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REVIEW ARTICLE

Ultra-processed food consumption and children and adolescents' health

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KEYWORDS
Ultraprocessed food;
Chronic non-communicable diseases;
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Abstract
Objectives: To present observational studies investigating associations between the consumption of ultra-processed foods and health outcomes in childhood and adolescence.
Data source: Observational, cross-sectional, or longitudinal studies were considered, and identified in the Scopus, Web of Science, Pubmed and Scielo databases, without date restrictions.
Data synthesis: The most frequent combinations of risk factors in children and adolescents involved an unhealthy diet, with regular consumption of ultra-processed foods to the detriment of a diet based on fresh or minimally-processed foods and insufficient levels of physical activity; records on alcohol and tobacco use were identified. Combined, these practices contribute to the findings that indicate an increase in the prevalence of obesity in children and adolescents and a sedentary lifestyle, with a decrease in physical activity, in addition to representing a risk for the development of chronic non-communicable diseases, such as cardiovascular diseases and periodontal disease in childhood and adolescence.
Conclusions: The present study maps the current literature on the topic and indicates the direction of the approach for health promotion and prevention of NCDs in children and adolescents. Among the different risk factors that negatively affect the full development of this population, frequently eating breakfast and practicing physical activity is most strongly associated with a lower consumption of ultra-processed foods and should be part of an integrated approach to promoting eating practices that favor the reduction of diseases also in adult life.

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Introduction

According to the NOVA Classification, which groups foods according to their level of processing, ultra-processed (UP) foods represent formulations prepared by exclusively industrial processes, with fractions extracted or derived from foods, added with substances capable of simulating desired sensory characteristics. This processing aims to ensure that these products are attractive, both from a sensorial point of view — since aroma, color, texture and flavor are modified to achieve a pleasant result, and from an economic point of view, given that they require low production costs and have greater durability when compared to natural or minimally-processed foods and culinary ingredients.[1,2]

Studies on contemporary eating patterns indicate an increase in the consumption of ultra-processed foods with relevant participation of this group in the total amount of energy consumed daily; they also indicate the tendency towards the reduction or, in many cases, the replacement of traditional meals with these products.[3,4] Since the 2010s, evidence has been growing about the relationship between the consumption of ultra-processed foods and the prevalence of harmful health outcomes, with emphasis on chronic Non-Communicable Diseases (NCDs).[2,5]

NCDs are described as long-term health conditions that have long-term effects and do not result from an infectious origin. According to the World Health Organization (WHO), NCDs are related to disabilities and are responsible for more than 70 % of all deaths globally and, of these, more than 85 % are considered premature when they occur before the age of 70.[6,7] Among children aged 0 to 9 years, the three main risk factors for diseases or loss of capacity throughout life due to chronic diseases are related to a poor diet; for adolescents, the main risk factor for these diseases is also related to micronutrient deficiency.[6]

Food and nutrition have a recognized influence on the burden of risk and protective factors on the health of the population, and consequently on the pattern of morbidity and mortality due to chronic NCDs. Although research into the consumption of ultra-processed foods and their association with health outcomes among adults is well demonstrated, there are few studies on this topic with children and adolescents. This narrative review aims to present observational studies on the consumption of ultra-processed foods and the occurrence of chronic diseases in childhood and adolescence.

Method

Search strategy

The following combined descriptors comprised the search strategies, ((Noncommunicable chronic disease) AND ((Ultra-processed) OR (Processed) OR (Dietary pattern) OR (NOVA) OR (Food classification)) AND ((Children) OR (Adolescents)), which were adapted for each of the databases: Scopus, Web of Science, Pubmed and Scielo, without date restrictions.

Eligibility criteria

Observational, cross-sectional and longitudinal studies were considered, investigating the association between UP food consumption and the occurrence of chronic NCDs; in children and adolescents; written in English or Portuguese.

Analysis and selection of articles

The identified studies were distributed and classified in a standardized spreadsheet by the authors. Duplicates were identified and removed from the list. Initially, two reviewers read the titles and abstracts considering the previously mentioned inclusion criteria; articles that did not meet the criteria were discarded; those with insufficient information for the analysis based on the title and abstract were analyzed in full and kept in a spreadsheet if the inclusion criteria were met or discarded. After the initial selection, the same reviewers read the full texts to select the studies to be included in the review.

The spreadsheet created by the authors was also used to identify relevant information from the selected articles and allowed the recording of the following data: authors, article title, year of publication, keywords, subject(s), objective (s), method(s), result(s), conclusions and comments. The articles were further subdivided according to the design: cross-sectional, longitudinal, retrospective, prospective, cohort, case-control or ecological studies.

Results

Article characterization

Figure 1 illustrates the study selection process. A total of 302 studies were identified, of which 19 remained, based on the eligibility criteria; the studies included approximately 300,000 children or adolescents; and the sample size ranged from 40 to 173,310 participants.

The studies carried out in Brazil ($n = 13$), Iran ($n = 2$), and China, Nepal and Singapore ($n = 1$ in each country) were selected.

Table 1 describes the main characteristics of the observational studies included in this review. The main indicators and results were identified and all topics present in the studies were addressed in sequence: dietary patterns, overweight and obesity, cardiovascular diseases, physical activity and sedentary lifestyle, and oral health.

Dietary patterns

Dietary patterns are among the recognized determinants of the health and disease profile of the population. For this reason, recent years have been characterized by studies that seek to look not only at isolated nutrients but mainly at foods, especially based on their classification according to the degree and purpose of industrial processing.[8]

The consumption of ultra-processed foods has been identified as a risk factor for the increase in chronic NCDs in general among different age groups.[9]

This review included studies that share the objective of analyzing and discussing the effects of dietary patterns and the relationship with chronic NCDs in children and adolescents.[9-27]

A temporal trend analysis on the behavioral risk factors for chronic NCDs in Brazilian school adolescents between

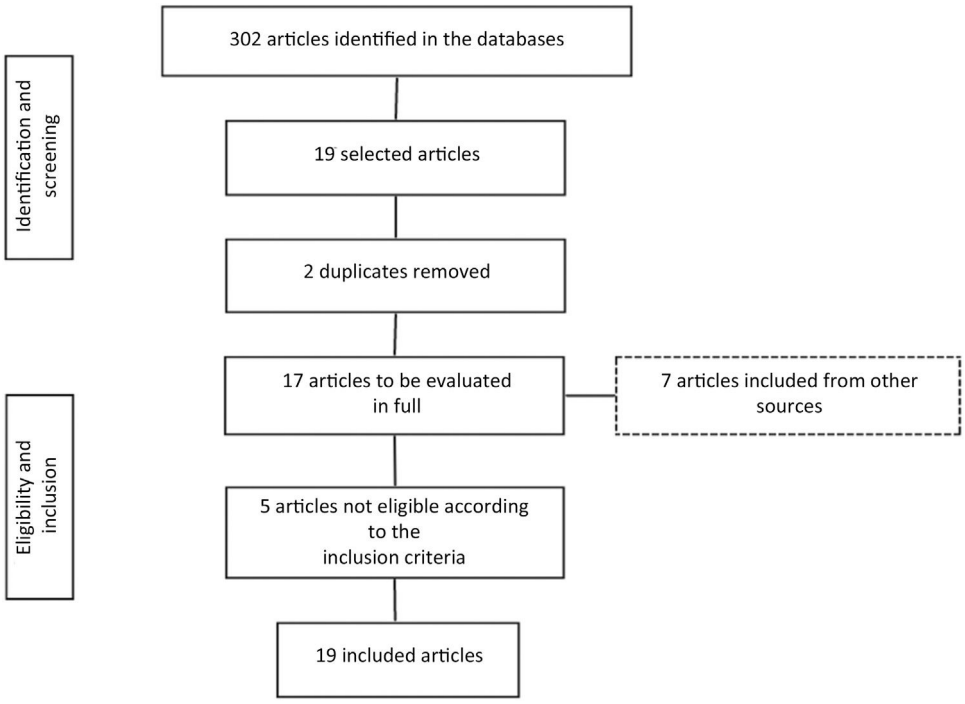

Figure 1 Study selection flowchart.

2009, 2012 and 2015[10] indicated that the regular consumption of processed and ultra-processed foods was the second risk factor for diseases, second only to little physical activity; the authors also found a tendency towards a decrease in the participation of UP foods in the diet, together with an increase in irregularity in the consumption of fresh and minimally-processed foods.

Tandon et al. (2022)[16] evaluated 1108 adolescents aged 13 to 19 years, students from public and private schools in Kathmandu, Nepal and found that 41 % of the adolescents had unhealthy eating habits - more than half did not consume vegetables and fruits five times a day or more, and more than half of the participants included soda in their diet at least once a week. The findings of this study also showed that 40.7 % of the adolescents had risk factors for chronic NCDs, including an unbalanced diet.

Other studies carried out in Brazil and Singapore also indicate that a significant proportion of children and adolescents do not consume fresh foods daily, such as fruits and vegetables or minimally processed foods, such as rice and beans.[17-19] In contrast, the prevalence of daily consumption of UP foods by adolescents in São Paulo was 64 %, and of soda 16.2 %, in 2017; this study also showed a negative association between participation in food purchases and soda consumption; regular cooking was positively associated with the consumption of rice and beans.[17] In the study conducted on 44 children in Diamantina, state of Minas Gerais, when evaluating lunch boxes, the UP foods were predominant, especially: yogurt (55.88 %); boxed chocolate milk (41.18 %); sandwich cookies and snacks (50 % and 35.29 %, respectively).[18]

Only one study showed results depicting high consumption of fruits (66.7 % of the sample) and vegetables (45.5 % of the sample) among school-aged children (5 to 10 years) who attended at Primary Care in the state of Pernambuco; however, high consumption of ultra-processed foods was also observed among the assessed students: 33 % consume hamburgers and/or cold cuts, 63 % consume sandwich biscuits, sweets or candy and 83 % consume sweetened beverages.[25]

In addition to food consumption, the structure of the diet was shown to be relevant for the assessed outcomes. Skipping breakfast, among other analysis variables, was associated with childhood obesity and excess weight in two studies in this review: with adolescents in the Central-West region of Brazil, and in Iranian children.[14,15] Consistent with this result, the literature indicates that eating breakfast is common for around half of adolescents (58.6 % in Curitiba, State of Paraná (South region of Brazil) and 48.5 % in Brazil);[28,29] however, skipping this meal is associated with eating most meals outside the home and not participating in the domestic meal preparation process. Regular breakfast consumption has also been positively associated with other protective behaviors, such as sleeping more than eight hours a day and engaging in regular physical activity.[28] Moreover, skipping breakfast is related to an increase in the consumption of high-energy snacks, rich in fats and sugars, as a strategy to compensate for the absence of a meal.[28]

The most frequent combinations of risk factors in children and adolescents involved an unhealthy diet.[13,19,21,24]

Overweight and obesity

A series of mechanisms may explain the relationship between the consumption of ultra-processed foods and overweight and obesity. In studies carried out in different parts of the world, UP foods have been characterized as nutritionally unbalanced, rich in free sugar, sodium, trans and saturated fats, with a low content of fibers and bioactive compounds.[3-5,30,31]

Table 1 Characteristics of studies on ultraprocessed food consumption and the occurrence of chronic diseases in childhood and adolescence.

Study	Study design	Participants	Objective	Main results	Conclusions
Louzada et al.[9] (2015)	Cross-sectional	7534 Brazilian individuals aged 10—19 years in 2008/2009.	To evaluate the relationship between the consumption of ultraprocessed foods and obesity indicators in Brazilian adults and adolescents.	Adolescents in the highest quintile of ultraprocessed food consumption had a higher mean BMI (adjusted coefficient: 0.84; 95 % CI: —0.16; 1.85) and a higher chance of having excess weight (adjusted OR = 1.52; 95 % CI: 0.75; 3.07) and obesity (adjusted OR = 2.74; 95 % CI: 0.78; 9.60) when compared to those in the lowest quintile.	The findings support the role of ultra-processed foods in the obesity epidemic in Brazil.
Araújo et al.[10] (2022)	Ecological	173,310 school adolescents, from PeNSE 2009, 2012 and 2015.	To analyze the temporal trend of the simultaneous occurrence of behavioral risk factors (RF) for NCDs in Brazilian school adolescents.	The isolated analysis of RF demonstrated that the insufficient level of leisure-time physical activity and the regular consumption of processed and ultraprocessed foods were the most prevalent during the three editions.	Health actions represented by official national health and education bodies must foster health promotion and the prevention of NCDs in adolescents, especially in dealing the different factors that compromise the full development of this population.
Zhao et al.[11] (2021)	Cross-sectional	895 Chinese adolescents aged 15 to 19 years.	To identify modifiable lifestyle behaviors and explore the best intervention in Chinese adolescents.	13.7 and 5.6 % of the participants were overweight and obese, respectively, and 8.4 and 14.1 % reported having prehypertension and hypertension, respectively. A two-class model identified by the authors reveals the prevalence of a healthy lifestyle pattern (65.8 %) and an unhealthy lifestyle pattern (34.2 %). The increased risk of cardiometabolic abnormality was not significant across lifestyle patterns, except for waist circumference. There was no significant difference in physical activity and fruit and vegetable consumption between the two patterns.	Primary prevention based on lifestyle modification should target high-risk behavior patterns in adolescents.

Table 1 (*Continued*)

Study	Study design	Participants	Objective	Main results	Conclusions
Bogea et al.[12] (2021)	Cross-sectional	391 Brazilian adolescents	To evaluate factors associated with inflammatory biomarkers in adolescents.	Three dietary patterns were identified (Western, basic Brazilian and healthy), with the Western pattern making the greatest contribution. No associations were found between the patterns and the latent inflammation variable. Excess weight was positively associated with the latent inflammation variable.	The extraction of the three patterns shows greater consumption of foods rich in carbohydrates and fats, which are nutrients directly related to the increase in NCDs. Excess weight was associated with higher levels of inflammatory biomarkers.
Ricardo et al.[13] (2021)	Cross-sectional	101,607 adolescents from the National School Health Survey (PeNSE) 2015.	To evaluate the co-occurrence and grouping of the main risk factors for NCDs in Brazilian adolescents.	There is a strong correlation between alcohol consumption and smoking, which were found together in 8 of the 13 identified clusters. The most frequent combinations of risk factors involved unhealthy eating and insufficient physical activity.	The main risk factors for NCDs are frequent and not randomly distributed among Brazilian adolescents.
Sena et al.[14] (2017)	Cohort	1716 adolescents aged 10 to 17 from Cuiabá. Initially evaluated between 1999 and 2000, and again after 10 years.	Identify patterns of risk behavior for NCDs in adolescents and analyze associated factors.	The most prevalent risk behaviors for NCDs were sedentary lifestyle (58.1 %), insufficient physical activity (49.7 %) and skipping breakfast (36.2 %). 27.7 % of the adolescents were overweight. From the division of three risk behaviors for NCDs, a sedentary lifestyle and a qualitatively low diet, in addition to skipping breakfast were associated with obesity, age and economic and social class.	This study confirmed the hypothesis that the main risk factors for NCDs tend to occur simultaneously in adolescents and are associated with sociodemographic, economic and body weight factors. Two main dietary markers (skipping breakfast and quality diet), vaguely explored as components of the risk pattern to date, were considered in this study.
Khashayar et al.[15] (2018)	Cross-sectional	13,486 Iranian students (6 to 18 years old) from urban and rural areas.	To explore multidimensional factors related to childhood overweight and obesity and determine the degree to which each ecological context contributes to childhood overweight and obesity.	32.8 % of students did not eat breakfast (eating breakfast $<$ 5 days/week). Daily consumption of fruits, vegetables and sugary drinks was reported by 55.74 %, 35.84 %, and 20.12 % of students, respectively. Around 9.7 % of students were overweight and 11.9 % were obese. Family history of obesity was reported by 45.47 % of the participants. Regular practice of physical activity was reported by 24 % of boys and 13 % of girls.	The results show a high prevalence of childhood overweight and obesity in Iranian children and adolescents. Associated factors are sociodemographic characteristics, birth weight classification, skipping breakfast and family history of obesity. Therefore, developing strategies that consider the effects of several sociodemographic factors would be the most effective methods.

Table 1 (*Continued*)

Study	Study design	Participants	Objective	Main results	Conclusions
Tandon et al.[16] (2022)	Cross-sectional	1108 adolescents aged 13 to 19 years attending grades 9 to 12 in public and private schools in Kathmandu, Nepal.	To determine the pattern of co-occurrence of NCD risk factors and associated factors in adolescents.	This study showed that 41 % of the adolescents attending school had unhealthy eating habits - more than half did not consume vegetables/fruit more than five times a day and consumed carbonated products. The findings of this study showed that 40.7 % of the adolescents had co-occurring NCD risk factors and 45.0 % had a risk factor for NCD - among them, an unbalanced diet.	The co-occurrence of NCD risk factors was prevalent in two-fifths of adolescents. Almost seven in ten adolescents reported physical inactivity and two-fifths of the adolescents had an unhealthy diet, followed by alcohol and tobacco consumption. Maternal ethnicity, religion and level of schooling were significantly and independently associated with the co-occurrence of NCD risk factors.
Nicolau et al.[17] (2018)	Cross-sectional	111 incoming students from all Integrated Technical High School Courses in 2017, of both sexes, up to 19 years old.	To characterize the diet of adolescent students from two technical schools in the east zone of the city of São Paulo according to the GAPB	An important number of the adolescents do not consume fresh foods (fruits, vegetables) or minimally processed foods (rice and beans) daily. The daily presence of the "fruits and vegetables" set is low among adolescents, with daily intake of fruits being more frequent than vegetables. In contrast, the daily consumption of ultraprocessed foods was 64 % and 16.2 % of soft drinks.	The diet of the adolescents in this group still does not fully meet the GAPB recommendations. It is observed that the consumption of ultraprocessed foods is still frequent. Therefore, nutritional education work aimed at disseminating GAPB recommendations is important for the adoption of healthier eating practices.
Souza et al.[18] (2018)	Cross-sectional	40 overweight or obese students, enrolled full-time in a public educational institution	To investigate the lifestyle of students with excess weight from a public educational institution in the city of Diamantina, MG.	The daily fruit consumption was low (35 %); however, more than half consumed vegetables and green vegetables daily (55 %). When evaluating the lunch boxes, UP foods were predominant: yogurt (55.88 %); pre-packaged chocolate milk (41.18 %); stuffed cookies or snacks (50 % and 35.29 %, respectively). BMI ranged between 18.63 (minimum) and 32.08 kg/m2 (maximum); 40 % were classified as overweight and 60 % as obese. The analysis of biochemical tests indicated glucose levels in the appropriate range, while cholesterol and triglyceride values were high.	It was evident that the investigated group had excess weight, lipid alterations, unhealthy eating habits and physical activity practices. These results reaffirm the importance of carrying out interventions to address the problem of overweight and obesity at the local level.

Table 1 (*Continued*)

Study	Study design	Participants	Objective	Main results	Conclusions
Choy et al.[19] (2021)	Cross-sectional	561 children from Singapore aged 6 to 12 years in 2016	To analyze dietary patterns, estimated nutrient provision and association between BMI and demographic factors.	Three dietary patterns were identified among the participants according to data from the 24HR. Each of the three groups had a high number of processed foods and low consumption of dietary fiber. Each dietary cluster was characterized by at least one risk food group: bakery products, red meat, local desserts and snacks, sweets, sweetened beverages and processed foods.	The cluster analysis supported the definition of dietary patterns in this multiethnic group of children. Of the three dietary patterns defined, all tended to provide an inadequate balance of nutrients and none were identified as presenting healthy food choices.
Kelishadi et al.[20] (2019)	Transversal	4288 Iranian students from urban and rural areas.	To determine the main nutritional patterns in Iranian children and adolescents and evaluate their relationship with anthropometric indices.	Three dietary patterns were defined; students in the fourth quartile of the first nutritional pattern tend to have higher weight, body mass index (BMI), waist circumference (WC) and hip circumference than those in the first quartile. Individuals in the fourth quartile of the second nutritional pattern had significantly lower average weight, WC and hip circumference than those in the first quartile. The third nutritional pattern did not correlate with any changes in BMI and wrist circumference in boys and girls.	The results indicated that a nutritional pattern characterized mainly by high consumption of monounsaturated and polyunsaturated fatty acids, potassium, calcium, vitamin E and biotin was associated with a lower prevalence of obesity, while a nutrient intake pattern with large amounts of carbohydrates, thiamine, iron and manganese was associated with greater obesity. Prospective studies are needed to evaluate any causal correlation between nutrients, patterns and obesity and confirm the present findings..
Cunha et al.[21] (2018)	Cohort	1035 Brazilian adolescents enrolled in the 1st year of High School between 2010 and 2012	To evaluate the trajectories of body mass index (BMI) and percentage of body fat (%BF) in adolescents over 3 years of follow-up according to the frequency of UP food consumption.	The consumption of ultraprocessed foods was not significantly associated with the outcomes.	This study confirmed that higher UPF intake is a marker of an unhealthy diet, but did not support the hypothesis of a high rate of change in BMI associated with higher UPF consumption, even after adjustment for physical activity.

Table 1 (*Continued*)

Study	Study design	Participants	Objective	Main results	Conclusions
D'Avila et al.[22] (2017)	Cross-sectional	784 Brazilian adolescents aged between 12 and 19 years old in 2013/2014.	To evaluate the consumption of ultra-processed foods and related factors in adolescents.	Adolescents with normal weight had a higher average consumption of ultraprocessed foods when compared to those with excess weight.	The consumption of ultra-processed foods was associated with socioeconomic level, level of physical activity and nutritional status. As this is a cross-sectional study, there is a temporal limitation; no association was found between the consumption of ultraprocessed foods and overweight/obesity in adolescence, but it is possible that such outcomes appear in adulthood.
Sparrenberger et al.[23] (2015)	Cross-sectional	204 children, between two and 10 years old, from southern Brazil.	To evaluate the contribution of ultraprocessed foods to the food consumption of children inside the coverage area of a Basic Health Unit, and the associated factors.	The frequency of excess weight was 34 %. Average energy consumption was 1672.3 kcal/day, 47 % coming from ultra-processed foods. In the multiple linear regression model, maternal level of schooling and the child's age were associated with the highest percentage contribution of ultraprocessed foods to the diet (weak magnitude associations $r = 0.23$; $r = 0.40$, respectively). Additionally, a significant linear trend was observed for greater consumption of ultraprocessed foods when the data were stratified by the child's age and maternal level of schooling.	The contribution of ultraprocessed foods is significant in children's nutrition and the child's age showed to be the most important associated factor for the consumption of these products.
De Melo et al.[24] (2017)	Cross-sectional	249 Brazilian adolescents aged between 14 and 19 years old.	To evaluate the consumption of minimally processed, processed and ultraprocessed foods by adolescents in a city with a low average *per capita* income, and verify the association with anthropometric measurements and arterial hypertension.	The consumption of ultraprocessed foods was not associated with the studied outcomes.	The consumption of minimally-processed foods is inversely associated with excess weight in adolescents. Investments in nutritional education are needed to prevent chronic diseases associated with the consumption of these foods.

Table 1 (*Continued*)

Study	Study design	Participants	Objective	Main results	Conclusions
Dantas et al.[25] (2021)	Cross-sectional	248 children aged 5 to 10, attended at Primary Care in the state of Pernambuco; 3663 were submitted to anthropometric assessment.	To analyze the prevalence of consumption of ultraprocessed foods and nutritional status in children in the state of Pernambuco.	High consumption of fruits and vegetables, but also high consumption of ultraprocessed foods among schoolchildren. The analysis of SISVAN reports between January and December showed that 33.84 % of the students were overweight and obese according to the BMI/A index.	The prevalence of the consumption of ultraprocessed foods is high among schoolchildren. It was also possible to observe that the number of overweight and obese children was higher than underweight ones, according to the BMI/age assessment. Therefore, nutritional education in the schools is shown as an important initiative to contribute to a healthier lifestyle.
Carmo et al.[26] (2018)	Cross-sectional	405 adolescents enrolled in public schools in São Luís, Brazil	To assess the association between added sugar consumption and the burden of chronic oral disease among adolescents, considering obesity and systemic inflammation pathways through structural equation modeling.	The majority of the sample comprised women, and most adolescents were classified as having normal weight based on BMI, followed by overweight and obese. Greater consumption of added sugar, higher levels of IL-6, and lower socioeconomic status have been linked to higher values of chronic oral disease burden. Obesity was not directly associated with the burden of chronic oral diseases. However, excess weight signaled a borderline indirect association with chronic oral disease and an association with elevated IL-6 levels.	Dental caries and periodontal diseases are associated with each other and with the consumption of added sugar, obesity and systemic inflammation, reinforcing the World Health Organization recommendations that any approach aimed at preventing non-communicable diseases must target common risk factors .

Table 1 (*Continued*)

Study	Study design	Participants	Objective	Main results	Conclusions
Silva et al.[27] (2021)	Cross-sectional	16,324 students who comprised sample 2 of PeNSE-2015 were studied.	To identify the prevalence and factors associated with the consumption of ultraprocessed foods in Brazilian adolescents.	The prevalence of excessive UPF consumption estimated in Brazil was 75.4 % (95 %CI 73.3—77.3) - the highest and lowest consumption were estimated in the Southeast and North regions of the country, respectively. Regarding nutritional status, 2.2 % were underweight, 63.6 % had normal weight and 34.2 % had excess weight. Nine factors were associated with excessive consumption of UPF, described in three categories - biological, behavioral, socioeconomic and demographic factors.	The results of the present study indicate that excessive consumption of UPF is very prevalent among Brazilian adolescents. The identification of the nine associated factors suggests the need to implement actions to regulate UPF advertising and promote the adoption of healthy lifestyle habits focused on reducing sedentary behaviors and food and nutritional education in the school and family environment.

The convenience and practical access, as well as the stimulation of consumption through the presence of and massive advertisements especially aimed at children, and the high palatability are aggravating factors that contribute to the consumption of these products[8]; the increase in energy density and glycemic load of meals, as well as uncontrolled neural and hormonal signals of hunger and satiety, are mechanisms that contribute to explaining the association between UP foods and chronic NCDs.[32]

A study conducted by Louzada et al. (2015)[9] with Brazilians aged 10 to 19 years or older in 2008/2009 ($n = 7534$) showed that participants in the highest quintile of ultra-processed food consumption had a higher mean Body Mass Index - BMI (adjusted coefficient: 0.84; 95 %CI: 0.42; 1.42) and a greater chance of being overweight (adjusted OR = 1.52; 95 %CI: 0.75; 3.07) or obese (adjusted OR = 2.74; 95 %CI: 0.78; 9.60) when compared to those in the lowest quintile.

Bogea et al. (2021)[12] evaluated the factors associated with inflammatory biomarkers in 391 Brazilian adolescents. Three dietary patterns were identified: Western, basic Brazilian and healthy pattern, with the Western pattern, which included greater consumption of foods rich in carbohydrates and fats, showing the greatest contribution. No associations were found between the patterns and the latent inflammation variable; however, these nutrients present in the diet, especially in UP foods, are directly related to the increase in chronic NCDs. Excess weight, in turn, was associated with higher levels of inflammatory biomarkers.

In a study carried out based on data present in the Food and Nutrition Surveillance System — SISVAN — between the months of January to December 2020, 33.84 % of the 3663 children evaluated across all health regions in the state of Pernambuco were overweight and/or obese according to the BMI/Age index, and UP food consumption.[25]

In another study carried out with schoolchildren in the state of Minas Gerais, BMI varied between 18.63 kg/m^2 and 32.08 kg/m^2, with a median of 21.8 kg/m^2. Among students classified as having excess weight, 40 % were classified as overweight and 60 % as obese.[18]

In line with these results, a study included in this review indicates that the consumption of minimally processed foods is inversely associated with excess weight in adolescents.[24]

According to the World Obesity Atlas (2023).[33] by 2035, approximately one-third of children and adolescents in Brazil may live with obesity. In 2020, the numbers indicated a 12.5 % prevalence of overweight and obesity among girls, while among boys this figure was 18 %. Projections indicate that in the coming years, around 23 % of girls and 33 % of boys could be in this situation. The constant increase in the prevalence of childhood obesity is associated with an increase in cardiovascular risk factors, obesity in adulthood and the emergence of comorbidities associated with obesity.[34,35]

The findings of the present study confirm the role of ultra-processed foods in the obesity epidemic in Brazil.

Cardiovascular diseases

Cardiovascular diseases represent around 50 % of deaths caused by chronic NCDs in middle- and low-income countries. Risk factors for the early development of

cardiovascular diseases have been observed to be increasingly present in the growth phases, with emphasis on smoking and alcohol consumption as the main variables and with considerations in relation to overweight and obesity.[36]

Thus, the risk factors manifested in adolescence tend to persist in adulthood and, when combined, increase the severity of the manifestations of cardiovascular diseases.[36] The analysis of data from 101,607 adolescents from the 2015 National School Health Survey (PeNSE) reveals that there is a strong correlation between alcohol consumption and smoking, found together in 8 of the 13 identified clusters. In the same study, only 2.9 % of the adolescents did not have any risk behavior, while 38.0 %, 32.9 %, 9.4 % and 1.8 % accumulated two, three, four and five risk factors, respectively.[13] and such findings were also identified in similar studies.[14,35]

In a study carried out with schoolchildren from a public educational institution in a city in the state of Minas Gerais, the analysis of biochemical tests revealed that total cholesterol (mean = 178.6 mg/dL; SD = 36.9 mg/dL) and triglyceride values (mean = 100.3 mg/dL; SD = 39.5 mg/dL) were high for the reference values used (< 170 mg/dL and < 75 mg/dL, respectively).[18]

Zhao et al. (2021)[11] sought to identify modifiable lifestyle-defining behaviors and explore the best form of intervention for Chinese adolescents. The sample included 895 adolescents and of these, 8.4 % and 14.1 % reported having pre-hypertension and hypertension, respectively. A two-class model identified by the authors showed that 65.8 % had a lifestyle pattern considered to be healthy, while 34.2 % were sub-healthy. There were more female participants with a healthy lifestyle (56.2 vs. 43.8 %), while for boys these values were inverted, with more participants living an unhealthy lifestyle (45.4 vs. 54.6 %; all with $p = 0.002$). In the same study, significant differences were also found in waist circumference between the two classes (70.5 vs. 69.1 cm; $p = 0.044$).[11]

Although several indicators related to chronic NCDs, such as overweight, obesity and adverse cardiovascular and metabolic conditions are often associated with the consumption of ultra-processed foods in adults, it is worth noting that the available information related to children and adolescents is less clear.[4]

Physical activity and sedentary behavior

The National School Health Survey (PeNSE), 2015 edition, indicates data that reveals the prevalence of physical inactivity among schoolchildren. With a sample of 16,324 participants, 75.2 % were classified as inactive/insufficiently active and 24.8 % as active. Therefore, a significant number of students did not meet the minimum recommendation for physical activity - around 300 min per week.[27] Hence, a sedentary lifestyle is defined as the time dedicated to static activities with low energy expenditure, in the sitting or lying positions.[37]

It is known that children and adolescents are influenced, above all, by family habits. Given the favorable socioeconomic conditions and family context, there is an encouragement to practice physical activity and reduce screen time.[37]

The Study of Cardiovascular Risks in Adolescents (ERICA, *Estudo de Riscos Cardiovasculares em Adolescentes*), carried out nationally in 2013–2014, analyzed the physical inactivity of schoolchildren, understood as a risk factor for the development of cardiovascular diseases and chronic NCDs. The sample mainly consisted of students from public schools in the urban areas of the Southeast and Northeast regions. The prevalence of leisure-time physical inactivity was evidenced in 54.3 % of adolescents (95 %CI = 53.4–55.2), higher among females, with 70.7 %, (95 % CI = 69.5–71.9) compared to data obtained for males, 38.0 % (95 %CI = 36.7–39.4).[38]

Focusing on healthy eating behaviors among Brazilian adolescents, the same study found that 68.0 % of the adolescents "always or almost always" ate meals with their parents or guardians. However, almost 25.0 % ate meals in the company of their parents or guardians only "sometimes" and 7.4 % "never" did it. Thus, almost half of the adolescents (48.5 %) reported having breakfast almost always or always; however, 21.9 % did not have this meal and, regarding water consumption, around half of the adolescents (48.2 %) reported drinking five or more glasses of water a day, while 18.9 % consumed only one to two glasses and 1.6 % reported not consuming water.[29]

These data, when combined, corroborate the findings of Silva et al. (2021)[27] who, when evaluating associations with excessive consumption of ultra-processed foods, indicated nine independent factors – age less than 15 years old, daily sitting time greater than four hours, eating while watching TV or studying for more than four days a week, daily TV viewing time of more than three hours, breakfast frequency of less than four days a week, having a cell phone, studying in a private school and located in an urban area and lack of maternal schooling. That said, sedentary habits, combined with inadequate eating practices, reveal an association with excessive consumption of ultra-processed foods among adolescents.[27]

Araújo et al. (2022)[10] conducted a study based on data collected in three periods – 2009, 2012 and 2015 with Brazilian schoolchildren; the data show that, in addition to the regular consumption of ultra-processed foods, the level of physical activity was insufficient. Similar results were found in two other studies carried out with Brazilian adolescents – one of them used secondary data from PeNSE (2015) and the other conducted a cohort with adolescents from the city of Cuiabá. Both studies point to an unbalanced diet and insufficient physical activity as the most frequent correlation of risk factors for the development of chronic NCDs among adolescents.[13,14]

Khashayar et al. (2018).[15] when exploring multidimensional factors related to childhood overweight and obesity in Iranian adolescents, revealed that regular physical activity was reported by 24 % of the boys and 13 % of the girls. Even though other factors such as sociodemographic characteristics, birth weight classification, skipping breakfast, and family history of obesity were more relevant in the conclusions of this study, there is still an indication of insufficient physical activity among the adolescents in the sample.

Zhao et al. (2021)[11] evaluated modifiable risk factors aiming to promote effective interventions for adolescents. Based on the definition of two patterns – healthy and unhealthy – no significant difference in physical activity was identified between the participants in each of the patterns since an insufficient level of physical activity was identified in the minority (36.4 %) of Chinese adolescents. In the study,

methodological limitations were also described, which may explain such results and the need for a prospective study.

According to a study that analyzes the relationship between age and changes in healthy behaviors in adolescents, as age increases, healthy practices decrease — in particular, physical activity tends to decrease between the ages of 11 and 15. Independence, exposure to new practices, new environments, and even socioeconomic conditions can influence this decline so it is possible to identify unhealthy lifestyles among adolescents.[39]

Physical inactivity and a sedentary lifestyle constitute risk factors for the development of chronic NCDs and, even though the findings of this review are scarce, there are studies that indicate multiple factors that, when combined, contribute to unfavorable health outcomes.[10]

Although the studies are incipient and have inconclusive results, the hypothesis of the association of physical inactivity as one of the risk factors for chronic NCDs that occur simultaneously in childhood and adolescence has been proven.

Oral health and chronic NCDs

Chronic NCDs represent a broad group of diseases responsible for the main patterns of morbidity and mortality around the world. It is known that periodontal diseases and dental caries are considered chronic NCDs; therefore, the literature shows a consistent relationship between these diseases and other chronic NCDs, such as obesity.[39] Furthermore, eating habits, especially high consumption of foods rich in sugar, are also associated with the prevalence of periodontal diseases.[26,40]

Carmo et al. (2018)[26] sought to assess the association of added sugar consumption with the burden of chronic oral diseases - COD among adolescents, considering obesity and systemic inflammation pathways through structural equation modeling. The results indicate that greater consumption of added sugar, higher levels of interleukin 6 (IL-6) — an indicator that is characterized by being elevated due to excessive sugar consumption and obesity, related to chronic oral disease — and lower socioeconomic class (standardized coefficient [SC] = 0.212, $p = 0.005$; SC = 0.130, $p = 0.036$; and, SC = −0.279, $p = 0.001$, respectively) were related to higher COD burden values. Obesity was not directly associated with COD burden; however, excess weight indicates an indirect association through higher levels of IL-6 (SC = 0.232, $p = 0.001$). Adolescents with obesity also had higher serum levels of IL-6 compared to those with normal weight (SC = 0.232, $p = 0.001$).[26]

Caries and periodontal diseases are interconnected, and these findings indicate that they are also related to sugar consumption, obesity and systemic inflammation. Health authorities, such as the WHO, advise that the approach to health promotion and chronic NCD prevention must act in a combined manner on the different risk factors that negatively affect the full development of this population.[40]

Limitations

This review had as inclusion criteria only observational studies carried out with children and adolescents. Studies are scarce and bring different methodological approaches, with possible limitations. Most of them used data from self-reported methods and secondary data, strategies that may present some inherent bias in food records. Although the evidence found indicates associations in the same direction and allows the exploration of the topic, some results can be considered inconclusive, especially for this age group.

Conclusions

The findings of this review disclose associations between the consumption of ultra-processed foods and harmful health outcomes in childhood and adolescence, such as overweight, obesity, physical inactivity, cardiovascular diseases and periodontal diseases.

Children and adolescents in different parts of the world have a predominantly unhealthy diet, with the regular consumption of ultra-processed foods to the detriment of a diet based on fresh or minimally processed foods. Combined with other risk factors, this practice contributes to the findings that indicate an increase in childhood obesity among schoolchildren, a high prevalence of physical inactivity, and a sedentary lifestyle, in addition to representing a risk for both the development of chronic NCDs and cardiovascular diseases and dental caries in childhood and adolescence.

The present study maps the current literature on the topic and indicates important ways to direct actions that seek to promote health, aiming to prevent and control chronic NCDs. The identification of risk factors and conditions that may influence them can contribute to the construction and improvement of effective measures for this population, whose development period can also indicate health outcomes in adult life. Among the most relevant findings is the fact that the consumption of UP foods and the association with chronic NCDs also lead to unhealthy lifestyles in childhood and adolescence; the low frequency of breakfast consumption and the high prevalence of physical inactivity are markers of this scenario, behaviors with a proven association in different contexts.

Finally, given the scenario about the consumption of ultra-processed foods among children and adolescents and the harmful health outcomes, added to the scarcity of scientific studies available for this age group and little or no conclusive results, the indication remains for future studies aimed at evaluating this association.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Brasil. Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Atenção Básica. Guia Alimentar para a População Brasileira. 2014. 2. ed., 1. reimpr.
2. Louzada ML, Costa CS, Souza TN, Cruz GL, Levy RB, Monteiro CA. Impact of the consumption of ultra-processed foods on children, adolescents and adults' health: scope review. Cad Saude Publica. 2021;37:Se00323020.

3. Matos RA, Adams M, Sabaté J. Review: the Consumption of ultra-processed foods and non-communicable diseases in Latin America. Front Nutr. 2021;8:622714.
4. Lane MM, Davis JA, Beattie S, Gómez-Donoso C, Loughman A, et al. Ultraprocessed food and chronic noncommunicable diseases: a systematic review and meta-analysis of 43 observational studies. Obes Rev. 2021;22:e13146.
5. Elizabeth L, Machado P, Zinöcker M, Baker P, Lawrence M. Ultra-processed foods and health outcomes: a narrative review. Nutrients. 2020;12:1955.
6. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990—2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396:1223—49.
7. WHO. Noncommunicable Diseases. [Cited 2020 Apr 1st]. Available from https://www.who.int/news-room/fact-sheets/detail/noncommunicablediseases.
8. Monteiro CA, Cannon G, Moubarac JC, Levy RB, Louzada ML, Jaime PC. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. Publ Health Nutr. 2018;21:5e17.
9. Louzada ML, Baraldi LG, Steele EM, Martins AP, Canella DS, Moubarac JC, et al. Consumption of ultra-processed foods and obesity in Brazilian adolescents and adults. Prev Med. 2015;81:9—15.
10. Araujo DA, de Carvalho RB, de Oliveira AS, Oliveira EA, Machado AL, Lima LH. Temporal trend of simultaneous risk factors for chronic non-communicable diseases: national School Health Survey 2009, 2012, 2015. Rev Bras Epidemiol. 2022;25:e220013.
11. Zhao W, Su D, Mo L, Chen C, Ye B, Qin S, Liu J, Pang Y. Lifestyle clusters and cardiometabolic risks in adolescents: a Chinese school-based study using a latent class analysis approach. Front Pediatr. 2021;9:728841.
12. Bogea EG, Martins ML, do Carmo CD, Nascimento JX, Arruda SP, Ribeiro CC, et al. Factors associated with inflammatory biomarkers in adolescents: analysis by structural equation modeling. Cad Saude Publica. 2021;37:e00212220.
13. Ricardo CZ, Azeredo CM, Machado de Rezende LF, Levy RB. Co-occurrence and clustering of the four major non-communicable disease risk factors in Brazilian adolescents: analysis of a national school-based survey. PLoS One. 2019;14:e0219370.
14. Sena EM, Muraro AP, Rodrigues PR, Fiuza RF, Ferreira MG. Risk behavior patterns for chronic diseases and associated factors among adolescents. Nutr Hosp. 2017;34:914—22.
15. Khashayar P, Kasaeian A, Heshmat R, Motlagh ME, Mahdavi Gorabi A, Noroozi M, et al. Childhood overweight and obesity and associated factors in Iranian children and adolescents: a multilevel analysis; the CASPIAN-IV study. Front Pediatr. 2018;6:393.
16. Tandon K, Adhikari N, Adhikari B, Pradhan PM. Co-occurrence of non-communicable disease risk factors and its determinants among school-going adolescents of Kathmandu Metropolitan City. PLoS One. 2022;17:e0272266.
17. Nicolau DA, Castro AG. Characterization of adolescents' diet with the Dietary Guidelines for the Brazilian population. Mundo Saude. 2018;42:98—122.
18. Souza P, Meira JB, Fernandes BG, Moreira LL, Ferreira VA, Guimaraes OS, et al. Obesity and overweight in schools: the importance of diagnosis to subsidiate health promotion initiatives in school space. Braz J Obes Nutr Weight Loss. 2018;12:786—95.
19. Choy MJ, Brownlee I, Murphy AM. Data-driven dietary patterns, nutrient intake and body weight status in a cross-section of Singaporean children aged 6-12 years. Nutrients. 2021;13:1335.
20. Kelishadi R, Heidari-Beni M, Esmaeil-Motlagh M, Pourmasoumi M, Malekshah AF, Qorbani M. Association of nutrient patterns with anthropometric indices in children and adolescents: the weight disorders survey of the CASPIAN-IV study. Mediterranean J Nutr Metab. 2019;12:223—34.
21. Cunha DB, Costa TH, Veiga GV, Pereira RA, Sichieri R. Ultra-processed food consumption and adiposity trajectories in a Brazilian cohort of adolescents: ELANA study. Nutr Diabetes. 2018;8:28.
22. D'Avila HF, Kirsten VR. Energy intake from ultra-processed foods among adolescents. Rev Paul Pediatr. 2017;35:54—60.
23. Sparrenberger K, Friedrich RR, Schiffner MD, Schuch I, Wagner MB. Ultra-processed food consumption in children from a Basic Health Unit. J Pediatr. 2015;91:535—42.
24. de Melo IS, Costa C, dos Santos JV, Santos AF, Florencio T, Bueno NB. Consumption of minimally processed food is inversely associated with excess weight in adolescents living in an underdeveloped city. PLoS One. 2017;12:e0188401.
25. Dantas CD, Cavalcanti RD. Consumption of ultra-processed foods and nutritional status of schoolchildren in the state of Pernambuco. Braz J Obes Nutr Weight Loss. 2021;15:669—77.
26. Carmo CD, Ribeiro MR, Teixeira JX, Alves CM, Franco MM, França AK, et al. Added sugar consumption and chronic oral disease burden among adolescents in Brazil. J Dent Res. 2018;97:508—14.
27. Silva JB, Elias BC, Warkentin S, Mais LA, Konstantyner T. Factors associated with the consumption of ultra-processed food by Brazilian adolescents: National Survey of School Health, 2015. Rev Paul Pediatr. 2021;40:e2020362.
28. Simões AM, Machado CO, Höfelmann DA. Association of regular consumption of breakfast and health-related behavior among adolescents. Cien Saude Colet. 2021;26:2243—51.
29. Barufaldi LA, Abreu Gde A, Oliveira JS, dos Santos DF, Fujimori E, Vasconcelos SM, et al. ERICA: prevalence of healthy eating habits among Brazilian adolescents. Rev Saude Publica. 2016;50:S6—9.
30. Machado PP, Steele EM, Levy RB, Sui ZX, Rangan A, Woods J, et al. Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: evidence from a nationally representative cross-sectional study. BMJ Open. 2019;9:e029544.
31. Rauber F, Louzada ML, Steele EM, Millett C, Monteiro CA, Levy RB. Ultra-processed food consumption and chronic non-communicable diseases-related dietary nutrient profile in the UK (2008-2014). Nutrients. 2018;10:587.
32. Fardet A. Minimally processed foods are more satiating and less hyper-glycemic than ultra-processed foods: a preliminary study with 98 ready-to-eat foods. Food Funct. 2016;7:2338e46.
33. World Obesity Federation, World Obesity Atlas 2023. [Cited 2023 Aug 28]. Available from: https://data.worldobesity.org/publications/?cat=19
34. Juonala M, Magnussen CG, Berenson GS, Venn A, Burns TL, Sabin MA, et al. Childhood adiposity, adult adiposity, and cardiovascular risk factors. N Engl J Med. 2011;365:1876—85.
35. Bahia L, Schaan CW, Sparrenberger K, Abreu GA, Barufaldi LA, Coutinho W, et al. Overview of meta-analysis on prevention and treatment of childhood obesity. J Pediatr. 2019;95:385—400.
36. Silva TP, Matozinhos FP, Guedes GR, Gratão LH, Silva AC, Vilela LA, et al. The association between multiple cardiovascular risk factors and overweight in Brazilian adolescents: an analysis based on the grade of membership. Cienc Saude Colet. 2023;28:1937—48.
37. Santana CP, Soares HA, Silva AN, Azeredo CM. Association between parental supervision and sedentary behavior and physical inactivity and among Brazilian adolescents. Cienc Saude Colet. 2021;26:569—80.
38. Cureau FV, Silva TL, Bloch KV, Fujimori E, Belfort DR, Carvalho KM, et al. ERICA: leisure-time physical inactivity in Brazilian adolescents. Rev Saude Publica. 2016;50:S4.
39. Marques A, Loureiro N, Avelar-Rosa B, Naia A, Matos MG. Adolescents' healthy lifestyle. J Pediatr. 2020;96:217—24.
40. World Health Organization. Guideline: Sugars Intake for Adults and Children. Geneva, Switzerland: WHO Library Cataloguing; 2015, [Cited 2023 Aug 28]. Available from http://www.who.int/nutrition/publications/guidelines/sugars_intake/en/.