Consumption of Ultra-processed Foods and Obesity in Brazilian Adolescents and Adults

Running title: Ultra-processed Foods and Obesity

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ABSTRACT

Objectives: to evaluate the relationship between the consumption of ultra-processed foods and obesity indicators among Brazilian adults and adolescents.

Methods: We used cross-sectional data on 30,243 individuals aged ≥10 years from the 2008–2009 Brazilian Dietary Survey. Food consumption data were collected through 24-hour food records. We classified food items according to characteristics of food processing. Ultra-processed foods were defined as formulations made by the food industry mostly from substances extracted from foods or obtained with the further processing of constituents of foods or through chemical synthesis, with little if any whole food. Examples included candies, cookies, sugar-sweetened beverages, and ready-to-eat dishes. Regression models were fitted to evaluate the association of the consumption of ultra-processed foods (% of energy intake) with body-mass-index, excess weight, and obesity status, controlling for socio-demographic characteristics, smoking, and physical activity.

Results: Ultra-processed foods represented 30% of the total energy intake. Those in the highest quintile of consumption of ultra-processed foods had significantly higher body-mass-index (0.94 kg/m^2; 95%CI: 0.42,1.47) and higher odds of being obese (OR=1.98; 95%CI: 1.26,3.12) and excess weight (OR=1.26; 95%CI: 0.95,1.69) compared with those in the lowest quintile of consumption.

Conclusion: Our findings support the role of ultra-processed foods in the obesity epidemic in Brazil.

Key-words: Food; Nutrition; Risk factor; Obesity; Prevention

INTRODUCTION

Ultra-processed foods are formulations made by the food industry mostly from substances extracted from foods or obtained from the further processing of constituents of foods or through chemical synthesis, with little if any whole foods (Monteiro *et al.*, 2012; Moodie *et al.*, 2013). Compared to the rest of the diet, these formulations have less fiber and protein, more added sugar, and, when solid, higher energy density (Monteiro *et al.*, 2011; Moubarac *et al.*, 2012). They are also extremely palatable and habit-forming, convenient, sold in large portion sizes, and aggressively advertised and marketed (Monteiro *et al.*, 2012; Moodie *et al.*, 2013; Ludwig, 2011). Sales of ultra-processed foods have increased in parallel with the rates of obesity worldwide, particularly in middle-income countries (Monteiro *et al.*, 2013).

One analysis in Brazil showed that household purchase of ultra-processed foods was associated with greater prevalence of obesity (Canella *et al.*, 2014). However, this study had only used purchase data rather than individual-level consumption data. To our knowledge, no evidence in a developing country is available for how much people consume ultra-processed foods across different demographic groups and how it is related to obesity.

The objective of the present study was to evaluate the association of the intake of ultra-processed foods with obesity indicators in a nationally representative sample of Brazilian adolescents and adults.

METHODS

Design and population

We performed a cross-sectional analysis based on individual-level dietary data from 34,003 individuals aged ≥10 years in Brazil, collected as part of the 2008–2009 National Household Budget Survey (Ibge, 2011a). These individuals represented a randomly selected subsample of 25% of the 55,970 total households randomly selected for the budget survey. The survey employed a complex clustered sampling procedure, first selecting census tracts and then selecting households within those tracts. The selection of census tracts was preceded by an examination of the tracts of the Master Sample of Household Surveys or Common Sample (containing the pool of the 12,800 tracts of the country) to obtain strata of households with high geographic and socioeconomic homogeneity. The geographic locations of tracts (region, state, capital city or other, urban or rural) and the years of schooling of the heads of households in the sector were considered, and 550 strata of households that were geographically and socioeconomically homogeneous were selected. For this study, we excluded pregnant women and individuals with diabetes, hypertension or cancer, each defined by self-reported medication (n=3,760).

The project was approved by the Ethics Committee of the University of São Paulo.

Food consumption

Individuals completed two non-consecutive 24-hour food records days spanning one week (Ibge, 2011a). Nutrient intakes were estimated based on a Brazilian food composition table (Ibge, 2011b).

Food items were divided into three main groups (Supplementary Figure 1). The first was composed of *unprocessed, minimally, or moderately processed foods.* Unprocessed foods were defined as having not undergone any kind of industrial processing, minimally processed foods as processed in ways that did not add substances or subtract edible parts, and moderately processed foods as those that had an edible part subtracted, but no substance added. This category also included handmade dishes made from these foods and culinary ingredients such as oils, salt, and sugar. The second category was *processed foods,* and the third, *ultra-processed foods.* Processed and ultra-processed foods were defined as products made by the food industry with at least two ingredients. We characterized processed foods as those manufactured by adding salt, sugar, or oil to unprocessed, minimally processed or moderately processed foods; and ultra-processed foods as those formulations mostly made from substances extracted from foods or obtained with the further processing of constituents of foods or through chemical synthesis, such as oils, hydrogenated fats, starches, sugars, protein isolates, amino acids, and additives like flavors and colors (Monteiro *et al.*, 2012; Moodie *et al.*, 2013; Ludwig, 2011; Monteiro and Cannon, 2012). Examples of ultra-processed foods include: ice-creams, soft drinks, industrialized baked products, and sausages.

For each category, we computed the relative contribution of foods in that category to each person's total energy intake. We evaluated intake as the percentage to total energy intake in order to reduce variation due to body size, physical activity, and metabolic efficiency (each major determinants of total energy intake).

Obesity indicators

Weight and height were measured by researchers with standard techniques and recorded in specific questionnaires (Ibge, 2011a). In individuals aged ≥20 years old, excess weight and obesity were defined as BMI ≥25 kg/m^2 and 30 kg/m^2, respectively (WHO, 1995). Excess weight and obesity of 10 to 19 year-old individuals were defined as BMI-for-age z-scores from the World Health Organization references ≥+1 and +2, respectively (de Onis *et al.*, 2007). Excess weight includes excess weight and obesity.

Covariates

Information on age, sex, race, education, and income were obtained via standardized interviews. Annual household income per person was calculated using a purchasing power parity basis (PPP 2009: US$ 1.00=R$ 1.63) (World Bank, 2015). Geographic region and urban status of the household were also used as covariates.

Smoking was assessed based on data from each individual's purchases, with current smokers defined as those having purchased any type of cigarettes during the previous 7 days. Because physical activity was not assessed in the household survey, we predicted physical activity levels by evaluating data from the VIGITEL Survey (Ministério da Saúde, 2010) for adults and from the PENSE Survey (Ministério da Saúde, 2009) for adolescents. Using these datasets, we modeled a regression equation predicting the likely leisure-time and transportation physical activity (minutes/week) by age, sex, race, years of education, and smoking status used as the predictors. Using two regression equations, we obtained predicted leisure-time and transportation physical activity duration for individuals in the dataset of the current study.

Statistical analyses

Analyses were performed with Stata 13.0 (Texas, US) with two-tailed alpha=0.05. Analyses accounted for sample weights and the design effect of the survey.

Linear regression models were used to assess differences in BMI across quintiles of consumption of ultra-processed foods (% of total energy).

Logistic regression models were fitted in order to evaluate the odds ratio (OR) for being excess weight or obese according to quintiles of consumption of ultra-processed foods (% of total energy).

Multivariate models were fitted to adjust for age, sex, race, region, urban status, education, income, smoking status, and physical activity levels. We further adjusted for each person's consumption of fruits, vegetables, and beans to evaluate if the association was independent of these other components of the diet. Total energy intake was not included as a covariate because it may plausibility mediate (i.e., be in the causal pathway of) the effects of ultra-processed foods on BMI and obesity. We performed sensitivity analyses using the energy intake of ultra-processed foods (and not the percentage of total energy intake of the diet) as the explanatory variable.

We explored potential effect modification by sex, age, household income and food consumption outside home. For any significant interactions, subgroup analyses were conducted.

Lastly, we examined whether the association remained significant after adjustment, one at a time, for dietary intakes of saturated fatty acids (g/day), trans fatty acids (g/day), added sugars (% of total energy), fiber (g/1,000 kcal), and total energy (kcal/day). We calculated the percent change in the regression coefficient for a linear relationship of the association between the consumption of ultra-processed foods and BMI before and after adjustment for each of the selected factors, by using an ordinal variable for quintile categories of consumption of ultra-processed foods (% of total energy).

RESULTS

A total of 30,243 Brazilian adults were evaluated (Table 1). Consistent with the national population, the great majority resided in urban areas, 51% were women and 52% African-descendent. Forty-one percent of the participants were excess weight and 12% obese.

Mean reported energy intake was 1,908 kcal. Nationally, more than two thirds (68.6%) of these calories came from unprocessed, minimally, or moderately processed foods, while 29.6% came from ultra-processed foods.

On average, rice and beans represented about 25% of the energy consumed throughout the day (Supplementary Table 1). Other major foods in the Brazilian diet were red meat (9.3% of total energy), fruits (6.9%) and cereals other than rice (5.9%). Among ultra-processed foods, the categories with the highest energy contribution were industrialized breads (9.2% of total energy intake), pizzas, hamburgers and sandwiches (4.7%), and cakes and cookies (3.0%).

The consumption of ultra-processed foods ranged from an average of 6.0% of total energy intake in the lowest quintile to 56.0% in the highest quintile of consumption of ultra-processed foods (% of total energy). In crude (unadjusted) analyses, the percent energy from ultra-processed foods was higher among woman, those with urban residency, non-smokers, and those with higher levels of physical activity, education, and income (Supplementary Table 2). Total energy intake ranged from 1,784 kcal in the bottom quintile to 2,060 kcal in the top quintile of ultra-processed foods.

Ultra-processed foods and obesity

After adjustment for sociodemographics, smoking, and physical activity, the consumption of ultra-processed foods was associated with higher BMI and greater prevalence of both excess weight and obesity (Table 2). Compared to those in the first quintile of consumption of ultra-processed foods, mean BMI was 0.94 kg/m^2 higher among those in the top quintile (95%CI=0.42,1.47). The adjusted odds ratio (OR) of being obese or excess weight were, respectively, 1.98 (95%CI=1.23,3.12) and 1.26 (95%CI=0.95,1.69) in the top quintile of ultra-processed foods intake. Further adjustment for consumption of fruits, vegetables, and beans had little effect on these risk estimates (Table 2).

Analysis of interaction

We observed a significant effect modification in the relationship between consumption of ultra-processed foods and BMI by both age and sex (P<0.001 each), but neither by income nor by food consumption outside home (P>0.05). No effect modification in the relationship between the consumption of ultra-processed foods and obesity was observed (P>0.05). Subgroup analyses showed that the trend toward positive associations for both BMI and obesity remained in all age groups (Table 3).

A strong association between the consumption of ultra-processed foods and both BMI, excess weight and obesity was observed among women, but not among men (Table 4). The mean difference in BMI was 1.13 kg/m^2 comparing women in the top to the bottom quintile groups of ultra-processed food consumption (95%CI=0.38,1.87). The OR of being obese was 1.96 in women with the highest consumption of ultra-processed foods (95%CI=1.09,3.56).

Additional analyses

Additional adjustment for saturated fat, trans fat, and added sugar had little effect on the magnitude of the associations. For example, after adjustment for fiber, the association of consuming ultra-processed foods with BMI was attenuated by only 7%, Adjustment for total energy intake, a key potential mediator of the association, attenuated the association with BMI by 50%, although the association remained statistically significant (*P*=0.001). The adjustment for total energy reduced the magnitude of the linear relationship from 0.22 kg/m^2 (95%CI=0.12 to 0.32) to 0.10 kg/m^2 (0.04, 0.17) per quintile category of ultra-processed foods.

The results were similar when we evaluated the quintiles of energy intake of ultra-processed foods rather than the percentage of total energy intake of the diet as the explanatory variable (data not shown). Compared to those in the bottom group, adjusted mean BMI was 0.78 kg/m^2 higher among those in the last quintile group (95% CI=0.0.49,1.08; *P* for trend=0.001). The adjusted OR of being obese and excess weight were, respectively, 1.53 (95% CI=1.21,1.94; ; *P* for trend=0.001) and 1.33 (95% CI=1.13,1.57; *P* for trend =0.01).

DISCUSSION

We found a cross-sectional association between the intake of ultra-processed foods and excess weight and obesity among Brazilian adolescents and adults. Although there was heterogeneity by sex and age, our finding supports that, on average, there are potential detrimental effects of consuming ultra-processed foods.

We suggest that this association is, at least partially, explained by intrinsic characteristics of ultra-processed foods that promote overconsumption. This is particularly important when we attempt to the fact that the consumption of these foods has widely increased worldwide, in parallel with the global increase in obesity (Monteiro *et al.*, 2013; Finucane *et al.*, 2011; Martins *et al.*, 2013).

Our study showed that almost one third of the energy consumed in Brazil came from ultra-processed foods. This may partly related to their convenience, portability, and perceived time-saving compared with less processed foods. Typically, ultra-processed foods are designed to be consumed anywhere and often, without implements. These foods are usually sold in the form of snacks, drinks, or ready-to-consume dishes and can readily displace handmade meals. Also, the processing techniques and the cosmetic additives make ultra-processed foods hyper-palatable. They are therefore liable to cause “mindless eating” and to damage the processes that control satiety and appetite (Ludwig, 2011; Ogden *et al.*, 2013). SSBs are a particular case. Their consumption can lead to weight gain by an incomplete compensatory reduction in energy intake at subsequent meals following intake of liquids (Dimeglio and Mattes, 2000). Another possible link between the consumption of ultra-processed foods with obesity is the portion size. Portion sizes of many ultra-processed foods significantly increased in past decades (Piernas and Popkin, 2001; Nielsen and Popkin, 2003) and several studies have linked their increases to increased total energy intake (Albar *et al.*, 2014; Steenhuis and Vermeer, 2009; Diliberti *et al.*, 2004) All these characteristics are amplified by aggressive marketing, which makes these products attractive and ubiquitous, and modifies social norms (Mallarino *et al.*, 2013).

Due to the lack of water and the type of carbohydrates, ultra-processed foods have high glycemic loads and, when solid, high energy density (Monteiro *et al.*, 2011; Ludwig, 2011). This is particularly relevant since individuals regulate food consumption by volume more so than calories and energy density is inversely related to diet quality and directly associated to energy intake (Rolls, 2009). Likewise, high glycemic loads can cause an increased insulin response, which might promote weight gain by directing nutrients away from oxidation in muscle and towards storage in fat (Ludwig, 2002; Brand-Miller *et al*., 2009).

Ultra-processed foods are nutritionally unbalanced (Monteiro *et al.*, 2011; Moubarac *et al.*, 2012); they have poor quality fat and low contents of fiber, micronutrients, and phytochemicals. Still, we couldn't show a significant importance of the contents of saturated fat, *trans* fat, added sugar, and fiber to explain the results. Nevertheless, food composition table can have imprecise information, biasing the results to null. Further studies, thus, should explore the impact of the consumption of ultra-processed foods and the effects of their entire nutrient profile on health outcomes.

We observed a strong effect modification related to sex. We hypothesized that unmeasured confounders or confounders measured with error may partly explain the absence of effect among men. Previous Brazilian studies described higher levels of physical activity and smoking among men (Malta *et al.*, 2011). Since it is well established that both characteristics are inversely correlated to BMI, the lack of an appropriate control may be biasing the results to null. Growing evidence suggests that women are more predisposed to adverse metabolic effects of rapidly digested, carbohydrate-rich foods than men, which might explain larger effects of ultra-processed foods on adiposity in women (Mirrahimi *et al*, 2014). Different stress coping mechanisms between both sexes could also be considered as a possible cause of the different findings between men and women. For instance, perceived stress has been an important predictor of both diet quality and adiposity, and women are particularly susceptible to perceived stress (de Vriendt *et al.*, 2012; Isasi *et al.*, 2015; Nastaskin *et al.*, 2015). In addition, a population-based study showed different socioeconomic determination of obesity in men and women, increasing the complexity of modeling these variables (Monteiro *et al.*, 2001). Our study brings novel evidence on sex-specific associations even though the reasons behind these results remain unknown and should be further explored.

On the other hand, other subgroup analyses confirmed that the association is consistent across age, socioeconomic status groups, and different patterns of outside home consumption, increasing the confidence in the results.

Our findings are consistent with studies from high-income countries that have assessed the influence on obesity of foods that could be classified as ultra-processed. In the US, positive associations have been seen between consumption of potato chips, SSBs, and processed meat and long-term weight gain; with protective associations of unprocessed or minimally processed foods such as fruits, vegetables, nuts, and yogurt (Mozaffarian *et al.*, 2011). Also, a 15-year prospective study showed that fast food consumption among young adults was directly associated with changes in body weight and insulin resistance (Pereira *et al.*, 2005). Regarding SSBs, strong epidemiological evidence describes their role in the etiology of obesity and other cardiovascular diseases (Woodward-lopez *et al.*, 2010; HU and Malik, 2010).

Our study has several strengths. We analyzed contemporary data on more than 30,000 people on the first nationally representative individual dietary survey from Brazil. Availability of socioeconomic and demographic variables allowed adjustment for many important covariates, as well as evaluation of consistency among population subgroups. We believe that the food classification used in this study is advantageous compared to previous classifications. In prior studies, foods were usually grouped according to their nutrient profile. For example, unprocessed and processed meats were frequently classified in the same category because of their protein content, and grains and flour-based products were grouped together because they are both sources of carbohydrates (Monteiro *et al.*, 2012). These classifications could be important when most of the nutrition-related diseases were caused by deficiencies of nutrients (Monteiro *et al.*, 2012). However, the classifications based solely on nutrient composition have been shown to be unable to explain the entire influence of food consumption on obesity. We strongly believe that considering industrial food processing in the assessment of food consumption can bring novel evidence for the elucidation of the framework of the obesity epidemic.

There are several limitations to the interpretation of our findings as well. First, this study is cross-sectional. Our results are susceptible to reverse causation and provide little causal information. Although we attempted to control for potential confounders for the association between the consumption of ultra-processed foods and obesity, residual confounding could remain because of unmeasured confounders and inaccuracy in measurement of smoking and physical activity. Smoking was assessed based on purchase of cigarettes, which may have underestimated smoking exposure, particularly in adolescents. Physical activity was also estimated indirectly by using a predictive model based on socioeconomic characteristics. Since it is well established that both smoking and physical activity are inversely correlated to BMI, the lack of an appropriate control may be biasing the results to null.

Despite this, effect sizes were large and the results are biologically plausible and consistent with the previous literature. Also, the study might have some bias related to inherent limitations of food records. To minimize these problems, food records were evaluated against gold standard methods, the questionnaire was validated, and quality control procedures were carried out (Ibge, 2011a). The dietary survey was not designed specifically to classify foods according to characteristics of industrial processing, which would further increase misclassification and limit ability to detect associations.

CONCLUSION

In conclusion, our findings support the role of ultra-processed foods consumption in the obesity epidemic in Brazil. In conclusion, our findings support the role of ultra-processed foods in obesity epidemic in Brazil. While cross-sectional, the size and generalizability of our study provides evidence that may support the role of ultra-processed foods in the obesity epidemic. These results demonstrate a need for interventional studies, including policy interventions, to test the effects of reducing ultra-processed foods on obesity.

Supplementary information is available at Preventive Medicine's website

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Table 1. Characteristics of a nationally representative sample of 30 243 adolescents and adults (≥ 10 years old). Brazil 2008-2009 [a].

Age, %	
10 to 19 y	24.2
20 to 39 y	41.3
40 to 59 y	26.0
60 y or more	8.5
Sex, %	
Men	49.8
Women	50.2
Race, %	
White	47.3
African-descendant	51.3
Other	1.4
Urbanity, %	
Rural	16.8
Urban	83.2
Weight status, %	
Underweight[b]	2.8
Normal weight[c]	43.7
Excess weight[d]	40.9
Obese[e]	11.7
Smoking status%	
Current smoker[f]	8.2
Years of education, %	
≤ 4 y	30.8
5 to 8 y	27.6
9 to 12 y	31.1
> 12 y	10.5
Annual household income per person in US$[g], %	
≤2 200 (R$ 3 600)	31.7
2 201 to 4 400 (R$ 3 600 to 7 200)	27.7
>4 400 (R$ > 7 200)	40.6
Leisure-time and transportation physical activity in min/week[h], %	
< 150	32.7
≥ 150	67.3
Energy intake in kcal, mean	
Total	1908.1
Inside home	1598.7
Outside home	383.8
Food consumption (% of total energy) [i], mean	

Unprocessed, minimally and moderately processed foods	68.6
Processed foods	1.8
Ultra-processed foods	29.6

[a]All statistics accounted for sample weights from the national survey

[b]BMI-for-age z-scores < -2 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI < 18.5 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

[c]BMI-for-age z-scores ≥ -2 and < +1 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 18.5 kg/m^2 and < 25 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

[d]BMI-for-age z-scores ≥ +1 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 25 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

[e]BMI-for-age z-scores ≥ +2 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 30 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

[f]The number of smokers was estimated based on the number of individuals that purchased cigarettes (budget survey data). Former smoker data was not available.

[g]Annual household income per person was calculated using a purchasing power parity basis (PPP 2009: US$ 1.00 = RS 1.63), multiplying by 12 months, and dividing by the number of residents in the household.

[h]Physical activity was estimated with a linear regression model fitted with original data from previous Brazilian population-based surveys with age, sex, race, years of education and smoking status as the predictors.

[i] Details are given in Supplementary Materials. Unprocessed foods have not undergone any kind of industrial processing, minimally processed foods were processed in ways that did not add substances or subtract edible parts, and moderately processed foods had an edible part subtracted, but no substance added. This category includes all handmade dishes made from these foods and culinary ingredients such as fats, oils, salt, and sugar. Processed foods are manufactured by adding salt, sugar, oils or fats to unprocessed, minimally processed or moderately processed foods and ultra-processed foods are formulations mostly or entirely made from substances extracted from foods, such as oils, fats, starches, sugar, and substances obtained with the further processing of constituents of foods or through chemical synthesis, such as hydrogenated fats, modified starches, and additives used to provide the products with attractive taste, flavor, color, and texture.

Table 2. Association of the consumption of ultra-processed foods (% of total energy) with BMI and the prevalence of obesity and excess weight among 30 243 individuals aged ≥ 10 years old[a]. Brazil 2008-2009.

	Quintiles of consumption of ultra-processed foods (% of total energy)									
	1	2		3		4		5		
	(≤ 13%)	(14 to 22%)		(23 to 31%)		(32 to 43%)		(≥ 44%)		*P* for trend
Mean difference (95% CI) in BMI, kg/m²										
Crude	0.0 (Reference)	0.28	(0.03,0.52)	0.19	(-0.07,0.44)	0.12	(-0.14,0.38)	-0.53	(-0.79,-0.27)	<0.001
Multivariate[b]	0.0 (Reference)	0.33	(0.10,0.56)	0.51	(0.25,0.76)	0.69	(0.37,1.00)	0.94	(0.42,1.47)	<0.001
Multivariate + other components of the diet[c]	0.0 (Reference)	0.33	(0.10,0.56)	0.51	(0.25,0.77)	0.69	(0.38,1.00)	0.95	(0.43,1.48)	<0.001
Odds ratio (95% CI) for being obese[d]										
Crude	1.0 (Reference)	1.27	(1.08,1.50)	1.27	(1.06,1.52)	1.26	(1.05,1.49)	1.16	(0.97,1.40)	0.18
Multivariate[b]	1.0 (Reference)	1.3	(1.09,1.54)	1.43	(1.17,1.76)	1.58	(1.22,2.05)	1.98	(1.26,3.12)	<0.001
Multivariate + other components of the diet[c]	1.0 (Reference)	1.29	(1.09,1.54)	1.43	(1.16,1.75)	1.57	(1.22,2.03)	1.97	(1.26,3.09)	<0.001
Odds ratio (95% CI) for being excess weight[e]										
Crude	1.0 (Reference)	1.1	(0.98,1.22)	1.1	(0.98,1.23)	1.07	(0.95,1.20)	0.93	(0.82,1.05)	0.2
Multivariate[b]	1.0 (Reference)	1.1	(0.98,1.24)	1.17	(1.02,1.35)	1.21	(1.02,1.43)	1.26	(0.95,1.69)	0.02
Multivariate + other components of the diet[c]	1.0 (Reference)	1.1	(0.98,1.24)	1.17	(1.02,1.35)	1.21	(1.02,1.43)	1.27	(0.95,1.69)	0.02

BMI: body mass index

CI: confidence interval

[a]All statistics accounted for sample weights from the national survey

[b]Adjusted for age (natural logged), sex (men/women), race (white, African-descendent and other), region (north, northeast, south, southeast, and midwest), urbanity (urban/rural), smoking (yes/no), physical activity (min/week), quintiles of years of education (age- and sex-specific), per capita household income (natural logged) and the interaction between sex and income.

[c]Covariates in the multivariate model[a] and consumption of fruits, vegetables and beans (each in % of total energy intake from non-ultra-processed food)

[d]BMI-for-age z-scores ≥ +2 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 30 kg/m² for ≥ 20 years old individuals (WHO, 1995).

[e]BMI-for-age z-scores ≥ +1 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 25 kg/m² for ≥ 20 years old individuals (WHO, 1995).

Table 3. Association of the consumption of ultra-processed foods (% of total energy) with BMI and the prevalence of obesity and excess weight among 30 243 individuals aged ≥ 10 years old by age groups[a]. Brazil 2008-2009.

	Quintiles of consumption of ultra-processed foods (% of total energy)[b]					
	1	2	3	4	5	*P* for trend[c]
Mean difference (95% CI) in BMI, kg/m^2[d]						
10 to 19 y (n= 7 534)[e]	≤ 17%	18 to 28%	29 to 39%	40 to 52%	≥ 52%	
	0.0 (Reference)	0.01 (-0.33,0.31)	0.34 (-0.12,0.81)	0.40 (-0.17,0.97)	0.84 (-0.16,1.85)	0.08
20 to 39 y (n= 12 586)	≤ 13%	14 to 23%	24 to 32%	32 to 44%	≥ 45%	
	0.0 (Reference)	0.02 (-0.30,0.35)	0.02 (-0.37,0.41)	0.36 (-0.17,0.90)	0.47 (-0.42,1.36)	0.15
40 to 59 y (n= 7 534)	≤ 11%	12 to 19%	20 to 28%	29 to 38%	≥ 39%	
	0.0 (Reference)	0.58 (0.09,1.07)	0.51 (0.02,1.00)	0.70 (0.10,1.31)	1.12 (0.25,2.00)	<0.001
60 y or more (n= 2 589)	≤ 10%	11 to 18%	19 to 25%	26 to 36%	≥ 37%	
	0.0 (Reference)	0.21 (-0.65,1.07)	0.87 (0.00,1.74)	1.49 (0.24,2.74)	1.66 (0.12,3.20)	<0.001
Odds Ratio (95% CI) for being obese[d,e]						
10 to 19 y (n= 7 534, 5% obese)	≤ 17%	18 to 28%	29 to 39%	40 to 52%	≥ 52%	
	1.0 (Reference)	0.96 (0.55,1.68)	1.74 (0.82,3.73)	1.90 (0.88,4.09)	2.74 (0.78,9.60)	0.05
20 to 39 y (n= 12 586, 11% obese)	≤ 13%	14 to 23%	24 to 32%	32 to 44%	≥ 45%	
	1.0 (Reference)	1.27 (0.96,1.68)	1.31 (0.95,1.79)	1.48 (0.99,2.20)	1.53 (0.76,3.06)	0.08
40 to 59 y (n= 7 534, 18% obese)	≤ 11%	12 to 19%	20 to 28%	29 to 38%	≥ 39%	
	1.0 (Reference)	1.24 (0.94,1.65)	1.32 (0.97,1.81)	1.36 (0.92,2.00)	1.69 (0.93,3.09)	<0.001
60 y or more (n= 2 589, 16% obese)	≤ 10%	11 to 18%	19 to 25%	26 to 36%	≥ 37%	
	1.0 (Reference)	1.65 (1.14,2.38)	1.74 (1.14,2.67)	2.07 (1.24,3.45)	2.62 (1.22,5.64)	<0.001
Odds Ratio (95% CI) for excess weight[d,f]						
10 to 19 y (n= 7 534, 22% excess weight)	≤ 17%	18 to 28%	29 to 39%	40 to 52%	≥ 52%	
	1.0 (Reference)	1.05 (0.78,1.41)	1.12 (0.77,1.61)	1.15 (0.74,1.77)	1.52 (0.75, 3.07)	0.25
20 to 39 y (n= 12 586, 41% excess weight)	≤ 13%	14 to 23%	24 to 32%	32 to 44%	≥ 45%	
	1.0 (Reference)	1.00 (0.81,1.25)	1.01 (0.81,1.25)	1.14 (0.86,1.51)	1.35 (0.83,2.18)	0.14

40 to 59 y (n= 7 534, 55% excess weight)	≤ 11%	12 to 19%	20 to 28%	29 to 38%	≥ 39%	
	1.0 (Reference)	1.06 (0.86,1.31)	1.10 (0.88,1.38)	1.21 (0.95,1.53)	1.19 (0.92,1.55)	0.25
60 y or more (n= 2 589, 53% excess weight)	≤ 10%	11 to 18%	19 to 25%	26 to 36%	≥ 37%	
	1.0 (Reference)	0.87 (10.59,1.28)	1.24 (0.83,1.85)	1.23 (0.74,2.03)	1.55 (0.58,4.12)	0.02

BMI: body mass index CI: confidence interval

[a]All statistics accounted for sample weights from the national survey

[b]The quintiles of consumption (% of total energy) of ultra-processed foods are specific for each subgroup

[c]*P* for the interaction term on the linear regression <0.001

[d]Adjusted for age (ln), sex (men/women), race (white, African-descendent and other), region (north, northeast, south, southeast, and midwest), urban status (yes/no), smoking (yes/no), physical activity (min/week), quintiles of years of education (age- and sex-specific) per capita household income (ln), consumption of fruits, vegetables and beans (each in % of total energy intake from non-ultra-processed food) and the interaction between sex and income.

[e]BMI-for-age z-scores ≥ +2 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 30 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

[f]BMI-for-age z-scores ≥ +1 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 25 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

Table 4. Association of the consumption of ultra-processed foods (% of total energy) with BMI and the prevalence of obesity and excess weight among 30 243 individuals aged ≥ 10 years old by sex[a]. Brazil 2008-2009.

	Quintiles of consumption of ultra-processed foods (% of total energy)[b]					
	1	**2**	**3**	**4**	**5**	*P* for trend[c]
Mean difference (95% CI) in BMI, kg/m^{2}[d]						
Men (n= 14 396)	≤ 11%	12 to 20%	21 to 30%	30 to 42%	≥ 43%	
	0.0 (Reference)	0.21 (-0.05,0.48)	0.16 (-0.17,0.48)	0.30 (-0.10,0.71)	0.32 (-0.36,1.01)	0.21
Women (n=15 847)	≤ 14%	15 to 23%	24 to 33%	34 to 45%	≥ 46%	
	0.0 (Reference)	0.54 (0.17,0.90)	0.67 (0.26,1.08)	0.86 (0.39-1.32)	1.13 (0.38,1.87)	<0.001
Odds ratio (95% CI) for being obese[d,e]						
Men (n= 14 396, 10% obese)	≤ 11%	12 to 20%	21 to 30%	30 to 42%	≥ 43%	
	1.0 (Reference)	1.36 (1.04,1.78)	1.15 (0.84,1.55)	1.30 (0.89,1.89)	1.06 (0.55,2.04)	0.28
Women (n=15 847, 13% obese)	≤ 14%	15 to 23%	24 to 33%	34 to 45%	≥ 46%	
	1.0 (Reference)	1.29 (1.03,1.61)	1.49 (1.13,1.97)	1.53 (1.09,2.14)	1.96 (1.09,3.53)	<0.001
Odds ratio (95% CI) for excess weight (overweight+obese)[d,e]						
Men (n= 14 396, 42% excess weight)	≤ 11%	12 to 20%	21 to 30%	30 to 42%	≥ 43%	
	1.0 (Reference)	1.14 (0.96,1.34)	1.06 (0.87,1.29)	1.12 (0.87,1.43)	1.17 (0.78,1.76)	0.37
Women (n=15 847, 40% excess weight)	≤ 14%	15 to 23%	24 to 33%	34 to 45%	≥ 46%	
	1.0 (Reference)	1.22 (1.03,1.44)	1.34 (1.10,1.62)	1.42 (1.11,1.80)	1.69 (1.12,2.54)	<0.001

BMI: body mass index

CI: confidence interval

[a]All statistics accounted for sample weights from the national survey

[b]The quintiles of consumption (% of total energy) of ultra-processed foods are specific for each subgroup

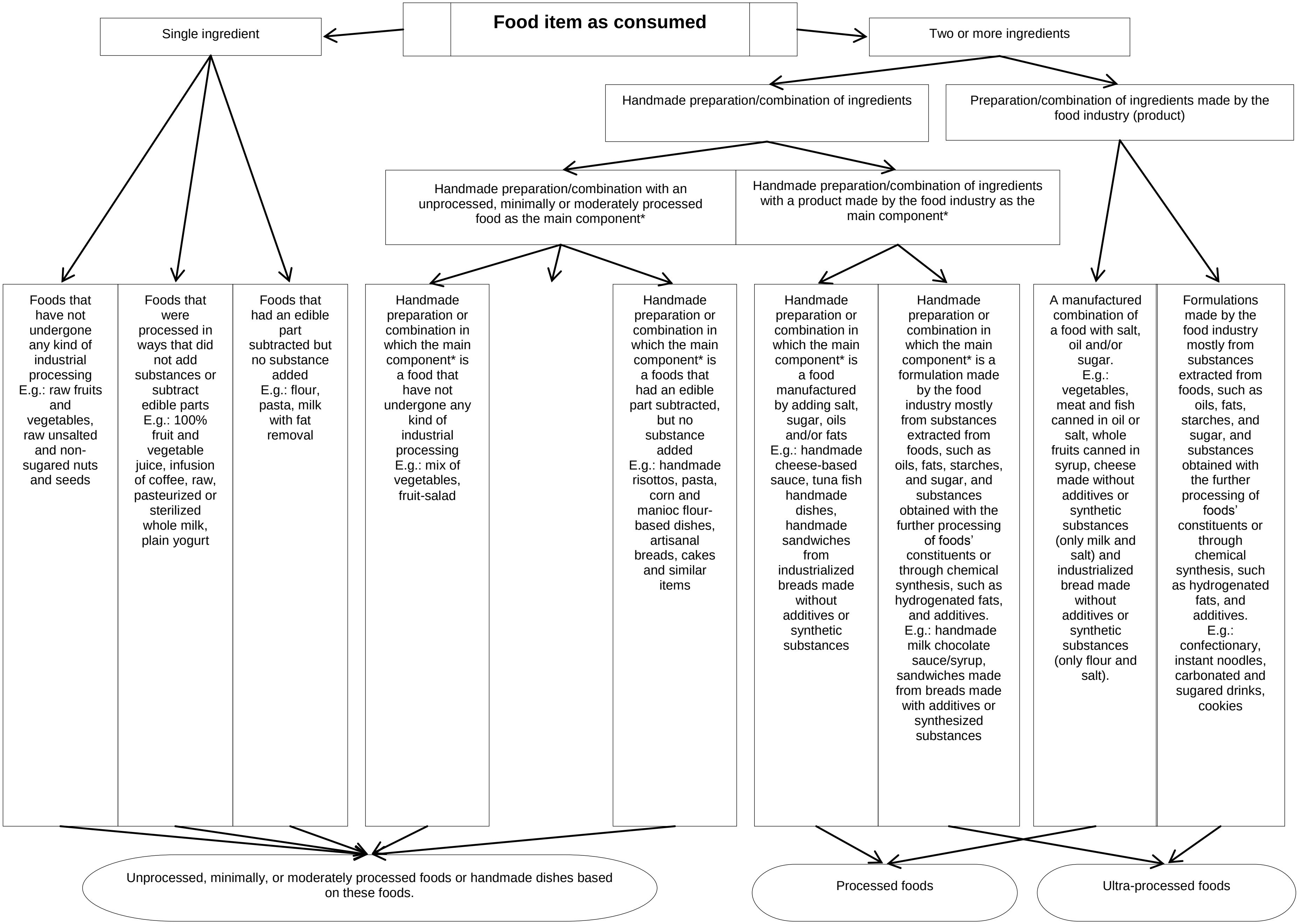
[c]*P* for the interaction term on the linear regression <0.001

[d]Adjusted for age (ln), race (white, African-descendent and other), region (north, northeast, south, southeast, and midwest), urban status (yes/no), smoking (yes/no), physical activity (min/week), quintiles of years of education (age- and sex-specific) per capita household income (ln), consumption of fruits, vegetables and beans (each in % of total energy intake from non-ultra-processed food) and the interaction between sex and income.

[e]BMI-for-age z-scores ≥ +2 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 30 kg/m^{2} for ≥ 20 years old individuals (WHO, 1995).

[f]BMI-for-age z-scores ≥ +1 for 10 to 19 year-old individuals (de Onis et al., 2007) and BMI ≥ 25 kg/m^2 for ≥ 20 years old individuals (WHO, 1995).

Supplementary Figure 1. Decision tree for the classification of the food items based on characteristics of food processing and examples.



*The main component is that one that is essential for the characterization of this dish/preparation. For example, the main ingredient of a risotto is the rice (regardless the inclusion of vegetables, meat, etc.), of a pasta dish is the pasta (regardless the inclusion of sauces) and of a sandwich is the bread (regardless of what it is filled with).

Supplementary Table 1. Characteristics of the food consumption (% of total energy) of nationally representative adolescents (10 to 19 year-old) and adults (≥ 20 years old)[a]. Brazil 2008-2009.

Food category[b]	**Total (n=30 243)**	**Inside home[c] (n=29 984)**	**Outside home[d] (n=14 229)**
Unprocessed, minimally and moderately processed foods	68.6	69.4	53.2
Rice	12.5	12.6	7.7
Beans	10.2	10.2	5.9
Red meat	9.3	9.1	7.1
Fruits and 100% fruit juices	6.9	6.7	9.9
Corn, oatmeal, wheat (including pasta)	5.9	6	4.5
Milk	5.3	6	2.5
Poultry	5.3	5.1	3.9
Roots and tubers	3.6	3.5	2.8
Coffee and tea	2.9	3.1	4.2
Fish	1.7	1.7	1
Vegetables	1.6	1.6	1.9
Eggs	1.4	1.6	0.4
Other foods[e]	2	2.1	1.5
Processed foods	1.8	1.9	1
Salted meat and fish	0.7	0.7	0.4
Cheese	1	1.2	0.5
Vegetables in brine or oil and fruits in syrup	0.1	0.1	0.1
Ultra-processed foods	29.6	28.7	45.8
Industrialized bread	9.2	10.3	5.6
Pizzas, hamburgers, sandwiches	4.7	3.7	12.8
Cakes, pies and cookies	3	2.8	4.6

Sugar-sweetened beverages	2.7	2.3	7
Candies, chocolates, gelatin, flan and ice cream	2.2	1.8	6.7
Crackers and chips	2	1.9	3.5
Reconstituted meat products	1.7	1.8	1
Flavored or sweetened yogurts or milk beverages	1.7	2	1.2
Alcoholic beverages	0.8	0.5	2.7
Other products[f]	1.5	1.7	0.8

[a]All statistics accounted for sample weights from the national survey

[b]Unprocessed foods have not undergone any kind of industrial processing, minimally processed foods were processed in ways that did not add substances or subtract edible parts, and moderately processed foods had an edible part subtracted, but no substance added. This category includes all handmade dishes made from these foods and culinary ingredients such as fats, oils, salt, and sugar. Processed foods are manufactured by adding salt, sugar, oils or fats to unprocessed, minimally processed or moderately processed foods and ultra-processed foods are formulations mostly or entirely made from substances extracted from foods, such as oils, fats, starches, sugar, and substances obtained with the further processing of constituents of foods or through chemical synthesis, such as hydrogenated fats, modified starches, and additives used to provide the products with attractive taste, flavor, color, and texture.

[c]Consumption of food groups (% of total energy intake consumed inside the home) of the 29 984 individuals that reported consumption inside home.

[d]Consumption of food groups (% of total energy intake consumed inside the home) of the 14 229 individuals that reported consumption inside home.

[e]Nuts and seed, lentil, peas and soy, plain yogurt, shellfish and other mixed dishes

[f]Margarine, ready-to-eat sauces and breakfast cereals

Supplementary Table 2. Characteristics of the 30 243 individuals aged ≥ 10 years old across quintiles of consumption of ultra-processed foods (% of total energy)[a]. Brazil 2008-2009.

	Quintiles of ultra-processed foods (% of total energy)				
	1	**2**	**3**	**4**	**5 [b]**
	(≤ 13%)	**(14 to 22%)**	**(23 to 31%)**	**(32 to 43%)**	**(≥ 44%)**
Total energy intake in kcal, mean (SD)	1784 (770)	1849 (701)	1884 (697)	1964 (726)	2060 (823)
% of food consumption outside home, mean (SD)	12 (23)	17(25)	19 (25)	23 (26)	26 (27)
Age					
10 to 19 y, %	16	19	26	35	38
20 to 39 y, %	38	41	43	44	41
40 to 59 y, %	32	30	27	24	17
60 y or more, %	14	11	8	6	4
Sex					
Men, %	59	50	49	47	45
Women, %	41	50	51	53	55
Race					
White, %	34	43	49	54	57
African-descendent, %	64	56	50	45	41
Other, %	2	1	1	1	1
Urbanity					
Rural, %	37	20	12	9	6
Urban, %	63	80	88	91	94
Smoking status					
Current smokers[c],%	12	8	7	8	5
Leisure-time and transportation physical activity in min/week[d]					
< 150, %	45	40	32	27	20

≥ 150, %	55	60	68	73	80
Years of education					
≤ 4, %	53	37	27	20	17
5 to 8, %	27	28	26	29	29
9 to 12, %	17	28	35	38	38
> 12, %	4	8	12	13	16
Annual household income per person[e] in US$, %					
≤2200	49	37	28	25	19
2201 to 4400	27	30	29	27	26
>4400	23	34	43	49	55

[a]All statistics accounted for sample weights from the national survey

[b]All the characteristics were significantly associated with the consumption of ultra-processed foods (*P*<0.001)

[c]The number of smokers was estimated based on the number of individuals that purchased cigarettes (budget survey data). Former smoker data not available.

[d]Physical activity was estimated with a linear regression model fitted with original data from previous Brazilian population-based surveys with age, sex, race, years of education and smoking status as the predictors.

[e]Annual household income per person was calculated using a purchasing power parity basis (PPP 2009: US$ 1.00 = RS 1.63), multiplying by 12 months, and dividing by the number of residents in the household.