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Associations of ultra-processed food and drink products with asthma and wheezing among Brazilian adolescents

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Abstract

Background: Although both consumptions of ultra-processed products and asthma are common during adolescence, the epidemiological evidence in regarding their association is unclear. We investigated the associations of ultra-processed products consumption with asthma and wheezing in a representative sample of Brazilian adolescents.

Methods: We used data from a representative sample of 109 104 Brazilian adolescents enrolled in the National Survey of School Health, 2012. The consumption of ultra-processed products was based on the weekly consumption (0-2, 3-4, ≥ 5 d/wk) of sweet biscuits, salty biscuits, ultra-processed meats, sweets/candies, soft drinks, and packaged snacks over the previous 7 days. We also calculated an ultra-processed consumption score by adding partial scores corresponding to weekly frequency intake of each ultra-processed product. The ultra-processed consumption score ranged from 0 to 42, the higher score, the higher the intake of these products. The presence of wheezing in the previous 12 months and asthma at any time in the past was self-reported.

Results: The adjusted odds ratios of asthma comparing the extreme categories ranged from 1.08 (95% CI 1.03-1.13) for sweets/candies to 1.30 (1.21-1.40) for ultra-processed meats. Similar magnitude of associations was found for wheezing outcome. The ultra-processed consumption score was positively associated with the presence of asthma and wheezing in a dose-response manner. The adjusted OR of asthma and wheezing comparing highest to lowest quintile of ultra-processed consumption score was 1.27 (95% CI 1.15-1.41) and 1.42 (1.35-1.50), respectively.

Conclusions: The consumption of ultra-processed products was positively associated with the presence of asthma and wheezing in adolescents.

KEYWORDS

adolescents, asthma, food consumption, respiratory sounds, ultra-processed food

1 | INTRODUCTION

Asthma stands out among the non-communicable diseases (NCD) with the greatest impact during adolescence^{1,2} due to its high prevalence (14%)³ and physical and psychosocial consequences on individual well-being.^{4,5} In 2012, asthma was the third greatest cause of years lost due to disability among adolescents aged 10-14 years.^{4,5}

According to the Global Initiative for Asthma Guidelines, dietary factors are considered crucial for primary prevention of asthma.⁶ An overview of systematic reviews focused on nutritional components showed a negative association of vitamins C, E, D, fruits, and the adherence to Mediterranean diet with asthma and wheeze among general population.^{7,8} However, the evidence on dietary exposure to address asthma is still

inconclusive, especially relative to the damaging effects of unhealthy foods.

Previous studies suggested a positive association of ultra-processed food consumption with the presence of asthma and wheezing.⁹⁻¹¹ According to the new food classification system (NOVA),¹² ultra-processed food and drink products are industrial formulations that, in addition to salt, sugar, oils, and fats, include substances obtained from the further processing of constituents of foods (ie, modified starch and maltodextrin) or through chemical synthesis (ie, dyes and other additives), such as soft drinks, salty snacks, sausages, and other reconstituted meats. In particular, flavors and colors present in these products might exacerbate wheezing and asthma. In addition, the consumption of ultra-processed products is associated with obesity,^{13,14} which in itself is a risk factor for wheezing and asthma,¹⁵ although the hypothesis that asthma causes obesity has also been postulated.^{16,17} Both the consumption of ultra-processed foods and the prevalence of asthma have dramatically increased over the last decades in Brazil. However, epidemiological studies analyzing the association of ultra-processed food consumption with the presence of asthma and wheezing are sparse in the literature.⁷⁻¹¹

In this study, we investigated the associations of ultra-processed products consumption with asthma and wheezing in a representative sample of Brazilian adolescents.

2 | METHODS

2.1 | Study population, sampling, and data collection

We used cross-sectional data collected from the National Survey of School Health (Pesquisa Nacional de Saúde do Escolar—PeNSE), conducted between April and September 2012. PeNSE was designed to monitor risk and protective factors among 9th graders from public and private schools.^{18,19} PeNSE 2012 used a complex multistage sampling process to select a sample of 9th graders representative of Brazil as a whole, its main 5 regions (north, northeast, southeast, south, and midwest), the 26 state capitals, and the Federal District. From 3004 selected schools, 162 institutions did not participate in the study because they did not have 9th grade classes, they were on strike at the time of data collection, or the school board refused to participate. A total of 110 873 students from 2842 schools were invited to participate in the study (84% of the total number of students enrolled in the sampled schools). A total of 1651 students refused participation, and 118 youths did not report their gender and/or age. The final sample size enrolled data from 109 104 students to 2842 schools (final response rate: 82.7%). Additional information about PeNSE sampling procedures is provided elsewhere.^{18,19}

Data collection was performed through smartphones and involved the application of a self-administered structured questionnaire with approximately 140 questions distributed across thematic modules, such as sociodemographic characteristics, diet, body image, physical activity, smoking, alcohol and drug

consumption, and asthma prevalence. Trained technician distributed the devices to participants and explained to them how to use it.^{18,19}

2.2 | Description of variables

The presence of wheezing and asthma was evaluated using the following questions: “In the past 12 months, did you have a wheezing (or whistling) chest?” (yes, no) and “Have you ever had asthma?” (yes, no). The same questions were also considered in the International Study of Asthma and Allergies in Childhood (ISAAC), which used a standardized questionnaire with satisfactory sensitivity and specificity to detect cases of asthma in population-based studies.⁴

The students' food consumption was assessed through questionnaire based on weekly frequency consumption of different food items. In this study, we used only questions related to ultra-processed products, such as sweet and salty biscuits, sweets/candies, ultra-processed meats, soft drinks, and packaged snacks. The weekly consumption of these products was assessed through the following question: “How many days did you eat (product name) in the past 7 days?” The responses were categorized as 0-2, 3-4, and ≥ 5 days for analysis. We additionally created an ultra-processed consumption score by adding partial scores corresponding to weekly frequency intake of each ultra-processed product (ie, 0, did not consume; 7, consumed every day). The ultra-processed consumption score ranged from 0 to 42 points, the higher score, the higher the intake of these products (eg, a 42 score means the adolescent consumed all 6 ultra-processed products 7 days a week). For means of analyses, we categorized the ultra-processed consumption score into quintiles (Q1: 0-9 points; Q2: 10-14 points; Q3: 15-19 points; Q4: 20-26 points; Q5: 27-42 points).

The following covariates were used to describe the participants' characteristics and included in the multiple regression models (ie, as potential confounders): sex (female and male), age (≤ 13 , 14-15, ≥ 16), mother's education level (did not complete middle school, completed middle school, completed high school, and completed higher education), parents as smokers (none, the father or male guardian only, the mother or female guardian only, both parents, and I don't know), having smoked in the past 30 days (yes, no), alcohol consumption in the past 30 days (yes, no), school type (public, private), physical activity level (≥ 420 min/wk, result of the sum of the weekly time spent in active commuting, physical education at school, and sports and leisure activities), regular consumption of fruits and vegetables (≥ 5 d/wk), geographical region (North, Northeast, South, Southeast, Midwest), and municipality of residence (state capital, non-capital).

2.3 | Statistical analysis

We performed descriptive analyses of covariates by asthma and wheezing status. Unadjusted (crude) and multiple logistic regression models were fit to investigate the association between independent (consumption of each ultra-processed product and ultra-processed

consumption score) and dependent (wheezing and asthma) variables. All covariates associated with wheezing and asthma (at P -values $\leq .20$ on crude logistic regression analysis) were included in the multiple regression models. The final model (multivariable model) for wheezing included the following covariates: sex, age, mother's education level, parents as smokers, having smoked in the past 30 days, alcohol consumption in the past 30 days, school type, geographical region, and municipality of residence. For asthma, we additionally included physical activity level. In addition, to verify whether the associations were independent of other dietary factors that might influence the risk of developing asthma and wheezing, we run an additional multivariable model including regular consumption of fruits and vegetables.

Finally, to explore whether associations of ultra-processed consumption score with asthma and wheezing differ by potential effect modifiers, we conducted stratified analyses by sex, smoking status, levels of physical activity, regular consumption of fruits and vegetables, parents smoking status, and municipality of residence. Test for interaction was performed by including cross-product terms of exposure and stratification variables in the models. All analyses took the sampling complexity into consideration and were performed using Stata version 14.1. The significance level was set to $P < .05$.

2.4 | Ethical issues

The study was approved by the National Research Ethics Commission ruling no. 192/2012, corresponding to registry no. 16805, March 27th, 2012.

3 | RESULTS

3.1 | Participants' characteristics

Characteristics of the participants are shown in Table 1. Approximately 18% performed physical activity at least 420 min/wk, one-fourth reported having consumed alcohol, and 5% reported having smoked tobacco in the past 30 days. Most student's parents were non-smokers; more than one-third of the mothers had low education level (did not complete middle school) (Table 1).

The majority of the adolescents consumed ultra-processed products (ie, sweet and salty biscuits, sweets/candies, ultra-processed meats, soft drinks, and packaged snacks) ≥ 3 days a week (Table S1). The distribution of ultra-processed consumption score was right-skewed (positive skewness), with mean and median of 17 and 16 points, respectively, and interquartile range of 10-23 points, indicating an overall high consumption of these products (Figure S1).

The prevalence of wheezing in the previous 12 months and asthma at any time in the past was 23.2% and 12.4%, respectively (Table S2). Adolescents with asthma and wheezing, as compared to those who did not have these conditions, were more likely to be male, to have smoked and consumed alcohol in the past 30 days,

having parents with high education level, and to live in state capitals (Table 1).

3.2 | Associations of ultra-processed products consumption with asthma and wheezing

Table 2 shows the associations of each ultra-processed product with asthma and wheezing. We found positive associations of all ultra-processed products with the presence of asthma and wheezing. Adjustment for potential confounders (multivariable model) attenuated the observed associations, although the majority remained statistically significant. The adjusted odds ratios of asthma comparing the extreme categories (0-2 d/wk vs ≥ 5 d/wk) ranged from 1.08 (95% CI 1.03-1.13) for sweets/candies to 1.30 (95% CI 1.21-1.40) for ultra-processed meats. When 0 d/wk was used as reference group, overall, the magnitude of associations remained the same (data not shown). Similar magnitude of associations was found for wheezing outcome (Table 3). We did not observe changes in the magnitude of association when we further included fruits and vegetables intake in the models (Tables 2 and 3).

The ultra-processed consumption score was positively associated with the presence of asthma and wheezing in a dose-response manner (Figure 1). The adjusted OR of asthma and wheezing comparing highest to lowest quintile of ultra-processed consumption score was 1.27 (95% CI 1.15-1.41) and 1.42 (95% CI 1.35-1.50), respectively (Figure 1). The positive association with asthma was stronger (on the multiplicative scale) among male and adolescents that did not consume fruits and vegetables regularly. For wheezing, associations were stronger among adolescents' non-smokers, who did not consume fruits and vegetables regularly, who had non-smokers parents, and lived in non-capital cities (Table S3).

4 | DISCUSSION

In this cross-sectional study, we investigated the association of ultra-processed consumption with the presence of asthma and wheezing in adolescents. We found a positive and statistically significant association with all ultra-processed products examined (sweet and salty biscuits, sweets/candies, ultra-processed meats, soft drinks, and packaged snacks). The ultra-processed consumption score summarizing all 6 ultra-processed products showed positive association with both asthma and wheezing in a dose-response manner. Associations were stronger among male adolescents, those who did not consume fruits and vegetables regularly, non-smokers, with parents who did not smoke, and those living in non-capital cities.

In the past few decades, concentration of food market to just a few transnational companies has led to severe changes in food systems, allowing ultra-processed products to become dominant worldwide.²⁰ In Brazil, the caloric share of ultra-processed products significantly increased in recent decades,²¹ and these products currently account for approximately 30% of the total caloric intake of adults and adolescents.²² Among the ultra-processed products

TABLE 1 Sociodemographic characteristics and health behaviors of Brazilian adolescents by asthma and wheezing status; PeNSE 2012

Variables	Asthma		Wheezing		Total
	Yes (N = 16 280)	No (N = 91 891)	Yes (N = 25 038)	No (N = 83 312)	(N = 109 104)
Sex (%)					
Female	49.1	47.3	44.2	48.6	52.2
Male	50.9	52.7	55.8	51.4	47.8
Age (%)					
≤13	19.1	20.9	20.7	20.6	22.9
14-15	66.9	65.9	66.3	65.9	63.9
≥16	14.0	13.2	13.0	13.4	13.2
Fathers' education level (%)					
Did not complete middle school	37.1	42.6	40.5	42.2	46.8
Complete middle school	16.2	16.9	16.8	16.8	17.6
Complete high school	28.1	26.8	27.2	26.9	25.1
Complete higher education	18.7	13.7	15.5	14.1	10.5
Mother's education level (%)					
Did not complete middle school	31.0	35.0	33.6	34.7	39.0
Complete middle school	16.7	17.5	17.1	17.4	17.8
Complete high school	33.6	32.4	32.9	32.5	30.7
Complete higher education	18.7	15.1	16.3	15.4	12.5
Parents as smokers (%)					
Neither	69.1	70.9	67.9	71.4	68.4
Father or male guardian only	14.1	13.4	14.3	13.3	14.1
Mother or female guardian only	0.9	0.9	0.10	0.8	9.6
Both parents	0.5	0.5	0.5	0.4	5.4
I don't know	0.3	0.3	0.3	0.3	2.5
Health-risk and health-protective behaviors (%)					
Practice of physical activity ^a	20.5	19.0	19.7	19.1	18.3
Having smoked in the past 30d	8.0	4.7	8.4	4.3	5.1
Alcohol consumption in the past 30d	29.8	24.8	32.6	23.4	26.1
Regular consumption of fruits and vegetables ^b	17.3	16.4	16.6	16.5	16.5
School type (%)					
Private	24.5	20.1	22.2	20.2	17.2
Public	75.5	79.9	77.8	79.7	82.8
Geographical region (%)					
Midwest	26.7	19.8	21.8	20.6	7.9
Northeast	29.1	28.7	24.7	30.0	25.3
North	15.9	18.4	19.6	17.8	8.0
Southeast	12.9	13.8	14.4	13.4	44.3
South	15.4	19.3	19.5	18.5	14.6
Municipality of residence (%)					
State capital	64.8	54.6	57.3	55.8	22.4
Non-capital	35.2	45.4	42.7	44.2	77.6

PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health).

^a≥420 min/wk.^b≥5 d/wk.

The presence of wheezing and asthma was evaluated using the following questions: "In the past 12 mo, did you have a wheezing (or whistling) chest?" (yes, no) and "Have you ever had asthma?" (yes, no).

TABLE 2 Associations of consumption of ultra-processed products with asthma among Brazilian adolescents; PeNSE 2012

		Asthma					
Variables	N cases	Crude		Multivariable model ^a		Multivariable model ^a plus fruits and vegetables ^b	
		OR	95% CI	OR	95% CI	OR	95% CI
Sweet biscuits							
0-2d	7362	1		1		1	
3-4d	3465	1.04	0.93-1.15	1.02	0.92-1.13	1.02	0.92-1.13
≥5d	5415	1.16	1.12-1.21*	1.13	1.08-1.18*	1.12	1.07-1.16*
Salty biscuits							
0-2d	6730	1		1		1	
3-4d	3648	1.02	0.96-1.08	1.00	0.95-1.05	1.00	0.95-1.05
≥5d	5882	1.16	1.07-1.26*	1.13	1.05-1.21*	1.12	1.04-1.20*
Ultra-processed meats							
0-2d	10 357	1		1		1	
3-4d	3212	1.10	1.04-1.17	1.07	1.01-1.12	1.07	1.01-1.12
≥5d	2699	1.36	1.26-1.47*	1.30	1.21-1.40*	1.29	1.20-1.40*
Sweets							
0-2d	6141	1		1		1	
3-4d	3208	1.01	0.94-1.08	0.99	0.93-1.05	0.98	0.93-1.05
≥5d	6905	1.12	1.08-1.17*	1.08	1.03-1.13*	1.07	1.02-1.13*
Soft drinks							
0-2d	6765	1		1		1	
3-4d	3653	1.07	0.98-1.17	1.04	0.95-1.13	1.04	0.96-1.13
≥5d	5839	1.23	1.13-1.33*	1.14	1.06-1.22*	1.13	1.05-1.22*
Packaged snacks							
0-2d	11 616	1		1		1	
3-4d	2352	1.15	1.09-1.22	1.13	1.06-1.20	1.12	1.06-1.19
≥5d	2279	1.35	1.26-1.46*	1.29	1.22-1.37*	1.28	1.20-1.35*

PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health); OR, odds ratio; CI, confidence interval.

^aAdjusted for sex, age, mother's education level, parents as smokers, having smoked in the past 30 d, alcohol consumption in the past 30 d, school type, geographical region, and municipality of residence.

^bAdjusted for variables in full model^a plus regular consumption of fruits and vegetables (≥5 d/wk).

* $P < .05$ for linear trend between the categories.

The presence of asthma was evaluated using the following questions: "Have you ever had asthma?" (yes, no).

consumed by Brazilians aged ≥10 years, the most consumed products were cakes, pies, and cookies (3.0%), fast food (2.9%), sugar-sweetened beverages (2.6%), ultra-processed meats (2.4%), and sweets (2.2%).²³ The majority of these products were included in our study.

Additives and excess of weight are the main possible mediators of the association between ultra-processed products and asthma. When consumed in minimal amounts, food additives might not pose a risk to health. However, the impacts of these additives when they are consumed in large amounts, such as in ultra-processed products, are subject to debate in the literature.^{10,24} In fact, we did not find an association between small consumption of ultra-processed

products (ie, 3-4 d/wk for each ultra-processed product [Table 2]; 2nd quintiles of ultra-processed consumption score [Figure 1]) with asthma and wheezing, but only with regular and large consumption of these products. We also showed that these associations were stronger among low-risk individuals. These results were expected as the majority of the asthma cases might be related to stronger risk factors such as smoking and air pollution.²⁵ Some studies have shown that food dyes, especially cochineal red^{24,26} and tartrazine,²⁴ and the preservatives sodium benzoate and sodium sulfite²⁷ might be associated with the formation of pro-inflammatory cytokines,²⁸ which play a central role in the development of asthma.¹⁵ Studies in humans have also found an association between food additives, such

TABLE 3 Associations of consumption of ultra-processed products with wheezing among Brazilian adolescents; PeNSE 2012

		Wheezing					
Variables	N cases	Crude		Multivariable model ^a		Multivariable model ^a plus fruits and vegetables ^b	
		OR	95% CI	OR	95% CI	OR	95% CI
Sweet biscuits							
0-2d	11 345	1		1		1	
3-4d	5314	1.07	1.03-1.10	1.05	1.02-1.08	1.05	1.02-1.08
≥5d	8234	1.22	1.18-1.25*	1.15	1.12-1.18*	1.15	1.13-1.18*
Salty biscuits							
0-2d	10 163	1		1		1	
3-4d	5803	1.09	1.04-1.13	1.08	1.04-1.13	1.08	1.04-1.13
≥5d	9044	1.19	1.15-1.22*	1.15	1.11-1.18*	1.15	1.11-1.19*
Ultra-processed meats							
0-2d	15 839	1		1		1	
3-4d	5063	1.20	1.14-1.27	1.17	1.11-1.23	1.17	1.11-1.23
≥5d	4108	1.38	1.22-1.55*	1.29	1.13-1.47*	1.29	1.14-1.47*
Sweets							
0-2d	8683	1		1		1	
3-4d	4962	1.17	1.09-1.25	1.12	1.05-1.20	1.12	1.05-1.20
≥5d	11 364	1.39	1.34-1.44*	1.27	1.22-1.31*	1.27	1.22-1.32*
Soft drinks							
0-2d	10 270	1		1		1	
3-4d	5868	1.11	1.08-1.15	1.09	1.06-1.12	1.09	1.06-1.12
≥5d	8870	1.18	1.12-1.25*	1.10	1.04-1.15*	1.10	1.04-1.15*
Packaged snacks							
0-2d	17 944	1		1		1	
3-4d	3647	1.23	1.14-1.32	1.18	1.10-1.27	1.18	1.11-1.26
≥5d	3404	1.34	1.28-1.40*	1.24	1.19-1.29*	1.24	1.20-1.29*

PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health); OR, odds ratio; CI, confidence interval.

^aAdjusted for sex, age, mother's education level, parents as smokers, having smoked in the past 30 d, alcohol consumption in the past 30 d, school type, geographical region, and municipality of residence.

^bAdjusted for variables in full model^a plus regular consumption of fruits and vegetables (≥5 d/wk).

* $P < .05$ for linear trend between the categories.

The presence of wheezing was evaluated using the following questions: "In the past 12 mo, did you have a wheezing (or whistling) chest?" (yes, no).

as tartrazine and sodium benzoate, and histamine released by human basophils.^{29,30} Histamine is one of the substances that triggers allergic symptoms, such as chest wheezing and shortness of breath.⁶

Regular consumption of ultra-processed products may influence the development of asthma through obesity/adiposity. Recently, a study with Brazilian population aged 10 years or older found an association between consumption of ultra-processed products and obesity.²² In addition, a systematic review of epidemiological studies on children and adolescents has found an association between excess weight and the development of asthma and wheezing.³¹ Excess weight increases adipokines, which are related to reductions in the functional residual capacity of the lungs.^{15,31} Beyond the fact that

obesity is related with elevated pro-inflammatory cytokines such as visfatin, high body weight is also associated with airway smooth muscle contractility (ie, hyper-responsiveness).^{15,32} Indeed, the levels of adiponectin, which contributes to anti-inflammatory responses, are reduced among obese individuals.³² Although we could not estimate the extent to which excess weight mediated the associations found in our study (due to low-quality self-reported data on body weight and height), our study strengthens the hypothesis that obesity might influence the risk of developing asthma.

The main strength of our study is the representative sample of Brazilian adolescent students from the National Survey of School Health 2012. In addition, we used NOVA food classification

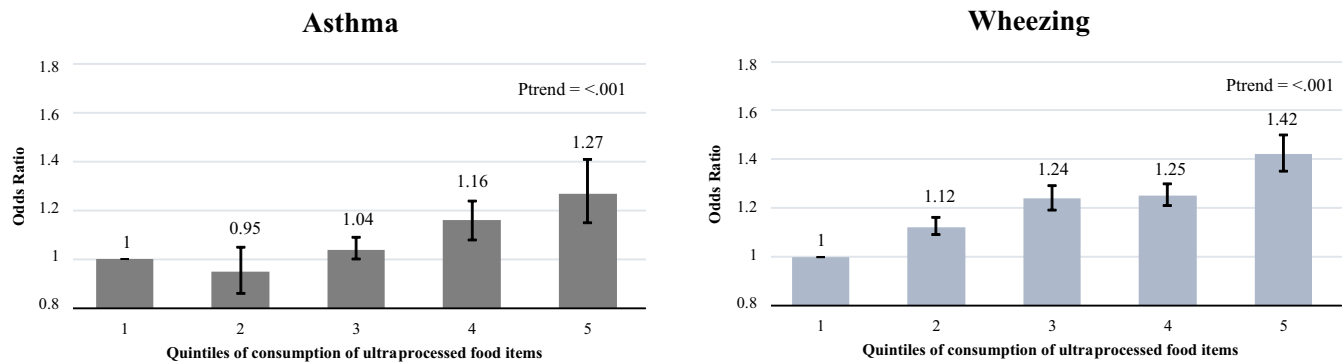


FIGURE 1 Association of ultra-processed consumption score with asthma and wheezing among Brazilian adolescents; PeNSE 2012. PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health). *Ultra-processed consumption score was calculated by adding partial scores corresponding to weekly frequency intake of each ultra-processed product. The ultra-processed consumption score ranged from 0 to 42 points, the higher score, the higher the intake of these products. Quintiles of ultra-processed consumption score: Q1 (0–9 points); Q2 (10–14 points); Q3 (15–19 points); Q4 (20–26 points); Q5 (27–42 points) [Colour figure can be viewed at wileyonlinelibrary.com]

system, which is based on the extension and purpose of industrial processing and has been recognized in the literature as relevant to combating obesity and NCD.¹² Nevertheless, some limitations deserve mention. First, this is a cross-sectional study, and thus, reverse causation cannot be ruled out. Ultra-processed food consumption refers to the last 7 days, whereas wheezing refers to the last 12 months and asthma ever in life. The extent of consumption of ultra-processed foods may have changed over child's life. Therefore, wheezing and asthma diagnoses could have changed adolescents' health behaviors, including diet. In fact, we found high prevalence of regular consumption of fruits and vegetables and high levels of physical activity among adolescents who reported asthma and wheezing (Table 1). These changes are also likely to have occurred in the consumption of ultra-processed foods, by reducing overall intake among adolescents with asthma and wheezing, hence attenuating the magnitude of the associations. Both exposures and outcomes were self-reported and thus likely to misclassification bias. If non-differential, misclassification tends to toward OR to null association. Finally, residual confounding due to unmeasured confounders (eg, pollution) and variables with measurement error included in the models (eg, mother's educational level) could explain at least in part the associations.

In conclusion, the consumption of ultra-processed products was positively associated with the presence of asthma and wheezing in a dose-response manner among Brazilian adolescents. Cohort studies and randomized controlled trials are needed to provide further evidence for these associations, as well as elucidate the underlying biological mechanisms.

CONFLICT OF INTEREST

The authors do not have any competing interests to declare.

AUTHOR CONTRIBUTION

BLM, LFM, PPM, NG and RBL formulated the research question, designed, carried out the study, conducted the data analyses and

wrote the article. All authors have also read and approved the final version of the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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1 **Supplementary Materials**

2

3

Table S1. Frequency of ultra-processed products consumption among Brazilian adolescents; PeNSE 2012.

Exposures	0-2 days/week			3-4 days/week			≥5 days/week		
	n	%	95% CI	n	%	95% CI	n	%	95% CI
Sweet biscuits	52,057	46.2	(45.5-47.0)	23,102	21.3	(20.2-22.3)	35,562	32.5	(31.5-33.6)
Salty biscuits	46,874	42.2	(41.2-43.2)	24,712	22.7	(21.8-23.6)	38,211	35.1	(33.2-37.0)
Ultra-processed meats	73,174	66.0	(64.3-67.3)	21,010	19.3	(18.0-20.7)	16,002	14.7	(14.0-15.3)
Sweets	42,849	39.1	(36.7-41.5)	21,328	19.6	(19.1-20.2)	44,941	41.3	(39.2-43.4)
Soft drinks	47,868	44.0	(42.0-45.9)	24,820	22.8	(22.4-23.3)	36,141	33.2	(31.7-34.8)
Packaged snacks	81,628	72.8	(71.8-73.8)	15,341	14.1	(13.1-15.2)	14,145	13.0	(12.4-13.7)

PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health).

CI, Confidence Interval

Ultra-processed meats (e.g., hamburger, frankfurter, bologna sausage, salami, ham, nuggets, and sausage).

4

5 **Table S2:** Prevalence of asthma and wheezing by ultra-processed food categories among Brazilian
6 adolescents; PeNSE 2012.

Variables	Asthma		Wheezing	
	Prevalence		Prevalence	
	%	95% CI	%	95% CI
Total sample (N=109,104)	12.3	(11.4-13.5)	23.2	(21.2-25.4)
Quintiles of ultra-processed food items				
Q1 (0-9 items)	11.3	(10.7-11.9)	19.2	(17.7-20.8)
Q2 (10-14 items)	11.0	(9.7-12.4)	21.6	(19.9-23.5)
Q3 (15-19 items)	11.2	(11.4-12.6)	23.6	(21.2-26.2)
Q4 (20-26 items)	13.3	(12.1-14.7)	24.4	(22.4-26.4)
Q5 (27-42 items)	14.7	(12.9-16.7)	27.8	(24.8-31.0)
<i>Frequency of consumption of ultra-processed food items</i>				
Sweet biscuits				
0-2 days	11.8	(10.7-13.0)	21.8	(20.0-23.8)
3-4 days	12.2	(11.5-13.0)	23.0	(20.7- 25.3)
≥5 days	13.5	(12.1-14.9)	25.4	(23.1-27.8)
Salty biscuits				
0-2 days	11.8	(11.2-12.5)	21.8	(19.8-24.0)
3-4 days	12.0	(10.9-13.2)	23.2	(20.8-25.9)
≥5 days	13.4	(11.9-15.1)	24.9	(22.9-27.0)
Ultra-processed meats				
0-2 days	11.7	(10.9-12.6)	21.7	(20.1-23.5)
3-4 days	12.8	(11.6-14.1)	25.0	(23.1-27.1)
≥5 days	15.3	(13.6-17.2)	27.6	(23.5-32.1)
Sweets				
0-2 days	11.9	(10.9-12.9)	20.3	(18.3-22.5)
3-4 days	12.0	(11.1-12.8)	22.9	(21.1-24.9)
≥5 days	13.2	(12.0-14.4)	26.1	(24.1-28.3)
Soft drinks				
0-2 days	11.5	(10.8-12.3)	21.8	(19.9-23.8)
3-4 days	12.2	(10.8-13.9)	23.7	(21.6-26.0)
≥5 days	13.8	(12.5-15.2)	24.8	(22.3-27.4)
Packaged snacks				
0-2 days	11.7	(10.9-12.6)	22.0	(20.2-23.8)
3-4 days	13.3	(11.9-14.8)	25.7	(22.5-29.2)
≥5 days	15.3	(13.5-17.3)	27.4	(24.9-30.2)

7 PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health).

8 CI, Confidence Interval

9

Table S3. Subgroup analysis: Association of quintiles of ultra-processed consumption score with asthma and wheezing among Brazilian adolescents; PeNSE 2012 (continues).

Variables†	Quintiles of ultra-processed consumption score					P _{interaction}
	Q1 (0-9 points)	Q2 (10-14 points)	Q3 (15-19 points)	Q4 (20-26 points)	Q5 (27-42 points)	
Asthma	OR	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	
<i>Sex</i>						0.010
Female (N=8,277)	1	0.98 (0.83-1.15)	1.02 (0.97-1.08)	1.13 (1.04-1.22)	1.23 (1.10-1.40)	
Male (N=8,003)	1	0.94 (0.87-1.02)	1.07 (0.98-1.17)	1.19 (1.05-1.34)	1.30 (1.15-1.49)	
<i>Smoked in the past 30 days</i>						0.788
No (N=14,948)	1	0.98 (0.90-1.07)	1.05 (1.00-1.10)	1.15 (1.08-1.23)	1.28 (1.20-1.38)	
Yes (N=1,314)	1	0.69 (0.43-1.12)	0.94 (0.79-1.23)	1.06 (0.75-1.50)	1.06 (0.58-1.94)	
<i>Father or mother smoking</i>						0.971
No (N=11,227)	1	0.94 (0.88-1.01)	1.06 (0.97-1.16)	1.18 (1.09-1.27)	1.25 (1.17-1.34)	
Yes (N=4,569)	1	1.00 (0.83-1.22)	0.99 (0.85-1.14)	1.08 (0.91-1.30)	1.30 (1.05-1.60)	
<i>Municipality of residence</i>						0.058
State capital (N=10,551)	1	0.90 (0.80-1.00)	0.94 (0.84-1.07)	1.07 (0.94-1.21)	1.14 (1.01-1.30)	
Non-capital (N=5,729)	1	0.99 (0.83-1.17)	1.08 (1.01-1.16)	1.18 (1.04-1.35)	1.31 (1.10-1.58)	
<i>Practice of physical activity¹</i>						0.957
No (N=11,022)	1	0.97 (0.84-1.11)	1.08 (0.98-1.18)	1.15 (1.10-1.21)	1.28 (1.14-1.46)	
Yes (N=5,258)	1	0.94 (0.83-1.07)	0.96 (0.79-1.15)	1.14 (0.90-1.45)	1.22 (0.94-1.59)	
<i>Regular consumption of fruits and vegetables²</i>						0.038
No (N=13,467)	1	0.96 (0.87-1.07)	1.02 (0.94-1.11)	1.17 (1.10-1.24)	1.30 (1.19-1.41)	
Yes (N=2,813)	1	0.95 (0.82-1.11)	1.12 (0.85-1.48)	1.06 (0.84-1.35)	1.15 (0.94-1.40)	

PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health).

OR: Odds Ratio; CI, Confidence Interval

N: number of asthma cases.

†Adjusted for sex, age, mother's education level, parents as smokers, having smoked in the past 30 days, alcohol consumption in the past 30 days, practice of physical activity, regular consumption of fruits and vegetables, school type, geographical region, municipality of residence.

*** Ultra-processed consumption score was calculated by adding partial scores corresponding to weekly frequency intake of each ultra-processed product. The ultra-processed consumption score ranged from 0 to 42 points, the higher score, the higher the intake of these products.**

¹ ≥420 minutes per week

² ≥5 days per week

Table S3. Subgroup analysis: Association of quintiles of consumption of ultra-processed food items with asthma and wheezing among Brazilian adolescents attending 9th grade at private and public schools; PeNSE 2012 (continuation).

Variables†	Quintiles of ultra-processed consumption score					P _{interaction}
	Q1 (0-9 points)	Q2 (10-14 points)	Q3 (15-19 points)	Q4 (20-26 points)	Q5 (27-42 points)	
Wheezing	OR	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	
<i>Sex</i>						0.010
Female (N=11,062)	1	1.24 (1.17-1.31)	1.31 (1.25-1.37)	1.33 (1.19-1.48)	1.54 (1.43-1.66)	
Male (N=13,976)	1	1.04 (0.96-1.12)	1.20 (1.22-1.29)	1.21 (1.08-1.35)	1.35 (1.28-1.43)	
<i>Smoked in the past 30 days</i>						0.009
No (N=22,906)	1	1.14 (1.10-1.19)	1.25 (1.22-1.30)	1.28 (1.22-1.35)	1.46 (1.40-1.53)	
Yes (N=2,101)	1	0.90 (0.57-1.42)	1.05 (0.74-1.50)	0.89 (0.64-1.26)	1.03 (0.73-1.46)	
<i>Father or mother smoking</i>						0.005
No (N=16,989)	1	1.17 (1.06-1.30)	1.29 (1.23-1.36)	1.31 (1.25-1.38)	1.49 (1.35-1.65)	
Yes (N=7,317)	1	1.05 (0.87-1.26)	1.17 (1.09-1.25)	1.15 (1.05-1.27)	1.31 (1.19-1.46)	
<i>Municipality of residence</i>						0.029
State capital (N=14,331)	1	1.05 (0.94-1.17)	1.08 (0.98-1.18)	1.13 (0.99-1.29)	1.30 (1.14-1.47)	
Non-capital (N=10,707)	1	1.15 (1.10-1.20)	1.31 (1.25-1.36)	1.30 (1.25-1.36)	1.47 (1.38-1.58)	
<i>Practice of physical activity¹</i>						0.108
No (N=17,122)	1	1.09 (1.04-1.14)	1.22 (1.15-1.28)	1.23 (1.16-1.30)	1.37 (1.27-1.48)	
Yes (N=7,916)	1	1.25 (1.15-1.37)	1.35 (1.16-1.57)	1.37 (1.25-1.50)	1.58 (1.46-1.71)	
<i>Regular consumption of fruits and vegetables²</i>						0.005
No (N=20,887)	1	1.14 (1.08-1.20)	1.25 (1.21-1.30)	1.26 (1.18-1.34)	1.49 (1.41-1.57)	
Yes (N=4,151)	1	1.09 (0.84-1.40)	1.22 (0.97-1.54)	1.25 (1.02-1.54)	1.22 (1.03-1.46)	

PeNSE, Pesquisa Nacional de Saúde do Escolar (National Survey of School Health).

OR: Odds Ratio; CI, Confidence Interval

N: number of wheezing cases.

†Adjusted for sex, age, mother's education level, parents as smokers, having smoked in the past 30 days, alcohol consumption in the past 30 days, practice of physical activity, regular consumption of fruits and vegetables, school type, geographical region, municipality of residence.

*** Ultra-processed consumption score was calculated by adding partial scores corresponding to weekly frequency intake of each ultra-processed product. The ultra-processed consumption score ranged from 0 to 42 points, the higher score, the higher the intake of these products.**

¹ ≥420 minutes per week

² ≥5 days per week

Figure S1: Histogram and description of the calculated score of ultra-processed food items consumed by Brazilian adolescents; PeNSE 2012.

