Received: 30 May 2019 | Revised: 6 September 2019 | Accepted: 9 September 2019

DOI: 10.1111/pai.13126

ORIGINAL ARTICLE

WILEY

Ultra-processed food consumption during childhood and asthma in adolescence: Data from the 2004 Pelotas birth cohort study

Catarina Machado Azeredo[1,2] | Marianna Cortese[2] | Caroline dos Santos Costa[3] | Kjetil Bjornevik[2] | Aluisio J. D. Barros[3] | Fernando C. Barros[3,4] | Iná S Santos[3,5] | Alicia Matijasevich[3,6]

[1]School of Medicine, Federal University of Uberlandia, Uberlândia, Brazil

[2]Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, Massachusetts

[3]Post-graduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil

[4]Post-graduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

[5]Post-graduate Program in Pediatrics and Child Health, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil

[6]Departamento de Medicina Preventiva, Faculdade de Medicina FMUSP, Universidade de São Paulo, São Paulo, Brasil

Correspondence
Catarina Machado Azeredo, School of Medicine, Federal University of Uberlandia, Av Pará 1720, Bloco 2 U, Campus Umuarama, Umuarama, Uberlandia, MG, Brazil.
Email: catarina.azeredo@yahoo.com.br

Funding information
World Health Organization, Grant/Award Number: Grant no. 03014HNI; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Grant/Award Number: CAPESHVD 88881.162300/2017-01; National Support Program for Centres of Excellence (PRONEX), Grant/Award Number: Grant no. 04/0882.7; Conselho Nacional de Desenvolvimento Científico e Tecnológico, Grant/Award Number: Grant nos. 481012-2009-5, 484077-2010-4, 470965-2;

Abstract

Background: Diet has been of interest for asthma; however, it remains unknown whether the consumption of ultra-processed food (UPF) increases the risk of the disease. Our objective was to investigate whether UPF consumption during childhood was associated with wheeze, asthma, and severe asthma in adolescence.

Methods: We included 2190 11-year-old children from the 2004 Pelotas Birth Cohort Study, without asthma at the age of 6 years. Consumption of UPF was assessed by Food Frequency Questionnaires at 6- and 11-year follow-ups. Wheeze, asthma, and severe asthma data were assessed at 11-year follow-up. We classified foods according to the processing degree in ultra-processed food. We used logistic regression to estimate the odds ratio (OR) and 95% confidence intervals (CIs), for the association between UPF consumption and the asthma outcomes.

Results: Cumulative incidence of wheeze and asthma between 6 and 11 years was 12.7% and 23.2%, respectively. In prospective analyses, comparing children in the highest and the lowest quintile of UPF consumption at age 6, we found no association with wheeze (OR = 0.85; 95% CI = 0.54-1.34), asthma (OR = 0.84; 95% CI = 0.58-1.21), or severe asthma (OR = 1.12; 95% CI = 0.62-2.03) in early adolescence. In cross-sectional analyses, comparing adolescents in the highest and lowest quintile of UPF consumption at 11 years, we found no association with wheeze (OR = 1.12; 95% CI = 0.72-1.75), asthma (OR = 1.00; 95% CI = 0.7-1.44), or severe asthma (OR = 1.05; 95% CI = 0.59-1.86).

Conclusion: Our study provided evidence that UPF consumption during childhood or adolescence is not associated with asthma or wheeze among adolescents.

KEYWORDS
adolescents, asthma, cohort study, food consumption, ultra-processed food

Fundação de Amparo à Pesquisa do Estado de São Paulo, Grant/Award Number: Grant no. 2014/13864-6; Ministério da Saúde, Grant/Award Number: Grant no. 25000.105293/2004-83

Editor: Jon Genuneit

1 | INTRODUCTION

Asthma is the most prevalent chronic respiratory disease[1] and is among the top ten causes of years lost due to disability among adolescents.[2] Although asthma prevalence is stable or decreasing in developed countries, it is increasing in developing countries, which could be influenced by increasing adherence to a Western diet.[3]

A Western diet could influence the risk of asthma indirectly, through obesity-related mechanisms,[4] or directly through pro-inflammatory nutrients, additives, and diets low in antioxidants.[5,6] One component of a Western diet is ultra-processed food (UPF) that consists of foods and additives combined in multiple processing sequences. UPF includes, for example, fast foods, savory snacks, soft drinks and artificial juice, reconstituted meat products, ice cream, cookies, confectionery, among other pre-prepared frozen dishes.[7] It is often rich in salt, fat, and sugar[8] and could contribute to the above-mentioned mechanisms.

The results from previous studies on the association between specific UPF items with asthma have been inconsistent. A cross-sectional study found that consumption of specific UPF items was positively associated with asthma and wheezing among adolescents.[9] However, a cohort study found no association between early childhood consumption of soft drinks or sugar-sweetened beverages and asthma.[10] A recent systematic review[11] based mainly on case-control and cross-sectional studies found that fast foods, mainly hamburgers, were associated with asthma, while soft drinks and takeaway food were not. The lack of adjustments for socioeconomic status, parental allergy, smoking, and other dietary factors that could act as negative confounders,[11] in addition to the possibility of recall bias, could explain the associations found. Further, it is difficult to address the temporality in the associations in cross-sectional design. Thus, it remains unknown whether UPF increases the risk of asthma.

Key Message

This is the first study to use longitudinal data to assess the association between ultra-processed food (UPF) consumption in childhood with wheeze, asthma, and severe asthma in early adolescence. Findings from previous studies were inconsistent and limited by cross-sectional or case-control designs and insufficient adjustment for confounders. We analyzed data of 2190 11-year-old children from the 2004 Pelotas Birth Cohort Study and overcome these limitations. Our results suggest that UPF consumption during childhood or adolescence is not an important determinant of asthma among adolescents. More evidence is needed to guide dietary recommendation about UPF consumption on asthma prevention.

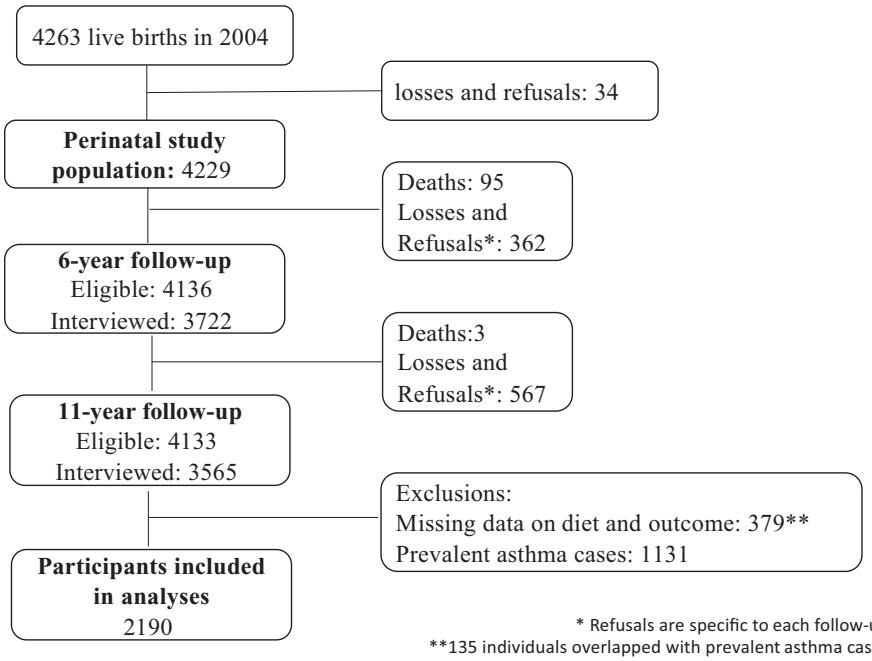

FIGURE 1 Flow chart of participants in the study – 2004 Pelotas Birth Cohort Study

Therefore, our objective was to investigate whether UPF consumption during childhood and adolescence was associated with wheeze, asthma, and severe asthma in early adolescence.

2 | METHODS

2.1 | Study population

We used data from the 2004 Pelotas Birth Cohort Study. All live births from mothers resident in the urban area of Pelotas, a medium-sized city in the south of Brazil, were eligible for inclusion/participation. Participants were recruited at the five maternity hospitals covering more than 98% of all deliveries in the city. A total of 4231 mothers were enrolled in the cohort study with their newborns (response rate of 99.3%, 4229 children). Six follow-up assessments were performed at home at ages 3, 12, 24, and 48 months, and at a research clinic at mean ages of 6.8 and 11.0 years (follow-up rates 87%-96%). In this study, we used data from the baseline (perinatal interview), and from the 6- and 11-year follow-ups. At 11-year follow-up 3565 participants were interviewed (follow-up rate = 86.6%, taking into account the deaths). The study flowchart in Figure 1 shows the included participants, losses, and exclusions. Details of the methodology can be found elsewhere.[12]

2.2 | Assessment of exposures

The mothers reported the child's diet at 6- and at 11-year follow-ups for a 12-month recall period using validated semi-quantitative food frequency questionnaires (FFQ). The adolescents assisted with the FFQ report. The FFQs were developed based on 24-hours recalls among children and among adolescents. Among 6-year-old children, the diet had less variety of foods than among 11 years old, and for that reason, the FFQs included 54 and 88 food items, respectively, at ages 6 and 11.[13] Despite the different number of food items, we classified the extra food items from the 11-year FFQ in each of the four groups of NOVA (in natura/minimally processed food, culinary ingredients, processed food, and ultra-processed food), and they were homogeneously distributed among all groups in both FFQ; therefore, the FFQs were not calibrated. For each food, the frequency (per day, month, or year) and the portion size consumed (small, medium, large, or extra-large) compared to medium portion size were reported. Food amounts were converted into grams or milliliters based on a food portion table,[14] and energy intake was estimated based on the Brazilian food composition table (TACO)[15] or USDA Nutrient Database for Standard Reference,[16] when not available in TACO. NOVA classification (a name, not an acronym) was used to identify the UPF,[8] as previously described.[17] Most of the UPF items were assessed at 6- and 11-year follow-up (sweet and salty biscuits, yogurt, ham, mortadella, sausage, margarine/butter, mayonnaise, candy, chocolate bar and powder, ice cream, soft drinks, artificial juice, salty baggage snacks); some foods were included only in the FFQ of the 6-year follow-up (gelatin), while others were included only in the 11-year follow-up (corn flakes, cereal bar and granola, spreadable cheese/cream cheese, instant noodles, Hamburger or nuggets, Pizza, "bauru"—toasted sandwich with cheese, beef, pickles, and tomato—cheeseburger or hot dogs).

In addition to the assessment of total UPF, we assessed the consumption of specific UPF items, such as sugar-sweetened beverages (artificial fruit juice and soft drinks), soft drinks, and ultra-processed meat (ham, sausage, and mortadella), because an association between these foods and asthma has previously been reported.[6,18,19]

We assessed body weight using a digital scale (TanitaVR BC-558, maximum 150 kg, and 100 g precision), and height using a stadiometer (HarpendenVR) at the 6-year follow-up.[12] We determined BMI (kg/m^2) and standardized BMI (z scores). Children were classified as normal weight (BMI *z* score within 1SD), overweight (BMI *z* score + 1-1.99 SDs), or obese (BMI *z* score ≥ 2 SDs) following z score BMI-for-age metrics as defined by the World Health Organization (WHO).[20]

2.3 | Assessment of outcomes

To assess wheeze and asthma at 11-year follow-up, we used the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire. This questionnaire was validated in Brazilian children and adolescents, showing good sensitivity, reliability, and a significant agreement between adolescents' and their parents' response.[21,22] Parents reported adolescents' wheezing in the past 12 months through the question: "Has your child had wheezing or whistling in the chest in the past 12 months?" (yes classified the adolescent as having wheeze). Asthma was defined according to parents report of a physician's diagnosis or of wheezing in the past 12 months. Severe asthma was defined based on parents report of any of the following, in the past 12 months: 4 or more attacks of wheeze, at least 1 weeknight of disturbed sleep from wheeze, and one episode of wheeze-affected speech.[23]

2.4 | Assessment of co-variables

In the perinatal interviews, we gathered information on family income in the previous month (categorized in quintiles), maternal education (0-4 years, 5-8, and ≥ 9 years of schooling), age (<20, 20-34, or > 34 years), skin color/ethnic background (white or black/mixed), asthma (no, yes), smoking during pregnancy, and parity (number of previous viable pregnancies 0, 1, and ≥ 2), as well as parental smoking at the 6-year follow-up and child's sex and exclusive breastfeeding (0-<2, 2-<4, 4-6 months). We also assessed the child's total energy intake (TEI), and the child's energy intake-expenditure ratio (TEI: EEI), described by Leech et al[24] The adjustment by this ratio reduces the misclassification due to energy under- or over-reporting, which is inherent to FFQs. The energy expenditure was calculated using the validated sex- and age-specific equations, taking into account the nutritional status and level of physical activity.[25] The child's physical activity level was

assessed by the Netherlands Physical Activity Questionnaire[26] at the 6-year follow-up and by raw triaxial wrist accelerometry (GENEActiv; ActivInsights, Kimbolton, UK, and Actigraph® GT3X) at the 11-year follow-up.

2.5 | Statistical analyses

The proportion (in energy, %calories/day) of UPF (%UPF) was estimated and divided into quintiles at 6 and at 11 years. We also assessed specifically the proportion of energy from sugar-sweetened beverages, soft drinks, and ultra-processed cured meat in quintiles. The distribution of quintiles of UPF, according to parents and child characteristics, was compared using the chi-square test.

We used logistic regression to estimate odds ratios (ORs) and 95% confidence intervals (95% CIs) for the associations between UPF at age 6 and at age 11 with wheeze and asthma at age 11. For severe symptoms of asthma (no, mild + moderate, or severe symptoms), we applied multinomial logistic regression models. We also ran models to assess the association between quintiles of specific UPF items at 6 and at 11 years with each of the outcomes. We adjusted analyses for factors that could potentially confound the associations between UPF consumption and asthma. We included an interaction term between the UPF quintiles and sex in the model. Finally, we ran a model for nutritional status as exposure to the asthma outcomes.

A hierarchical conceptual model was used to include variables in the models. Initially, energy adjustments obtained from the child's FFQ and the child's energy expenditure estimates were included (TEI and TEI:EEI). Since the dietary exposures at age 6 were assessed in a separated model from the dietary exposures at age 11, the energy adjustments were age-specific. After that, we included socioeconomic status variables (family income, maternal education), followed by maternal variables (age, race, parity, smoking during pregnancy, perinatal asthma), and finally child-related variables (sex, parental smoking at the age of 6). Findings at $P < .05$ were considered significant. All analyses were performed using Stata 15 software (Stata Corp., College Station, TX, USA).

2.6 | Standard protocol approvals, registrations, and patient consents

The study protocol and all follow-ups of the 2004 Pelotas cohort studies were approved by the Medical Ethics Committee of the Federal University of Pelotas, affiliated with the Brazilian National Commission for Research Ethics (CONEP). Mothers signed an informed consent form at each follow-up, after being informed of the study objectives. At the 11-year follow-up, adolescents also signed an informed consent form.

3 | RESULTS

Complete dietary and wheeze data were available for 3186 children at 11 years, out of 3565 interviewed. After excluding those who had asthma at age 6 (1131 children, 135 overlapped with children without complete data), we included a total of 2190 participants. These children had similar characteristics compared to children with information at 11-year visit and all respondents at baseline (Table 1). Baseline characteristics of children with information at 11-year visit and those who were lost/refused to participate are available in Table S1. Those who were lost had lower socioeconomic status, mothers with a higher prevalence of smoking during pregnancy and higher parity. Cumulative incidence of wheeze and asthma between 6 and 11 years of age was 12.7% (CI 95%: 11.4-14.2) and 23.2% (CI 95%: 21.4-25.0), respectively. Severe asthma was reported by 7.2% (CI 95%: 6.1-8.3) of the participants. The proportion of total energy intake contributed by UPF was 42.3% at 6 years and 33.7% at 11 years. The caloric contribution from the UPF items is shown in Table S2. We found no evidence of modification in our associations by sex (data not shown), and thus, our models are presented for the total sample.

Children and adolescents in the top quintile of percentage of caloric intake from UPF were more likely to have mothers with an intermediate level of education compared to the bottom quintiles, where mothers with either the highest or the lower level of education were more prevalent (Table 2). These children and adolescents were also more likely to have younger mothers at the time of delivery, have mothers with lower parity, as well as being exposed to smoking during pregnancy and at age 6.

In the prospective analyses, UPF consumption at the age of 6 was not associated with wheeze or asthma at age 11 (Table 3). The estimates did not materially change after we adjusted for potential confounders. Comparing children in the highest and the lowest quintile of UPF consumption, we found no association with current wheeze (OR = 0.85; 95% CI = 0.54-1.34), asthma (OR = 0.84; 95% CI = 0.58-1.21), or severe asthma (OR = 1.12; 95% CI = 0.62-2.03) in early adolescence.

The results were similar in cross-sectional analyses on UPF consumption and asthma risk at the age 11 (later exposure) (Table 4). Comparing adolescents in the highest and lowest quintile of UPF consumption, we found no association with current wheeze (OR = 1.12; 95% CI = 0.72-1.75), asthma (OR = 1.00; 95% CI = 0.7-1.44), or severe asthma (OR = 1.05; 95% CI = 0.59-1.86) in the multivariable models.

The subanalysis for specific UPF items, such as sugar-sweetened beverages, soft drinks, and cured meat, is shown in the Tables S3-S6. Regardless of the timing of the exposure (at age 6 or 11 years), higher consumption of these foods was not associated with current wheeze, asthma, nor severe asthma.

Table 5 shows the association between childhood obesity and asthma in early adolescence. Obese children were more likely to have asthma in adolescence (OR = 1.77, 95% CI = 1.20-2.60).

4 | DISCUSSION

Using data from a longitudinal study, we found no association between the consumption of UPF during childhood or adolescence and

TABLE 1 Maternal and adolescents' characteristics among those included and not included in the study—2004 Pelotas cohort study

Variables	Respondents at Baseline (4229) n (%)	Participants with complete data at 11 y (3186) n (%)	Previous, excluding those with physician diagnosis of asthma at 6 y (2190) n(%)
Child sex			
Female	2034 (48.1)	1555 (48.8)	1109 (50.6)
Male	2195 (51.9)	1631 (51.2)	1081 (49.4)
Family			
Family income (quintiles)			
1st quintile (poorest)	872 (20.62)	610 (19.1)	383 (17.5)
2nd to 5th quintile	3357 (79.4)	2576 (80.9)	1807 (82.5)
Maternal schooling (y)			
<4	645 (15.6)	462 (14.7)	283 (13.0)
4-7	1731 (41.4)	1324 (42.0)	888 (40.9)
8-11	1381 (33.0)	1061 (33.6)	776 (35.7)
>11	420 (10.0)	306 (9.7)	226 (10.4)
Maternal age (y)			
<20	799 (18.9)	597 (18.8)	390 (17.8)
20-34	2865 (67.8)	2147 (67.4)	1471 (67.2)
>34	563 (13.32)	440 (13.8)	329 (15.0)
Maternal skin color			
white	2581 (61.7)	1960(62.2)	1390 (64.0)
black or others	1600 (38.3)	1189 (37.8)	781 (36.0)
Parity			
0	1665 (39.4)	1268 (39.1)	868 (39.6)
1	1110 (26.3)	861 (27.3)	616 (28.1)
≥2	1453 (34.4)	1056 (33.2)	706 (32.2)
Smoking during pregnancy			
No	3067 (72.5)	2344 (73.6)	1664 (76.0)
Yes	1162 (27.5)	842(26.4)	526 (24.0)
Maternal asthma perinatal			
No	3355 (79.4)	2508 (78.7)	1818 (83.0)
Yes	873 (20.7)	677 (21.3)	372 (17.0)
Exclusive breastfeeding			
0-<2.0 mo	1776 (45.5)	1403 (45.4)	933 (43.8)
2-<4 mo	945 (24.2)	744 (24.0)	516 (24.3)
4-6 mo	1185 (30.3)	947 (30.6)	679 (31.9)
Maternal smoking at 6 y			
No		2305 (72.8)	1638 (75.4)
Yes		861 (27.2)	535 (24.6)
Paternal smoking at 6 y			
No		2127 (71.2)	1483 (72,2)
Yes		860 (28.8)	572 (27.8)
Nutritional status			
Normal		1905 (64.7)	1337 (65.6)
Overweight		532 (18.1)	349 (17.1)
Obese		509 (17.3)	352 (17.3)

(Continues)

TABLE 1 (Continued)

Variables	Respondents at Baseline (4229) n (%)	Participants with complete data at 11 y (3186) n (%)	Previous, excluding those with physician diagnosis of asthma at 6 y (2190) n(%)
Asthma		1272 (39.94)	507 (23.2)
Current wheeze (at 11 y)		698 (21.91)	279 (12.7)
Asthma severity[a]		459 (14.4)	156 (7.1)
%UPF total kcal (95% CI)		42.2 (41.80 - 42.6)	42.2 (41.8 - 42.7)
Mean total kcal (95% CI)		3603.1 (3555.9-3650.2)	3533 (3478.2-3587.8)

[a]Severe symptoms of asthma were defined as participants who, in the past 12 months, had ≥ 4 attacks of wheeze or ≥ 1 night per week sleep disturbance from wheeze or wheeze affecting speech.

wheeze, asthma, or severe asthma among young adolescents. The lack of association was consistent for specific UPF items, such as sugar-sweetened beverages, soft drinks, and cured meat. Childhood obesity was, however, significantly associated with asthma in early adolescence.

Our results differ from the only study among adolescents on UPF and asthma. In this previous study, the authors found that a higher intake of UPF was associated with a higher risk of both asthma and wheeze.[9] The inconsistent results could to some extent be explained by differences in study designs, as well as the assessment of UPF intake. First, the cross-sectional design of the previous study is prone to recall bias, as the outcome asthma/wheeze has already occurred and can influence how case answer compared to non-case. In addition, the exposure was a score created from the sum of consumption frequency of 6 UPF items, while we included a total of 18 and 21 items at 6 and 11 years, respectively, to calculate the amount of UPF. Moreover, while we also used the portion size to estimate intake of UPF, this information was not available in the previous study, which might have led to an underestimation of the total intake. When comparing the cross-sectional analysis of our study with this previous finding from Melo et al,[9] the different number of UPF items mentioned, the lack of adjustment for total caloric intake and a wider age range (from 11 to 19 years, mean age 14 years), could account for some variability in the results. Older adolescents tend to have more autonomy in their dietary choices; moreover, having a wide age range they could have been able to capture late adolescent-onset asthma, not yet manifested in our sample.

Our findings are consistent with those of a previous cohort study among children, which reported that consumption of sugar-sweetened beverages or juices in early childhood (at age 3.3 years) and mid-childhood (at age 7.7 years) was not associated with asthma.[10] Other cross-sectional studies found that soft drinks consumption[18,19] and 100% fruit juice were associated with increased asthma risk.[18]

Our results do not support an association between UPF consumption and severe asthma. A study following adults for 7 years found a worsening of asthma symptoms among those who ate cured meat.[6] It is possible that cured meat plays a role in worsening symptoms among those who already have asthma, while not playing a role in the development of the disease itself. It is also possible that the complexity and heterogeneity of asthma in both children and adults[3] could explain the divergent results.

There are plausible biologic mechanisms for a detrimental effect UPF on respiratory health that warranted this investigation. The UPF often contains high proportions of free sugars and total, saturated and trans fats, salt, and cosmetic and other additives.[27] Fatty acid composition in diet could modulate immune reactions by regulating T-helper (Th)2 (proallergic) immune responses that could lead to airway inflammation.[28] On the other hand, food preservatives in soft drinks, such as sodium benzoate or sulfites, could mediate an association between soft drinks and asthma.[19] The nitrite present in high amounts in cured meat could lead to nitrosative stress-related airway inflammation, which is involved in asthma.[29] Using the NOVA classification to define UPF or assessing food sources of these compounds in diet (eg, cured meat), we were not able to identify any evidence of asthma triggers. Unfortunately, we did not have data to conduct further analyses for these underlying compounds that might play a role in asthma. Among NOVA groups, processed food could also be associated with asthma due to a potential pro-inflammatory effect. However, we conducted analyses on the association between the percentage caloric intake from processed food (data not shown) and asthma and found no evidence of an association. Obesity could also link UPF to asthma. Despite the lack of association between UPF and asthma, we found an association between childhood obesity and a higher risk of asthma during adolescence, which has been established in the literature.[30] This adds support to the validity of the reports and measurements in our study.

The strengths of our study were as follows: a large prospective birth cohort with a high response rate; the use of validated measures of exposure and outcomes; adjustment for important confounders; to explore the association between adolescence consumption of UPF and asthma outcomes because from childhood to adolescence food consumption might change considerably, and maybe a later instead of early diet, could be related to asthma outcomes; the high proportion of UPF consumption and the wide variability among the quintiles of UPF.

TABLE 2 Participants characteristics by quintiles of ultra-processed food (UPF) as a percentage of total energy intake, at 6- and at 11-y follow-ups

	UPF quintiles at 6 y						UPF quintiles at 11 y					
Variables	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	***P*-value**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	***P*-value**
Median UPF intake												
%TEI	26.9	36.2	42.1	48.0	57.8		18.4	26.9	33.1	39.3	50.7	
Maternal schooling (years)												
<4	18.3	11.8	11.5	13.2	10.6	.010	12.0	12.6	14.5	11.6	14.6	.130
4-7	40.4	41.7	36.4	40.1	45.9		37.5	37.4	42.1	43.5	43.9	
8-11	31.3	34.9	40.0	36.3	35.8		37.8	38.8	36.0	33.6	32.7	
>11	10.1	11.6	12.0	10.4	7.8		12.7	11.1	7.5	11.3	8.8	
Income												
Quintiles 1st	20.3	14.8	16.8	18.6	17.1	.138	17.1	15.7	17.4	18.0	19.0	.488
2	21.2	19.0	19.0	21.7	18.1		21.0	19.4	16.4	21.2	22.0	
3	16.5	18.4	20.3	19.5	23.9		18.2	19.2	20.4	20.6	20.8	
4	22.2	27.8	20.7	21.1	21.6		21.0	23.3	25.0	22.6	21.3	
5	19.8	19.9	23.2	19.1	19.2		22.6	22.4	20.8	17.5	16.7	
Maternal age (years)												
<20	14.1	17.9	15.4	20.9	20.7	.002	12.7	15.4	20.4	20.1	20.6	.028
20-34	65.2	69.1	71.9	65.7	63.6		69.3	69.6	66.2	65.8	64.8	
>34	20.8	13.0	12.6	13.4	15.7		18	15	13.4	14.1	14.6	
Maternal skin color												
White	61.6	64.2	69.3	63.8	60.8	.075	66.2	63.6	62.6	67.6	59.3	.096
Black or others	38.4	35.8	30.7	36.2	39.2		33.8	36.4	37.4	32.4	40.7	
Parity												
0	37.7	39.0	39.1	43.9	38.3	.004	39	36.7	40.5	40.2	40.1	.804
1	23.6	26.7	30.7	31.2	28.2		25.9	30.9	27.3	28.9	28.2	
≥2	38.7	34.3	30.2	24.9	33.6		35.1	32.3	32.2	30.9	31.7	
Smoking during pregnancy												
No	77.1	76.0	78.8	76.2	71.6	.149	80.1	78.5	77.3	74.1	69.9	.004
Yes	22.9	23.9	21.2	23.8	28.4		19.9	21.5	22.7	25.9	30.1	
Maternal asthma perinatal												
No	80.9	82.2	87.2	83.2	81.2	.088	83.8	84.8	80.1	84.5	82.4	.334
Yes	19.1	17.8	12.8	16.8	18.8		16.2	15.2	19.9	15.5	17.6	
Maternal Smoking at 6 y												
No	76.0	76.7	78.2	75.3	70.4	.084	80.0	77.7	77.9	70.0	72.1	.001
Yes	24.0	23.3	21.7	24.7	29.6		20.0	22.3	22.1	31.0	27.9	
Paternal smoking at 6 y												
No	72.3	74.3	74.8	70.3	68.7	.243	74.3	73	72.6	72.4	68.9	.516
Yes	27.6	25.7	25.2	29.7	31.3		25.7	27	27.4	27.6	31.1	
Child sex												
Female	50.3	54.7	48.6	48.0	51.6	.269	51.7	49.7	50.0	52.2	49.8	.911
Male	49.6	45.3	51.4	52.0	48.4		48.3	50.3	50.0	47.8	50.2	
Nutritional status												
Normal	67.0	67.0	63.6	63.1	67.6	.453	58.0	67.0	65.2	69.2	68.8	.022
Overweight	15.3	15.2	17.4	19.4	18.3		21.7	14.8	16.4	16.8	15.6	
Obese	17.7	18.0	19.0	17.5	14.1		20.2	18.3	18.4	14.0	15.6	

*Chi-square test.

TABLE 3 Odds ratio (OR) of asthma, current wheeze, and severe asthma at 11 y, according to quintiles of intake of ultra-processed food at age 6 (prospective analyses)

	OR for asthma, current wheeze, and severe asthma																			
	Model 1				Model 2				Model 3				Model 4				Model 5			
	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P
Asthma																				
Q1	1				1				1								1			
Q2	0.94	0.69	1.29	.346	0.95	0.68	1.32	.322	1.00	0.71	1.39	.461	0.97	0.70	1.36	.329	1.01	0.71	1.43	.299
Q3	0.84	0.61	1.15		0.77	0.55	1.08		0.82	0.59	1.15		0.84	0.60	1.17		0.83	0.58	1.19	
Q4	0.96	0.70	1.31		0.93	0.67	1.29		0.98	0.71	1.37		0.94	0.67	1.32		0.93	0.66	1.32	
Q5	0.83	0.61	1.15		0.83	0.59	1.17		0.87	0.62	1.23		0.84	0.59	1.19		0.84	0.58	1.21	
Current wheeze																				
Q1	1				1				1				1				1			
Q2	0.95	0.64	1.40	.296	0.95	0.63	1.42	.198	1.00	0.66	1.50	.242	0.99	0.65	1.49	.292	1.06	0.69	1.62	.324
Q3	0.88	0.59	1.30		0.81	0.54	1.22		0.84	0.55	1.27		0.85	0.56	1.30		0.90	0.58	1.39	
Q4	0.93	0.63	1.38		0.85	0.56	1.28		0.88	0.58	1.33		0.89	0.59	1.35		0.89	0.58	1.38	
Q5	0.79	0.53	1.19		0.78	0.51	1.19		0.80	0.52	1.23		0.81	0.53	1.26		0.85	0.54	1.34	
Asthma severity (ref: no asthma)																				
Mild + moderate																				
Q1	1				1				1				1				1			
Q2	0.93	0.56	1.55	.012	0.97	0.57	1.67	.042	0.96	0.55	1.67	.033	0.93	0.54	1.61	.031	1.01	0.57	1.80	.047
Q3	0.54	0.30	0.97		0.56	0.30	1.03		0.55	0.29	1.02		0.53	0.29	0.99		0.60	0.32	1.15	
Q4	0.58	0.33	1.04		0.59	0.32	1.08		0.58	0.31	1.08		0.57	0.30	1.06		0.60	0.31	1.15	
Q5	0.57	0.32	1.02		0.63	0.34	1.17		0.60	0.32	1.12		0.59	0.31	1.11		0.61	0.31	1.19	
Severe																				
Q1	1				1				1				1				1			
Q2	0.97	0.55	1.69	.469	0.93	0.53	1.63	1.00	1.02	0.58	1.80	.798	1.04	0.59	1.85	.679	1.10	0.61	1.99	.672
Q3	1.29	0.77	2.18		1.08	0.63	1.85		1.17	0.68	2.01		1.25	0.72	2.16		1.26	0.71	2.24	
Q4	1.32	0.79	2.23		1.09	0.64	1.87		1.17	0.68	2.02		1.22	0.71	2.11		1.18	0.67	2.09	
Q5	1.07	0.62	1.84		0.94	0.54	1.65		1.03	0.58	1.81		1.07	0.61	1.90		1.12	0.62	2.03	

Model 1 = crude analysis; Model 2 = Model 1 + intake adjustments + TEI; Model 3 = Model 2 + family income and maternal education level; Model 4 = Model 3 + maternal age, maternal skin color, parity, smoking during pregnancy, maternal asthma; Model 5 = Model 4 + child´s sex, parental smoking.
P-values for trend.

TABLE 4 Odds ratio (OR) of asthma, current wheeze, and severe asthma, according to quintiles of intake of ultra-processed food at age 11 (cross-sectional analyses)

	OR for asthma, current wheeze, and severe asthma																			
	Model 1				Model 2				Model 3				Model 4				Model 5			
	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P	OR	95% CI		P
Asthma																				
Q1	1				1				1				1				1			
Q2	1.36	0.99	1.87	.733	1.30	0.94	1.80	.723	1.32	0.95	1.84	.728	1.34	0.96	1.87	.479	1.39	0.98	1.97	.713
Q3	1.08	0.78	1.49		0.98	0.70	1.38		0.99	0.70	1.40		0.96	0.67	1.36		0.98	0.68	1.41	
Q4	1.32	0.96	1.81		1.18	0.85	1.65		1.20	0.86	1.68		1.19	0.85	1.68		1.23	0.86	1.76	
Q5	1.09	0.79	1.51		0.99	0.71	1.39		0.99	0.70	1.40		0.93	0.66	1.32		1.00	0.70	1.44	
Current wheeze																				
Q1	1				1				1				1				1			
Q2	1.40	0.93	2.09	.488	1.31	0.86	1.97	.561	1.26	0.83	1.91	.613	1.26	0.83	1.90	.685	1.30	0.85	2.00	.552
Q3	1.03	0.67	1.57		0.90	0.58	1.40		0.88	0.56	1.36		0.86	0.55	1.35		0.85	0.54	1.36	
Q4	1.48	0.99	2.20		1.43	0.95	2.16		1.41	0.93	2.13		1.39	0.92	2.10		1.41	0.92	2.18	
Q5	1.15	0.76	1.74		1.10	0.72	1.69		1.07	0.70	1.65		1.05	0.68	1.62		1.12	0.72	1.75	
Asthma severity (ref: no asthma)																				
Mild + moderate																				
Q1	1				1				1				1				1			
Q2	1.30	0.71	2.39	.191	1.33	0.72	2.47	.226	1.24	0.66	2.31	.251	1.23	0.66	2.30	.261	1.26	0.66	2.39	.301
Q3	0.85	0.44	1.66		0.78	0.39	1.56		0.75	0.37	1.51		0.72	0.36	1.46		0.77	0.38	1.56	
Q4	1.84	1.04	3.25		1.88	1.05	3.39		1.83	1.02	3.30		1.77	0.98	3.20		1.68	0.90	3.13	
Q5	1.27	0.70	2.33		1.25	0.67	2.36		1.23	0.65	2.32		1.20	0.64	2.27		1.24	0.65	2.39	
Severe																				
Q1	1				1				1				1				1			
Q2	1.47	0.88	2.45	.801	1.29	0.76	2.18	.759	1.28	0.76	2.17	.675	1.29	0.76	2.19	.587	1.36	0.78	2.34	.885
Q3	1.15	0.68	1.97		0.98	0.57	1.71		0.95	0.55	1.66		0.95	0.54	1.66		0.90	0.50	1.62	
Q4	1.17	0.68	2.00		1.09	0.63	1.89		1.07	0.61	1.86		1.06	0.61	1.85		1.17	0.66	2.07	
Q5	1.06	0.61	1.83		1.00	0.58	1.74		0.96	0.55	1.67		0.94	0.54	1.65		1.05	0.59	1.86	

Model 1 = crude analysis; Model 2 = Model 1 + intake adjustments + TEI; Model 3 = Model 2 + family income and maternal education level; Model 4 = Model 3 + maternal age, maternal skin color, parity, smoking during pregnancy, maternal asthma; Model 5 = Model 4 + child´s sex, parental smoking.
P-values for trend.

TABLE 5 Odds ratio (OR) of asthma, current wheeze, and severe asthma, according to nutritional status

	OR for asthma, current wheeze, and severe asthma											
	Model 1			Model 2			Model 3			Model 4		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Asthma												
Normal	1			1			1			1		
Overweight	1.01	0.76	1.34	1.03	0.77	1.38	1.06	0.79	1.43	1.26	0.88	1.80
Obese	1.37	1.05	1.79	1.45	1.10	1.91	1.46	1.11	1.93	1.77	1.20	2.60
Current wheeze												
Normal	1			1			1			1		
Overweight	0.89	0.62	1.29	0.90	0.62	1.31	0.92	0.63	1.34	1.08	0.69	1.68
Obese	1.34	0.97	1.87	1.41	1.01	1.97	1.41	1.00	1.98	1.58	0.99	2.53
Asthma severity (ref: no asthma)												
Mild + moderate												
Normal	1			1			1			1		
Overweight	0.86	0.49	1.51	0.80	0.45	1.42	0.82	0.46	1.46	0.93	0.48	1.80
Obese	1.47	0.92	2.35	1.38	0.86	2.22	1.42	0.88	2.29	1.40	0.71	2.77
Severe												
Normal	1			1			1			1		
Overweight	0.93	0.58	1.48	1.00	0.62	1.62	1.02	0.63	1.65	1.27	0.71	2.24
Obese	1.26	0.82	1.94	1.44	0.93	2.24	1.42	0.91	2.21	1.81	0.98	3.35

Model 1 = crude analysis; Model 2 = Model 1 + family income and maternal education level; Model 3 = Model 2 + maternal age, maternal skin color, parity, smoking during pregnancy, maternal asthma; Model 4 = Model 3 + child´s sex, parental smoking +TEI.

Our study has also some limitations. First, the FFQ was not developed for evaluating the degree of food processing. Therefore, we lack information on the preparation of some food to enable distinguish between UPF and other groups. In these cases, we adopted a conservative approach and not classified indistinguishable foods as UPF. Also, the FFQ was administered to the child's mother, representing an indirect measure of the child's food consumption, which may result in measurement error. Despite the use of a validated instrument to assess asthma, we could not confirm cases through medical assessment or medical record; thus, some degree of misclassification might have occurred in the assignment of cases. The exclusions of prevalent cases of asthma at the age of six reduced the likelihood of reverse causation; however, this has also reduced the sample size and thus statistical power. Finally, our results were drawn for a single middle-sized city and may not represent the Brazilian population as a whole.

Our study suggests that UPF consumption during childhood or adolescence is not associated with asthma or wheeze among adolescents. Future longitudinal research in different populations is needed to confirm our results.

ACKNOWLEDGEMENTS

This article uses data from the study "Pelotas Birth Cohort, 2004" conducted by the Post-graduate Program in Epidemiology, Federal University of Pelotas, Brazil, in collaboration with the Brazilian Public Health Association (ABRASCO). Previous phases of the study were supported by the World Health Organization (Grant no. 03014HNI); National Support Program for Centres of Excellence (PRONEX) (Grant no. 04/0882.7); the Brazilian National Research Council (CNPq) (Grant nos. 481012-2009-5, 484077-2010-4, 470965-2010-0, 481141- 2007-3, and 474023/2011-7); the Brazilian Ministry of Health (Grant no. 25000.105293/2004-83); and the Children's Pastorate. IS Santos, AJD Barros, FC Barros, and A Matijasevich receive support from the National Council for Scientific and Technological Development (CNPq), Brazil. The present analyses were supported by the São Paulo Research Foundation (FAPESP) (Grant no. 2014/13864-6). CM Azeredo received support from CAPES Foundation CAPESHVD 88881.162300/2017-01.

ORCID

Catarina Machado Azeredo https://orcid.org/0000-0002-6189-4429
Marianna Cortese https://orcid.org/0000-0002-3665-2006
Caroline dos Santos Costa https://orcid.org/0000-0002-3522-1546
Kjetil Bjornevik https://orcid.org/0000-0002-2892-6986
Aluisio J. D. Barros https://orcid.org/0000-0002-2022-8729
Fernando C. Barros https://orcid.org/0000-0001-5973-1746

Iná S Santos https://orcid.org/0000-0003-1258-9249
Alicia Matijasevich https://orcid.org/0000-0003-0060-1589

REFERENCES

1. Soriano J, Abajobir A, Abate K, et al. Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet Respir Med*. 2017;5(9):691-706.
2. Mokdad AH, Forouzanfar MH, Daoud F, et al. Global burden of diseases, injuries, and risk factors for young people's health during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2016;387(10036):2383-2401.
3. Papi A, Brightling C, Pedersen SE, Reddel HK. Asthma. *Lancet*. 2018;391(10122):783-800.
4. Nguyen DV, Linderholm A, Haczku A, Kenyon N. Obesity-related, metabolic asthma: a new role for glucagon-like peptide 1 agonists. *Lancet Respir Med*. 2017;5(3):162-164.
5. Ellwood P, Asher MI, Garcia-Marcos L, et al. Do fast foods cause asthma, rhinoconjunctivitis and eczema? Global findings from the International Study of Asthma and Allergies in Childhood (ISAAC) phase three. *Thorax*. 2013;68(4):351-360.
6. Li Z, Rava M, Bedard A, et al. Cured meat intake is associated with worsening asthma symptoms. *Thorax*. 2017;72(3):206-212.
7. Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. *Public Health Nutr*. 2019;22(5):936-941.
8. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada M, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutr*. 2018;21(1):5-17.
9. Melo B, Rezende L, Machado P, Gouveia N, Levy R. Associations of ultra-processed food and drink products with asthma and wheezing among Brazilian adolescents. *Pediatr Allergy Immunol*. 2018;29(5):504-511.
10. Wright LS, Rifas-Shiman SL, Oken E, Litonjua AA, Gold DR. Prenatal and early life fructose, fructose-containing beverages, and mid-childhood asthma. *Ann Am Thorac Soc*. 2018;15(2):217-224.
11. Wang CS, Wang J, Zhang X, et al. Is the consumption of fast foods associated with asthma or other allergic diseases? *Respirology*. 2018;23(10):901-913.
12. Santos IS, Barros AJ, Matijasevich A, et al. Cohort profile update: 2004 Pelotas (Brazil) Birth Cohort Study. Body composition, mental health and genetic assessment at the 6 years follow-up. *Int J Epidemiol*. 2014;43(5):1437-1437f.
13. Schneider BC, Motta JV, Muniz LC, et al. Design of a digital and self-reported food frequency questionnaire to estimate food consumption in adolescents and young adults: birth cohorts at Pelotas, Rio Grande do Sul, Brazil. *Rev Bras Epidemiol*. 2016;19(2):419-432.
14. Pinheiro A, Lacerda E, Benzecry EH, Gomes M, Costa V. *Tabela para avaliação de consumo alimentar em medidas caseiras*, 5th ed. Rio de Janeiro: Atheneu; 2005.
15. UNICAMP UEdC, NEPA NdEePeA. *Tabela brasileira de composição de alimentos - TACO*, 2nd edn. Campinas, SP: UNICAMP; 2006.
16. National Nutrient Database for Standard Reference. [computer program]; 2011.
17. Bielemann RM, Santos LP, Costa C, Matijasevich A, Santos IS. Early feeding practices and consumption of ultraprocessed foods at 6 y of age: Findings from the 2004 Pelotas (Brazil) Birth Cohort Study. *Nutrition*. 2018;47:27-32.
18. Berentzen NE, van Stokkom VL, Gehring U, et al. Associations of sugar-containing beverages with asthma prevalence in 11-year-old children: the PIAMA birth cohort. *Eur J Clin Nutr*. 2015;69(3):303-308.
19. Park S, Blanck HM, Sherry B, Jones SE, Pan L. Regular-soda intake independent of weight status is associated with asthma among US high school students. *J Acad Nutr Diet*. 2013;113(1):106-111.
20. de Onis M, Lobstein T. Defining obesity risk status in the general childhood population: which cut-offs should we use? *Int J Pediatr Obes*. 2010;5(6):458-460.
21. Sole D, Vanna AT, Yamada E, Rizzo MC, Naspitz CK. International Study of Asthma and Allergies in Childhood (ISAAC) written questionnaire: validation of the asthma component among Brazilian children. *J Investig Allergol Clin Immunol*. 1998;8(6):376-382.
22. Camelo-Nunes IC, Wandalsen GF, de Melo KC, Naspitz CK, Solé D. Prevalência de asma e de sintomas relacionados entre escolares de São Paulo, Brasil: 1996 a 1999 – Estudo da reatividade brônquica entre adolescentes asmáticos e não asmáticos – International Study of Asthma and Allergies in Childhood (ISAAC). *Revista Brasileira de Alergia e Imunopatologia*. 2001;24(3):12.
23. Asher MI, Keil U, Anderson HR, et al. International Study of Asthma and Allergies in Childhood (ISAAC): rationale and methods. *Eur Respir J*. 1995;8(3):483-491.
24. Leech RM, Worsley A, Timperio A, McNaughton SA. The role of energy intake and energy misreporting in the associations between eating patterns and adiposity. *Eur J Clin Nutr*. 2018;72(1):142-147.
25. IOM. *Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: The National Academies Press; 2005.
26. Bielemann RM, Reichert FF, Paniz VM, Gigante DP. Validation of the Netherlands physical activity questionnaire in Brazilian children. *Int J Behav Nutr Phys Act*. 2011;8:45.
27. Louzada M, Ricardo CZ, Steele EM, Levy RB, Cannon G, Monteiro CA. The share of ultra-processed foods determines the overall nutritional quality of diets in Brazil. *Public Health Nutr*. 2018;21(1):94-102.
28. Julia V, Macia L, Dombrowicz D. The impact of diet on asthma and allergic diseases. *Nat Rev Immunol*. 2015;15(5):308-322.
29. Sugiura H, Ichinose M. Nitrative stress in inflammatory lung diseases. *Nitric Oxide*. 2011;25(2):138-144.
30. Kelishadi R, Roufarshbaf M, Soheili S, Payghambarzadeh F, Masjedi M. Association of childhood obesity and the immune system: a systematic review of reviews. *Child Obes*. 2017;13(4):332-346.

SUPPORTING INFORMATION

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

How to cite this article: Machado Azeredo C, Cortese M, dos Santos Costa C, et al. Ultra-processed food consumption during childhood and asthma in adolescence: Data from the 2004 Pelotas birth cohort study. *Pediatr Allergy Immunol*. 2020;31:27–37. https://doi.org/10.1111/pai.13126