purposes, all non-ultra-processed items were combined into a single complementary group.

The food items included in each category of the NOVA classification was presented as online supplementary material (Appendix A).

The price paid for each group, expressed in Reais (R$) per kilograms (kg) was then estimated by dividing the total expenditure of the group by the total quantity acquired (in kg) of the same group, in the stratum. The use of correction factors (such as excluding inedible parts (shells, seeds, and peels), among other losses that occur during food preparation) was not necessary because the price per food was estimated as purchased (some items may be raw). The price per unit of weight (R$/kg) were calculated instead of the price per calorie (R$/1000 kcal) to decrease the influence of food's energy density and to provide information beyond the nutritional perspective.

Anthropometric data

The weight and height of all individuals ($n = 190,159$) (in kg and centimeters, respectively) were directly measured in the households. The measurements were taken by trained researchers using standard techniques and a specific instrument. Weight was measured using portable electronic scales, with a maximum capacity of 150 kg, to the nearest 0.1 kg. The height comprises the measurement of length in children aged between 0 and 23 months and stature in individuals from 24 months of age. In those aged between 24 and 35 months, length and stature were measured (in centimeters). Infant anthropometers with a capacity of up to 105 cm (accurate to the nearest 0.1 cm) and portable stadiometers with a 200 cm-long (accurate to the nearest 0.1 cm) retractable tape measure were used to measure length and stature, respectively [27].

Body mass index (BMI) was estimated for all individuals. International classification standards recommended by the WHO were used for the classification of the nutritional status [29–31]. For adults and older adults, overweight was classified as BMI $\geq$25 kg/m^2 (including BMI $\geq$30 kg/m^2) and obesity as BMI $\geq$30 kg/m^2. For children, the classification was done in 2 ways: i) For children less than 5 years: overweight was classified as above +2 Z-score (including above +3 Z-score) and obesity as above +3 Z-score; and ii) For children aged 5 years or over and adolescent: overweight was classified as above +1 Z-score (including above +2 Z-score) and obesity as above +2 Z-score. These data were then used to estimate the proportion of overweight and obese individuals in each stratum.

Covariates

Monthly per capita income, expressed in R$, was estimated by dividing the sum of the income of all households in the stratum by the total number of individuals in the stratum. The mean age of the individuals in the stratum was estimated in an analogous way. The proportion of individuals by sex (women and men) and in the different age groups (0–1.99 years; 2–4.99 years; 5–9.99 years; 10–19.99 years; 20–59.99 years, and 60 years and over) in the stratum was then estimated. Finally, information regarding the geographic region (North, Northeast, Southeast, South, and Midwest) and area (urban and rural) of the strata complemented the analysis.

Food expenditure and income were deflated by IBGE at the end of data collection to a reference date (January 15, 2009) [27].

Data quality and imputation

After data collection was completed, critical review and imputation procedures were applied by IBGE to address errors that could potentially arise during the various research phases. This critical review identifies measurement, collection, and transcription errors (rejected values) through distortions in the scatter plots. Unresponsive errors (ignored values) are identified by missing or incomplete data. All rejected or ignored data were submitted for imputation. The imputation was especially necessary for those products, which the exact quantity purchased (in kg) is generally unknown to the consumer (such as fruits and vegetables, bread rolls, or eggs that are often purchased in units or in unlabeled packs; or small items such as candies or drops for which package it does not always contain information about the product quantity) (26.2% of total records). In these cases, the median price for the mentioned purchasing unit in each geographic location (considering the sociodemographic status of the location, based on valid values) was employed and the quantity purchased was defined as the ratio between the value expended in each acquisition (rarely missing) and this reference price. Imputation of anthropometric data (weight, height, or both) was also necessary for 15.2% of the individuals. In this case, Hot Deck procedure was employed to preserve the original distribution of the data [27,32]. These procedures follow international standards for data imputation in HBS. Further information on the imputation procedures used by IBGE can be found at the original report of the survey [27].

Data analysis

Initially, we presented the studied population through measures of central tendency (and dispersion).

We estimated the mean prevalence of overweight and obesity (and 95% confidence interval (95% CI)) by sex and age group, for the entire population and by quintiles of price of ultra-processed foods. Next, we estimated income-adjusted prevalence values for the same population groups. Linear regression models were used in both situations to analyze linear trends between the prevalence values and the price levels of ultra-processed foods. In these models, the value of mean increment corresponds to the regression coefficient (β).

We used linear regression models (log-log) to assess the relationship between the prevalence of overweight or obesity in the strata and the price of ultra-processed foods, and also estimate price (and income) elasticity. In these models, the elasticity value corresponds to the regression coefficient of the log-transformed independent variable. Elasticity coefficients indicate the percentage variation (positive or negative) in the prevalence of overweight or obesity given a 1.0% variation in the price of ultra-processed foods (price elasticity) or in income (income elasticity). We constructed the models in a sequence of increasing complexity, first involving only the price of the ultra-processed foods and then adding income, followed by the price of all other foods and beverages. The collapse of categories of the NOVA classification (except ultra-processed foods) in a single variable was important to control the price of all other non-ultra-processed food group vs. ultra-processed food group (main *exposure of the* study). Finally, a set of potential confounders: area, geographic region, and mean age of household strata members (in years) in the household strata.

The income level has been pointed as an important modifier factor of the effect of food prices on body weight [24,33–37]. Thus, the effect of ultra-processed food prices on the prevalence of overweight and obesity was tested not only in the total population, but also in the population stratified by two income groups (based on the median per capita income of the strata households).

The Stata 13.1 (STATA CORP., 2013[1]) software was used for data organization and analysis (considering the sampling design and weighting factors of the HBS 2008/9).

Ethical aspects

The present study was approved by the Ethics Committee for Research involving Human Subjects of the Federal University of Minas Gerais (CAAE number 88465018.1.0000.5149). Data from the HBS 2008/9 are publicly available and do not allow the identification of families.

[1] StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP.

Results

The study population was composed mostly of women (50.9%) and adults (between 20 and 59 years) (55.4%). The average education level of the adults (≥20 years) was 8 years of education. The majority lived in urban areas (84.4%) and in the Southeastern (44.1%) and Northeastern (26.1%) regions. The mean monthly per capita income

Table 1 Sociodemographic and economic characterization of the study units (550 household strata). Household Budget Survey, Brazil, 2008–2009.

Indicator	Mean	Standard-Error (SE)	Confidence Interval (95% CI)	
Females (%)	50.9	0.19	50.6	51.3
Age (%)				
Children under 2 years of age	2.68	0.08	2.52	2.84
Children 2–4 years of age	4.35	0.09	4.17	4.52
Children 5–9 years of age	8.40	0.15	8.11	8.69
Adolescents (10–19 years of age)	17.8	0.23	17.3	18.2
Adults (20–59 years of age)	55.4	0.28	54.8	55.9
Elderly (60 years or older)	11.5	0.27	10.9	12.0
Years of schooling (adults only ≥ 20 years)	8.03	0.12	7.80	8.26
Urban area (%)	84.4	1.72	80.7	87.5
Region (%)				
Northern	6.82	1.42	4.51	10.2
Northeastern	26.1	2.64	21.3	31.6
Southeastern	44.1	3.87	36.7	51.8
Southern	15.4	2.39	11.2	20.7
Midwestern	7.58	1.25	5.46	10.4
Monthly per capita income (R$)	887.7	42.2	804.7	970.6
Food prices (R$/kg)				
Fresh and minimally processed foods (1)	2.94	0.02	2.90	2.97
Processed culinary ingredients (2)	2.05	0.04	1.96	2.14
1 + 2[a]	2.81	0.02	2.77	2.84
Processed foods (3)	5.82	0.07	5.67	5.96
1 + 2 + 3[b]	3.03	0.02	2.99	3.08
Ultra-processed foods (4)	4.36	0.04	4.29	4.44

[a] Combination of the unprocessed or minimally processed foods group and of the processed culinary ingredients group.
[b] Combination of the unprocessed or minimally processed foods group, of the processed culinary ingredients group, and of processed foods group.

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corresponded to R$ 887.7 (US$ 262.6[2]). Ultra-processed foods were more expensive (R$ 4.36/kg or US$ 1.83/kg[2]) than non-ultra-processed foods (R$ 3.03/kg or US$ 1.27/kg[2]) (Table 1). The sociodemographic and economic characterization according to quintiles of price of ultra-processed foods were presented in the online supplementary material (Appendix B).

Higher overweight prevalence among men (42.0% vs. 39.8%, $p < 0.05$) and of obesity among women (13.8% vs. 11.7%, $p < 0.05$) were found (Table 2). After adjustment for income (necessary, since higher income families tend to pay more for the same food group due to increase in the quality of the product acquired), an inverse association was identified between the prevalence of overweight and obesity and the price of ultra-processed foods, for both sex ($p < 0.05$) (Table 2).

A relevant percentage of the children and adolescents were identified as overweight (34.6% of those aged between 6 and 9 years and 21.5% of those aged between 10 and 19 years) or obese (15.0% of those aged between 6 and 9 years and 5.3% of those aged between 10 and 19 years). Among the adults (aged between 20 and 59 years), 47.7% were overweight and 14.1% were obese. For both overweight and obesity, the highest prevalence values were observed among the older adults, 55.5% and 18.0%, respectively. Once again, after adjustment for income, an inverse relationship between the prevalence values (for all age) and the price of ultra-processed foods was observed ($p < 0.05$) (Table 3).

Table 4 presents adjusted price and income-elasticity coefficients for the prevalence of overweight and obesity in Brazil. The magnitude of the coefficients tended to be lower for the prevalence of overweight than for obesity. The price elasticity coefficient, for the price of ultra-processed foods was −0.33 for overweight and −0.59 for obesity (Model 4), indicating that a 1.00% increase in the price of ultra-processed foods would lead to a decrease in the prevalence of overweight and obesity (0.33% and 0.59%, respectively). Income elasticity was 0.17 for overweight and 0.22 for obesity, indicating an effect for income that was opposite in direction to and less than half the size of that of ultra-processed food prices: a 1.00% increase in income would lead to a 0.17% increase in the prevalence of overweight and 0.22% of obesity. The associations were concentrated in the lower half of the per capita income distribution of the population. For this group, the price elasticity coefficient for the price of ultra-processed foods was −0.34 for overweight and −0.63 for obesity. Coefficients for the upper half were not significant (Table 5).

Discussion

This is the first study to focus on the relationship between the price of ultra-processed foods and obesity, based on nationally representative data from a large middle-income

Table 2 Prevalence of overweight and obesity according to quintiles of price of ultra-processed foods by sex. Household Budget Survey, Brazil, 2008/9.

Sex		Quintiles of price of ultra-processed foods																			
		All			1st Quintile (2.41−3.90)			2nd Quintile (3.91−4.18)			3rd Quintile (4.19−4.40)			4th Quintile (4.41−4.75)			5th Quintile (4.76−7.76)			Mean Increment[a]	P-value
		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		β	
Overweight																					
Women	Unadjusted	39.8	39.0	40.6	39.5	38.3	40.7	39.9	38.1	41.7	40.5	38.1	42.8	39.6	37.9	41.3	39.8	38.0	41.5	0.03	0.889
	Income adjusted				42.4	41.1	43.6	41.1	40.2	42.0	39.8	39.1	40.6	38.6	37.6	39.5	37.3	35.9	38.7	−1.27	<0.001
Men	Unadjusted	42.0	40.9	43.1	38.5	36.9	40.0	39.6	36.9	42.3	41.4	39.0	43.9	43.1	40.8	45.4	47.4	45.8	49.1	2.14	<0.001
	Income adjusted				42.9	41.3	44.4	42.4	41.4	43.5	42.0	41.3	42.7	41.6	40.7	42.5	41.1	39.7	42.5	−0.43	<0.001
Total	Unadjusted	40.8	40.0	41.6	38.9	37.7	40.1	39.7	37.6	41.8	40.9	38.6	43.1	41.2	39.5	42.9	43.4	42.1	44.7	1.05	<0.001
	Income adjusted				42.6	41.4	43.8	41.7	40.9	42.5	40.8	40.2	41.4	39.9	39.1	40.7	39.0	37.9	40.2	−0.89	<0.001
Obesity																					
Women	Unadjusted	13.8	13.3	14.3	13.8	13.0	14.6	13.7	12.4	14.9	14.6	13.0	16.1	13.5	12.4	14.6	13.5	12.4	14.6	−0.07	0.669
	Income adjusted				15.4	14.4	16.4	14.6	13.9	15.3	13.8	13.3	14.3	13.0	12.4	13.6	12.2	11.3	13.1	−0.78	<0.001
Men	Unadjusted	11.7	11.2	12.1	10.2	9.6	10.9	11.0	10.0	12.1	11.8	10.4	13.2	12.3	11.2	13.5	12.9	12.2	13.6	0.67	<0.001
	Income adjusted				12.1	11.5	12.8	11.9	11.4	12.4	11.7	11.3	12.1	11.4	10.9	11.9	11.2	10.5	11.9	−0.24	<0.001
Total	Unadjusted	12.7	12.3	13.2	12.0	11.4	12.6	12.4	11.3	13.4	13.1	11.8	14.5	12.9	12.0	13.9	13.2	12.4	14.0	0.29	0.016
	Income adjusted				13.8	13.1	14.5	13.2	12.8	13.7	12.7	12.3	13.1	12.2	11.7	12.7	11.7	11.0	12.3	−0.53	<0.001

[a] Corresponding to the linear regression coefficient value of the indicator (prevalence of overweight and obesity) with increasing quintile of ultra-processed foods price, expressed in percentage points.

[2] Calculation based on dollar value as of January 15, 2009 (US$ 1.00 = R$ 2.38).

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Table 3 Prevalence of overweight and obesity according to quintiles of price of ultra-processed foods by age. Household Budget Survey, Brazil, 2008/9.

Variables		Quintiles of price of ultra-processed foods																			
		All			1st Quintile (2.41–3.90)			2nd Quintile (3.91–4.18)			3rd Quintile (4.19–4.40)			4th Quintile (4.41–4.75)			5th Quintile (4.76–7.76)			Mean Increment[a]	P-value
		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		β	
Overweight																					
Children under 2 years of age	Unadjusted	20.8	18.3	23.4	23.9	18.2	29.5	20.9	16.4	25.4	22.7	16.2	29.3	21.9	16.0	27.7	14.8	10.8	18.9	−1.71	0.037
	Income adjusted				24.3	18.8	29.8	22.6	18.9	26.2	20.8	18.4	23.3	19.1	16.2	22.0	17.4	12.9	21.8	−1.74	<0.001
Children 2–5 years of age	Unadjusted	18.2	16.7	19.8	18.7	15.9	21.5	17.9	15.4	20.4	18.3	14.5	22.1	18.9	14.2	23.7	17.4	14.9	19.9	−0.17	0.723
	Income adjusted				20.7	17.8	23.5	19.5	17.4	21.5	18.2	16.8	19.7	17.0	15.4	18.6	15.8	13.6	18.1	−1.21	<0.001
Children 6–9 years of age	Unadjusted	34.6	32.8	36.4	34.0	30.9	37.1	32.9	28.6	37.1	33.9	29.4	38.4	35.0	31.5	38.6	37.0	32.5	41.6	0.83	0.191
	Income adjusted				37.3	33.9	40.6	35.9	33.6	38.2	34.6	32.9	36.3	33.2	31.2	35.2	31.9	28.9	34.8	−1.35	<0.001
Adolescents (10–19 years of age)	Unadjusted	21.5	20.5	22.4	21.0	19.5	22.5	21.6	19.3	23.9	20.1	18.1	22.1	20.9	19.3	22.5	23.7	20.7	26.7	0.46	0.202
	Income adjusted				23.3	21.5	25.0	22.4	21.2	23.5	21.5	20.5	22.4	20.6	19.3	21.8	19.7	17.9	21.5	−0.90	<0.001
Adults (20–59 years of age)	Unadjusted	47.7	46.9	48.5	46.2	45.0	47.4	47.6	45.3	49.8	48.8	46.7	50.9	48.0	46.4	49.7	48.0	46.5	49.6	0.41	0.093
	Income adjusted				49.6	48.3	50.9	48.7	47.7	49.6	47.7	47.0	48.5	46.8	45.8	47.7	45.9	44.5	47.2	−0.94	<0.001
Elderly (60 years or older)	Unadjusted	55.5	54.1	56.9	51.9	49.2	54.5	54.4	50.1	58.7	55.4	52.4	58.4	57.3	54.0	60.6	58.5	56.3	60.7	1.62	<0.001
	Income adjusted				56.4	53.7	59.0	55.9	54.1	57.7	55.5	54.1	56.8	55.1	53.4	56.7	54.6	52.3	57.0	−0.44	<0.001
Total	Unadjusted	40.8	40.0	41.6	38.9	37.7	40.1	39.7	37.6	41.8	40.9	38.6	43.1	41.2	39.5	42.9	43.4	42.1	44.7	1.05	<0.001
	Income adjusted				42.6	41.4	43.8	41.7	40.9	42.5	40.8	40.2	41.4	39.9	39.1	40.7	39.0	37.9	40.2	−0.89	<0.001
Obesity																					
Children under 2 years of age	Unadjusted	11.2	9.2	13.1	14.0	8.7	19.3	11.8	7.4	16.1	11.6	7.2	16.0	10.7	6.2	15.1	7.8	5.3	10.2	−1.36	0.046
	Income adjusted				14.3	8.9	19.7	12.7	9.3	16.2	11.2	9.2	13.1	9.6	7.5	11.7	8.0	4.3	11.7	−1.57	<0.001
Children 2–5 years of age	Unadjusted	8.0	6.9	9.2	8.4	6.7	10.2	9.4	7.0	11.7	5.7	4.0	7.4	9.3	5.5	13.0	7.4	5.2	9.6	−0.21	0.570
	Income adjusted				9.1	7.1	11.0	8.6	7.1	10.0	8.0	6.9	9.2	7.5	6.3	8.8	7.0	5.3	8.7	−0.52	<0.001
Children 6–9 years of age	Unadjusted	15.0	13.8	16.2	14.9	12.6	17.2	14.2	11.9	16.5	14.0	11.5	16.5	15.2	12.1	18.4	16.6	13.9	19.3	0.44	0.288
	Income adjusted				16.5	14.3	18.6	15.7	14.2	17.2	15.0	13.9	16.1	14.3	12.9	15.6	13.5	11.5	15.5	−0.73	<0.001
Adolescents (10–19 years of age)	Unadjusted	5.3	4.8	5.7	4.6	3.8	5.4	5.4	4.4	6.3	5.2	4.2	6.1	5.7	4.8	6.6	5.5	4.4	6.7	0.22	0.154
	Income adjusted				6.0	5.2	6.8	5.6	5.1	6.2	5.3	4.9	5.7	4.9	4.4	5.4	4.6	3.8	5.3	−0.35	<0.001
Adults (20–59 years of age)	Unadjusted	14.1	13.5	14.6	13.5	12.7	14.2	13.8	12.6	15.1	15.2	13.7	16.7	13.9	12.7	15.0	14.0	12.8	15.2	0.12	0.484
	Income adjusted				15.2	14.2	16.1	14.6	14.0	15.3	14.1	13.6	14.6	13.5	12.9	14.2	13.0	12.1	13.9	−0.54	<0.001
Elderly (60 years or older)	Unadjusted	18.0	17.0	19.0	16.9	15.2	18.6	17.7	15.7	19.7	18.1	15.5	20.6	19.5	17.4	21.5	18.0	15.6	20.4	0.39	0.252
	Income adjusted				19.4	17.7	21.1	18.7	17.6	19.9	18.0	17.0	19.0	17.3	16.0	18.7	16.6	14.7	18.6	−0.69	<0.001
Total	Unadjusted	12.7	12.3	13.2	12.0	11.4	12.6	12.4	11.3	13.4	13.1	11.8	14.5	12.9	12.0	13.9	13.2	12.4	14.0	0.29	0.016
	Income adjusted				13.8	13.1	14.5	13.2	12.8	13.7	12.7	12.3	13.1	12.2	11.7	12.7	11.7	11.0	12.3	−0.53	<0.001

[a] Corresponding to the linear regression coefficient value of the indicator (prevalence of overweight and obesity) with increasing quintile of ultra-processed foods price, expressed in percentage points.

Table 4 Income and price-elasticity of the prevalence of overweight and obesity in Brazil, obtained by regression model. Household Budget Survey, Brazil, 2008/9.

Variables	Models 1 β	1 95% IC		2 β	2 95% IC		3 β	3 95% IC		4 [c] β	4 95% IC	
Overweight												
Price of ultra-processed foods (R$/kg)	0.29	0.17	0.41	−0.38	−0.53	−0.24	−0.39	−0.53	−0.24	**−0.33**	−0.46	−0.20
Income per capita (R$)	a	a	a	0.25	0.21	0.29	0.25	0.21	0.29	**0.17**	0.12	0.22
Price of other foods groups (R$/kg)[b]	a	a	a	a	a	a	−0.02	−0.06	0.01	−0.01	−0.06	0.03
R-squared	0.04			0.48			0.48			0.54		
Obesity												
Price of ultra-processed foods (R$/kg)	0.25	0.03	0.46	−0.68	−0.94	−0.43	−0.70	−0.95	−0.44	**−0.59**	−0.83	−0.36
Income per capita (R$)	a	a	a	0.34	0.25	0.43	0.38	0.30	0.47	**0.22**	0.11	0.34
Price of other foods groups (R$/kg)[b]	a	a	a	a	a	a	−0.11	−0.18	−0.03	**−0.10**	−0.20	0.00
R-squared	0.01			0.27			0.28			0.35		

Note: Bold represents regression coefficients presented are statistically significant ($p < 0.05$).
[a] The variable was not used in the model.
[b] The variable was composed of the prices of in nature or minimally processed food, culinary ingredients food, and processed foods.
[c] In addition to the variables presented, the model was also adjusted for area, regions, and mean age of household strata members (years old).

country (Brazil). An inverse association was found in the price of ultra-processed foods regarding both overweight and obesity: for each 1.00% increase in the price of ultra-processed foods, there was a mean 0.33% decrease in the prevalence of overweight and of 0.59% in that of obesity. This effect was also observed in the lower half of the income distribution of the population.

Changes in the price of a specific food group affect not only its demand, but also the consumption of other goods and services [25]. Thus, understanding the relationship between the price of ultra-processed foods and obesity provides important information for policy makers and complements current evidence on the relationship between ultra-processed foods and human health [9,13,15,37,38].

Other studies have analyzed the association between food prices and obesity [23,26]. However, few studies have focused on an entire food group (ultra-processed foods) [37]. The inverse association between the price of ultra-processed foods group and BMI was identified in a study conducted with American adults [37]. However, by using the prevalence of overweight and obesity as an outcome variable, our study complements these results by identifying a greater magnitude of association in the obese population.

As most current knowledge relies on different methodologies, direct comparisons of the results are not always possible. As a significant proportion of the impact of changes in specific food group prices over nutritional status is attributable to changes in the consumption of this same group, the magnitude of the effect depends on the level of consumption of the group observed in the target population. Thus, the magnitude of association related to changes in very specific food groups (with low levels of consumption) tend to be smaller than that observed for broader groups (with higher consumption). Furthermore, it is also important to mention that associations identified in studies focused on specific population groups tend to overestimate the effect of price changes on the entire population (as the consumption level may vary and generally the groups with higher levels of consumption are the focus of the study). Thus, this study focused on the entire ultra-processed food group (about 30% of total

Table 5 Income and price-elasticity of the prevalence of overweight and obesity in Brazil by income group, obtained by regression model. Household Budget Survey, Brazil, 2008/9.

Variables	All groups [b] β	All groups 95% IC		Lower income group [b] β	Lower 95% IC		Higher income group [b] β	Higher 95% IC	
Overweight									
Price of ultra-processed foods (R$/kg)	**−0.33**	−0.46	−0.20	**−0.34**	−0.50	−0.18	−0.08	−0.26	0.10
Income per capita (R$)	**0.17**	0.12	0.22	**0.26**	0.20	0.33	0.00	−0.07	0.07
Price of other foods groups (R$/kg) [a]	−0.01	−0.06	0.03	**0.09**	0.03	0.14	0.00	−0.06	0.06
R-squared	0.54			0.52			0.14		
Obesity									
Price of ultra-processed foods (R$/kg)	**−0.59**	−0.83	−0.36	**−0.63**	−0.91	−0.36	−0.11	−0.48	0.25
Income per capita (R$)	**0.22**	0.11	0.34	**0.42**	0.28	0.56	−0.14	−0.34	0.06
Price of other foods groups (R$/kg) [a]	**−0.10**	−0.20	0.00	0.07	−0.06	0.19	−0.06	0.22	0.09
R-squared	0.35			0.37			0.10		

Note: Bold represents regression coefficients presented are statistically significant ($p < 0.05$).
[a] The variable was composed of the prices of in nature or minimally processed food, culinary ingredients food, and processed foods.
[b] In addition to the variables presented, the model was also adjusted for area, regions, and mean age of household strata members (years old).

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calories in Brazil [39]) and analyzed its association with all population groups.

The higher price of ultra-processed foods found in the present study must be interpreted considering longitudinal evidence regarding food prices [40]. Healthy diets, mainly composed of non-ultra-processed items, have become increasingly more expensive in relation to unhealthy ones, especially in developing countries [40,41]. The cross-sectional scenario presented here is incapable of capturing this trend. However, it indicates that the maximum level of economic benefit for the consumption of ultra-processed foods in Brazil has still not been reached (with the price of these products below the others). In some developed countries, such as the United Kingdom and the US, this scenario is already present [42].

This situation presents a window of opportunity for the adoption of fiscal policies capable of rectifying the damage partially attributable to governmental incentives for foods and other goods linked to poor health in the last decades [43]. Although ultra-processed foods have an intentional relationship with poor health [9,10], currently, they are still relying on subsidies [43]. The basic ingredients and processing techniques of these products are used to induce passive overconsumption [13,15,38,44], and thus, obesity and various related adverse conditions [6–8]. In addition to these approaches, sophisticated marketing campaigns are also used for this purpose [45].

Our results indicate the adjustment of the price of unhealthy foods as a political action capable of influencing the advance of the obesity epidemic [46–48], mainly in lower income populations. These results are consistent with previous findings that also noticed greater effects for lower income populations [24,35–39]. In recent years, several countries already adopted some kind of fiscal measure to curb the consumption of some ultra-processed foods [48,49]. The present results indicate that the taxation of the entire group of ultra-processed foods would be an effective measure to curb obesity prevalence. This alternative brings together several benefits desirable for the development of a policy. It allows a firm definition of the products to be taxed (each and every ultra-processed food), as this food group can be formally classified [50,51]. The tax rate suggested for the taxation of sweetened beverages – capable of increasing prices by 20.0% – widely discussed internationally, could be employed (the present study indicates that a 20.0% increase in the price of ultra-processed foods and beverages would lead to a mean decrease of 6.6% in the prevalence of overweight and 11.8% of that of obesity). Given the current fiscal scenario in Brazil, the adoption of a Contribution of Intervention in the Economic Domain (CIDE) (similar to a regular excise tax, however, with the benefit of allowing the allocation of revenues for specific purposes, a situation prohibited for regular taxes in the country) per unit of volume of ultra-processed food would be the most desirable measure.

Taxation is likely to be less objectionable if revenues are used for programs that promote a healthy lifestyle, including public gyms and healthy meals in schools. Data from the Passport Global Market Information Database published online by Euromonitor International, analyzed in a specific report developed by the Pan-American Health Organization (PAHO) [14], show that approximately 22.6 billion kg of ultra-processed foods were purchased during 2013 in Brazil (~112.9 kg/person/year). Thus, a tax of 20% per kilogram (an mean increase of R$0.87 in price per kilogram) would generate R$ 19.7 billion in tax revenues (considering current demand) or almost US$ 5 billion (current exchange rate), a sufficient amount to increase the total budget of the National School Feeding Program (PNAE) by more than three times, which in 2018 relied on a budget of R$ 4.5 billion to feed 41 million students throughout the country [52,53].

The most important adverse effect of such a tax is its potential to shift consumption toward untaxed unhealthy foods, cheaper brands, or larger packages. The first issue causes less concern as the entire group of ultra-processed foods would be affected. However, the latter two suggest that the impact of taxation depends on additional measures, such as strengthening food and nutrition education actions and regulating package sizes, food/menu labeling, and advertising [54].

The food industry strongly objects to the taxation of foods both in the bigger markets [55,56] and in smaller markets such as Brazil [57]. Arguments range from general criticisms of the taxation system (i.e., taxes are already too high) to the impacts of the reduction of consumption on the food industry (especially unemployment). The tobacco [58] and alcoholic beverage [59] industries similarly fought proposals for the taxation of its products for years. Nonetheless, higher taxes are presently associated with a reduction in unhealthy behaviors and an improvement in the quality of life and were not associated with any economic crisis [58].

Finally, it should be noted that the consumption of ultra-processed foods has also been associated with numerous adverse health outcomes other than obesity [9,10], therefore the associations found in the present study represent only a fraction of the total health benefits from an increase in the price of these products.

As a limitation, we consider the fact that the food price information was based exclusively on purchases for household consumption. Therefore, food purchases made on-the-go (away from home) are not included in this analysis, representing around 17% of the calories consumed among Brazilians [28]. As food prices outside the home tend to be higher, the food group prices reported is likely to have been underestimated as well as the estimates. However, because household consumption still has a major role in food consumption in Brazil (about 83% of the calories consumed [28]), the values presented in the results can be seen as a reliable proxy for food prices in the country. It should also be mentioned that the prices used refer to the acquisitions of homogeneous clusters of households, realized throughout the four quarters of the year, incorporating seasonal variations.

Additionally, when interpreting the study results, it is important to acknowledge that despite using important

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and strong features for the adjusted model considering the set of individuals, data on food stores and their locations (as there are a number of supermarkets, grocery stores, and convenience stores) were not obtained. Foods and beverages purchased at supermarkets tend to be cheaper in comparison to other food stores [60]. Future studies with this unmeasured potential confounder should be considered, to verify their power of explanation of the observed associations.

In conclusion, the price of ultra-processed foods was inversely associated with the prevalence of overweight and obesity in Brazil, mainly in the lowest socioeconomic status population. Therefore, the taxation of ultra-processed foods emerges as a prominent tool in the prevention and control of obesity and related NCDs.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.numecd.2019.12.011.

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