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Association between ultraprocessed food consumption and excess adiposity in children and adolescents: A systematic review

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Summary

Ultraprocessed foods (UPF) consumption is associated with excess adiposity in adults, but this linkage remains unclear among children and adolescents. The present systematic review sought to address this research gap. Publications up to November 2023 were retrieved from PubMed, Web of Science, and Scopus databases. Outcomes included overweight/obesity anthropometric and body composition indicators; the exposure was UPF consumption based on the NOVA classification system. The review included 23 studies (i.e., 8 cohort and 15 cross-sectional); approximately half were carried out in Brazil. Inconclusive and heterogeneous evidence exists as few cohort studies found positive/mixed associations between UPF consumption and excess adiposity in pediatric populations, whereas most cross-sectional studies reported null associations. Such inconsistencies may be attributed to underlying methodological issues, especially heterogeneity in the outcomes assessed and UPF consumption operationalization and/or categorization. Future studies should adopt longitudinal designs with sufficiently extended follow-up periods, account for relevant confounding factors, employ validated and standardized measurement tools to assess dietary exposure, ensure consistent operationalization of variables, and encompass diverse geographic contexts. Ultimately, strengthening the quality of existing research evidence may better inform current and forthcoming policy and practice interventions aimed at mitigating the increasing prevalence of overweight/obesity in childhood and across the life course.

KEYWORDS

NOVA, overweight/obesity, pediatric populations, ultraprocessed foods

Abbreviations: BMI, body mass index; CI, confidence interval; FM, fat mass; FMI, fat mass index; LMI, lean mass index; NOS, Newcastle-Ottawa scale; NWO, normal-weight obesity; OR, odds ratio; PR, prevalence ratio; Q, quartile; Qntl, quintile; RR, relative risk; SAD, sagittal abdominal diameter; T, tertile/tercile; UPF, ultraprocessed food; WC, waist circumference; WHtR, waist-to-height ratio.

1 | INTRODUCTION

Consumption of ultraprocessed food (UPF), which is often assessed by the schema proposed by Monteiro et al. for classifying foods according to their processing level,¹ has been increasingly recognized

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as a public health problem around the world.^{2,3} While the definition of UPF has historically varied across studies, UPF has been more recently conceptualized as industrially processed formulations that contain five or more ingredients, such as salt, sugar, oils, fats, and/or food substances not often used in culinary preparation (e.g., hydrolyzed protein, modified starches, hydrogenated or interesterified oils, additives, and colorants).⁴

The advent of pervasive access to UPFs within the food supply can be traced back to the mid-20th century in high-income countries,¹ whereas the proliferation of these highly processed foods or the so-called “nutrition transition” is a recent phenomenon in middle- and low-income countries.⁵ Collectively, these global shifts from a traditional diet to one characterized by highly palatable processed foods (e.g., high in salt, sugar, and sodium) have coincided with upward trends in adverse noncommunicable health outcomes.⁵⁻⁷

A growing body of literature sheds valuable insight on the deleterious impact of UPF consumption on human health, especially in terms of exacerbating one's risk for noncommunicable diseases.⁸⁻¹² Particularly salient is overweight and obesity, a chronic condition that may be well connected to the aforementioned nutrition transition across diverse populations worldwide.¹³ Indeed, several studies carried out in recent years have bolstered evidence that linkages between UPF consumption and risk for excess adiposity exist in adults.¹⁴⁻¹⁶

However, the relationship between UPF consumption and excess adiposity outcomes among pediatric populations, such as overweight/obesity, is less understood. To date, only four systematic reviews exclusively focused on this group of individuals (typically between 0 and 19 years of age) have been conducted¹⁷⁻²⁰; they have yielded mixed findings and generally underscore the need for better-designed studies. Yet, since their publication, numerous relevant studies have been published, those which have not been captured by existing reviews on the topic. Synthesizing these new and more recent empirical findings offers an opportunity to elucidate the contribution of UPF consumption to the development of excess adiposity among children and adolescents.

Understanding the potential risk factors for excess adiposity among children and adolescents based on the latest scientific literature is imperative as the ramifications of experiencing this chronic condition in these populations appear to have a high cost to individuals throughout their lifetime. For example, children/adolescents who experience this chronic condition appear to be at an increased risk for a host of poor health outcomes earlier in life, such as liver disease,²¹ cardiovascular health problems,²¹ and psychological issues.²² Research evidence also suggests that experiencing overweight/obesity in childhood amplifies individuals' risk for obesity into adulthood,²³ lifetime risk for cardiovascular diseases,²⁴ and other poor health outcomes such as cancer.²⁵ Hence, the present systematic review seeks to advance this area of research by synthesizing existing and more recent studies that have examined the linkages between UPF and excess adiposity in pediatric populations.

2 | METHODS

The protocol for this review is registered in the Prospective Register of Systematic Reviews (2022, CRD42022375774). This study was conducted following the recommendations of the Preferred Reporting Items for Systematic reviews and Meta-Analyses 2020 checklist.²⁶

2.1 | Literature search

Relevant original articles, letters, or conference abstracts published up to November 21, 2023, were identified via PubMed, Web of Science, and Scopus databases. More details on the search string are delineated in Explanatory Note S1. Only publications written in English or Spanish were considered and no authors of these studies were contacted for additional information. We also reviewed the references of the final selected articles to identify relevant studies that may have been missed during the database searches.

2.2 | Study selection

After removing duplicates, all retrieved articles underwent an initial title and abstract screening and, subsequently, a full-text screening. Results were limited to peer-reviewed original publications or conference abstracts that fulfilled the following PICOTS criteria²⁷: (1) *population*: children and adolescents (0–19 years); (2) *exposure*: consumption of UPF assessed using the NOVA classification; (3) *comparison*: children/adolescents that had higher UPF consumption relative to lower UPF consumption; (4) *outcome*: overweight/obesity as measured by anthropometric indicators (e.g., body mass index [BMI], waist circumference [WC], and waist-to-height ratio [WtHR]) or body composition indicators (e.g., fat mass [FM], FM index [FMI], and lean mass index [LMI]); (5) *timing of weight measurement*: childhood or adolescence (0–19 years); and (6) *setting*: any environmental, clinical, or country setting. Studies were limited to only those with a cohort, case-control, or cross-sectional design and that reported their findings as estimates of relative risk (i.e., risk ratios [RR], odds ratios [OR], prevalence ratios [PR]), and β coefficients) of changes in anthropometric/fatness parameters, with the corresponding measure of variability including a 95% confidence interval (CI) and/or *p*-value.

2.3 | Data extraction

The following data were extracted from the articles selected for inclusion: first author name, year of publication, country, study design, sample size, the age range of subjects, exposure assessment, duration of follow-up for cohort studies, study findings (primary and secondary outcomes), and covariates for adjustment. Results of all selected studies were synthesized into the following sections: (1) BMI z-score; (2) overall overweight/obesity; (3) central overweight/obesity;

(4) other excess adiposity measures; and (5) other body composition indicators.

2.4 | Quality of studies

Two reviewers independently used the Newcastle-Ottawa Scale (NOS)²⁸ to assess the risk of bias in the included studies; a third reviewer was consulted to resolve scoring disagreements. An adapted version of the NOS was used to assess the risk of bias in the included cross-sectional studies.²⁹ Overall, a score ranging from 0 to 9 was assigned to each article; studies assessed were considered “poor quality” if they received ≤ 3 stars, “fair quality” if they received 4 to 6 stars, and “high quality” if they received ≥ 7 stars. This categorization aligns with a previous systematic review and meta-analysis focused on UPF consumption and the risk of overweight and obesity.¹⁴

3 | RESULTS

3.1 | Study overview

As indicated in Figure 1, a total of 23 observational studies were selected after eliminating duplicate publications or those that did not fulfill the inclusion criteria. Their main characteristics and findings are detailed in Table 1. There were eight prospective cohort^{31–38} and 15 cross-sectional studies,^{39–53} including a total of 99,069 children and adolescents. Moreover, 12 studies focused just on children,^{31,33–38,41,42,45,46,52} eight just on adolescents,^{39,40,43,44,47,48,50,51} and three on both age groups.^{32,49,53} However, the age ranges were inconsistent across studies. For example, some studies classified children as those aged 10 years or less,^{31,34–38,42,45,46,52} while others classified children as those aged up to 11^{33,49} or 12 years.⁴¹ Studies were also inconsistent in their classification of adolescents, with some, for example, considering adolescents as those between 12 and 17 years of age,⁵¹ 12 and 19 years of age,^{48,49} or 14 and 19 years of age.^{40,44}

Most studies were carried out in Brazil ($n = 10$)^{33,39,40,42–44,47,50–52}; other settings included North America ($n = 4$),^{31,34,35,37} Latin America ($n = 3$),^{36,38,49} Southern Europe ($n = 3$),^{31,34,35} the United Kingdom ($n = 1$),³² China ($n = 1$),⁵³ and Iran ($n = 1$).⁴⁵

Dietary assessments also differed across studies. Specifically, nine used a food frequency questionnaire,^{31,33,36,40,43,45,47,49,53} 10 dietary recalls,^{37–39,41,42,44,48,50–52} and four food diaries.^{32,34,35,46} All of them assessed UPF consumption based on the original NOVA classification, except for two studies—namely, those by Bleiweiss-Sande et al.⁴¹ and Gyimah et al.,³⁶ which employed adapted versions of the NOVA to better capture the food landscape of the United States⁵⁴ and Ecuador,⁵⁵ respectively. Yet, despite all studies using the NOVA classification or an adapted version of it, the operationalization of the exposure variable largely differed across studies. Specifically, it was computed as the percent of total kilocalories per day in 10 studies,^{39,41–44,46,50–53} as the percent of total kilocalories per day and percent of total grams per day in two studies,^{32,48} as absolute grams per day in five studies,^{31,33,35,45,47} as absolute kilocalories per day in three studies,^{34,37,49} and as frequency per day or week in three studies.^{36,38,40}

The way studies categorized the continuous exposure variable also varied. In particular, tertiles/terciles (T) were used in seven studies,^{31,36,44,45,48,51,52} quartiles (Q) in two studies,^{47,53} quintiles (Qntls) in two studies,^{32,39} and dichotomized by weekly UPF consumption level (i.e., either as “less than weekly” or “weekly or more”) in one study.⁴⁰ Furthermore, even within studies employing identical operationalizations and categorizations, there were substantial variations in the ranges across categories. To illustrate, although Chang et al. and Louzada et al. both operationalized UPF consumption as the percent of total kilocalories per day and categorized this operationalization into Qntls, the cut-off values for each Qntl were markedly different in each study.^{32,39} These and other discrepancies are presented in Table S1, which provides an overview of how UPF consumption was operationalized and categorized across studies.

All 23 studies measured weight and height, except one study by Hou and Qui that sourced this information from clinical (birth) records.⁵³ Eleven studies also measured WC,^{31,32,35,40,42–44,46–48,50}

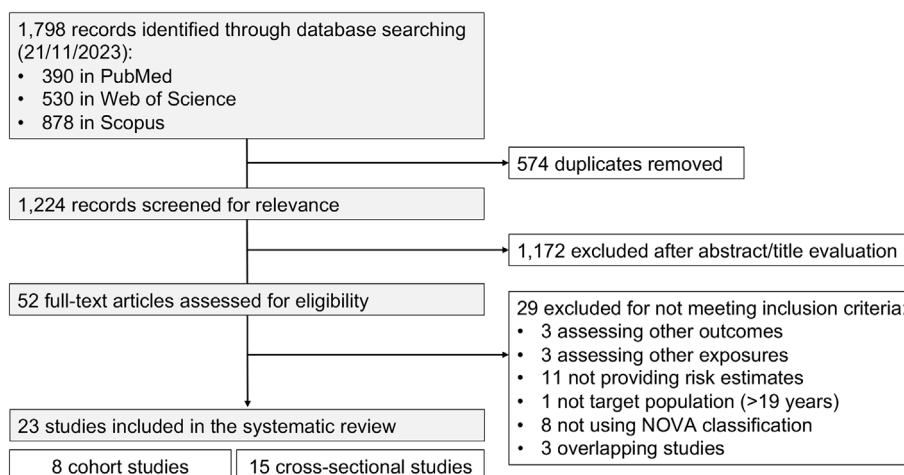


FIGURE 1 Flow chart.

TABLE 1 Summary of the included cohort and cross-sectional studies that investigated the association between ultraprocessed food (UPF) consumption and obesity/overweight in children and adolescents.

A: Cohort studies						
Author (year), country	Study design (study name), time frame	Sample size (age range), follow-up period	Exposure assessment	Outcome assessment	Model and adjustment variables	Main findings of maximally adjusted model
Gyimah et al. (2023), Ecuador	Follow-up cohort (Lulun II), 2017	125 children (2 years)	Measurement: 24-h FFQ, validated Operationalization: UPF intake frequency (# of times consumed in the past day) categorized into T	Measurement: weight and height measured by trained staff Operationalization: weight-for-height z-score based on WHO criteria	Model: linear regression Covariates: sex, age, household/caregiver socioeconomic characteristics (i.e., employment status, involvement in food production, and livestock ownership), minimum dietary diversity, and group assignment from the Lulun trial	Weight-for-height z-score (β , standard error): T1: reference T2: 0.03 (0.17) T3: -0.09 (0.16)
Heerman et al. (2023), United States	Prospective cohort (secondary analysis of Growing Right Onto Wellness [GROW] trial), 2012–2017	595 children (3–5 years); 3 years	Measurement: three 24-h diet recall completed by parents, not validated Operationalization: UPF intake (kcal/day)	Measurement: weight and height measured by trained staff Operationalization: age- and sex-specific sample z-scores for BMI	Model: longitudinal mixed-effects linear regression Covariates: age, sex, mean kcal/day, mean daily % of time spent in moderate-vigorous physical activity, parent ethnicity, household food security, household participation in federal nutrition assistance programs, and random assignment in the original RCT. The model also included two 3-way interactions to allow estimates vary over time and child baseline age, while also adjusting for mean daily caloric intake	BMI z-score overall (β , 95% CI): 0.4 (-0.02 to 0.7) BMI z-scores by age (β , 95% CI): 3 years: 1.2 (0.5 to 1.9) 4 years: 0.6 (0.2 to 1.0) 5 years: -0.1 (-0.6; 0.4)
Pereyra-González et al. (2023), Uruguay and Brazil	Two prospective cohorts: one from Uruguay (Encuesta de Nutrición, Desarrollo Infantil y Salud [ENDIS], 2013–2014 and 2015–2016); another from Brazil (Pelotas Birth Cohort, 2015)	6468 children (2–5 years); 2 years	Measurement: ENDIS: 24-h recall questionnaire (first wave) and FFQ assessing intake during previous week (second wave), not validated Pelotas: FFQ assessing intake during the previous day, not validated	Measurement: weight and height measured by trained staff Operationalization: BMI z-scores based on WHO criteria and categorization: • Obesity: BMI z-score > +2	Model: Poisson regression Covariates: z-score of birth weight, sex, age, country, exclusive breastfeeding duration, and time between measures	Obesity (RR, 95% CI): 1.02 (0.93 to 1.12)

TABLE 1 (Continued)

A: Cohort studies	Author (year), country	Study design (study name), time frame	Sample size (age range), follow-up period	Exposure assessment	Outcome assessment	Model and adjustment variables	Main findings of maximally adjusted model
Vilela et al. (2022), Portugal	Prospective birth cohort (Generation XXI - Porto node), 2005–2006	3034 children (7–10 years); 3 years	Operationalization: UPF intake frequency (# of items/week) Measurement: 3-day food diary for children at age 7 completed by parents or caregivers, not validated Operationalization: UPF intake (g/day)	Measurement: weight, height, WC, FM, and fat-free mass (by bioelectrical impedance analysis) for children at age 10 measured by trained staff and sex-specific sample z-scores for BMI, WC, FM, and fat-free mass	Model: generalized linear regression Covariates: remaining NOVA groups, sex, maternal age, and maternal education	WC z-score (β , 95% CI): -0.003 (-0.019 to 0.014) BMI z-score (β , 95% CI): -0.009 (-0.029 to 0.011) FM z-score (β , 95% CI): -0.006 (-0.022 to 0.011) Fat-free mass z-score (β , 95% CI): 0.012 (-0.005 to 0.029) Note: β per 100 g/day increase of UPF	
Chang et al. (2021), United Kingdom	Prospective birth cohort (The Avon Longitudinal Study of Parents and Children), 1998–2017	9025 children and adolescents (7–17 years); 24 years	Measurement: 3-day food diary for children at ages 7 and 10 and 13 completed by parents or caregivers of 7-year-old children and self-completed by 10- and 13-year-old children, not validated Operationalization: Qntls of UPF intake (based on % of total g/day and % kcal/day)	Measurement: weight, height, WC, FM, and LM (by DEXA) measured by trained staff annually between 7 and 17 years of age and once at 24 years of age Operationalization: • BMI z-scores based on British 1990 growth reference • FMI (FM in kg/height in m^2) • LMI (LM in kg/height in m^2)	Model: linear growth curve models Covariates: age at clinic assessment, sex, race, birth weight, baseline physical activity, mean daily calorie intake, Qntls of the Index of Multiple Deprivation 2004, maternal: pre-pregnancy, maternal BMI, maternal marital status, maternal education, and maternal socioeconomic status based on United Kingdom National Statistics Socioeconomic classification	Coefficient of the interaction term: examines the difference in mean growth trajectories among those in the higher UPF consumption Qntls compared with the lowest UPF Qntl reference group (β , 95% CI): UPF operationalized as % of total g/day: BMI in kg/m^2: 0.06 (0.04 to 0.08) FMI in kg/m^2: 0.03 (0.01 to 0.05) Total fat in %: 0.004 (-0.05 to 0.06) LMI in kg/m^2: 0.004 (-0.007 to 0.01) Weight in kg: 0.20 (0.11 to 0.28) WC in cm: 0.17 (0.11 to 0.22) BMI z-score: 0.01 (0.003 to 0.01) FM in kg: 0.15 (0.08 to 0.21) Lean mass in kg: -0.04 (-0.11 to 0.02)	

(Continues)

TABLE 1 (Continued)

A: Cohort studies							
Author (year), country	Study design (study name), time frame	Sample size (age range); follow-up period	Exposure assessment	Outcome assessment	Model and adjustment variables	Main findings of maximally adjusted model	
Costa et al. (2021), Brazil	Prospective birth cohort (Pelotas - Brazil Birth Cohort), 2004	3128 children (at age 6 years); 3454 children (at age 11 years); 5 years	Measurement: FFQ assessing consumption during previous year (at 6-year follow up, 54 items and reported by mothers; at 11-year follow-up, 88 items and reported by mothers and participants), not validated Operationalization: UPF intake (g/day)	Measurement (at age 6 and 11 years): weight, height, and FM (by BOD POD) measured by trained staff Operationalization: FMI (FM in kg/height in m ²)	Model: generalized estimation equations Covariates: Model A: maternal, skin color, maternal age, maternal schooling, sex, birth weight, screen time, energy intake/ Model B: maternal age, maternal schooling, sex, birth weight, screen time, energy intake/ and 11-year follow-ups, and grams from other food sources than UPF Model B: maternal skin color, maternal age, maternal schooling, sex,	UPF operationalized as % of total kcal/day: BMI in kg/m² : 0.05 (0.02 to 0.07) FMI in kg/m² : 0.04 (0.01 to 0.05) Total fat in % : 0.04 (−0.01 to 0.09) LMI in kg/m² : −0.002 (−0.01, 0.009) Weight in kg : 0.14 (0.06 to 0.22) WC in cm : 0.11 (0.05 to 0.16) BMI z-score : 0.01 (0.005 to 0.01) FM in kg : 0.14 (0.07 to 0.19) Lean mass in kg : −0.05 (−0.12, 0.01)	FMI in kg/m² (β, 95% CI) Model A (other foods sources adjustment): 0.14 (0.13 to 0.15) Model B (total calorie intake adjustment): 0.05 (0.04 to 0.06) Note : β per each 100 g/day increase of UPF

TABLE 1 (Continued)

A: Cohort studies	Author (year), country	Study design (study name), time frame	Sample size (age range), follow-up period	Exposure assessment	Outcome assessment	Model and adjustment variables	Main findings of maximally adjusted model
Vedovato et al. (2021), Portugal	Prospective birth cohort (Generation XXI, Porto Node), 2005–2006	8647 children (4–10 years); 6 years	Measurement: 2- or 3-day food diaries for children at ages 4 and 7 (one or two weekdays and one weekend day) completed by parents or caregivers, not validated Operationalization: UPF intake (kcal/day)	Measurement (at age 10): weight and height measured by trained staff Operationalization: BMI z-scores based on WHO criteria	Model: linear regression Covariates: maternal age, maternal education, pregnancy, exclusive breastfeeding for the first 6 months, physical exercise, and screen time	BMI z-score (β , 95% CI): Exposure at 4 years: 0.028 (0.006 to 0.051) Exposure at 7 years: 0.014 (–0.007 to 0.036) Note: β per 100 kcal/day increase of UPF	
Bawaked et al. (2020), Spain	Prospective birth cohort (Infancia y Medio Ambiente - INMA), 2003–2008	1480 children (4–7 years); 3 years	Measurement: 105-item semiquantitative FFQ (assessing diet during the previous year) for children at age 4 completed by parents, validated Operationalization: T of UPF intake (g/day)	Measurement (at ages 4 and 7): weight, height, and WC measured by trained staff Operationalization: BMI z-score based on WHO criteria and WC z-scores based on age, sex, height, and cohort	Model: linear regression Covariates: age, sex, cohort, maternal education, and maternal BMI	BMI z-score (β , 95% CI): T3: reference T1: 0.01 (–0.12 to 0.14) T2: –0.05 (–0.18 to 0.08) WC z-score (β , 95% CI): T3: reference T1: 0.00 (–0.15 to 0.15) T2: –0.10 (–0.25 to 0.05) Note: β per 100 g/day	
B: Cross-sectional studies							
Cota et al. (2024), Brazil	Cross-sectional (PASE Health Assessment Survey), 2015	364 children (8–9 years)	Measurement: three 24-h dietary recalls on nonconsecutive days (answered by child and guardian simultaneously), not validated Operationalization: UPF intake (% of total kcal/day) categorized into T	Measurement: weight, height, and body fat measured by trained staff Operationalization: NWO phenotype based on adequate BMI z-scores (according to WHO criteria) and high fat % ($\geq 25\%$ or 20% for girls and boys, respectively); those with NWO phenotype considered as having overweight or obesity placed in the excess weight group	Model: Poisson regression with robust variance Covariates: sex, age, per capita income, and screen time	NWO in normal-weight group (PR, 95% CI): T1: reference T2: 1.9 (1.1 to 3.4) T3: 1.8 (1.01 to 3.1) NWO in excess weight group (PR, 95% CI): T1: reference T2: 2.0 (1.2 to 3.3) T3: 1.2 (0.7 to 2.2)	
Hou and Qui (2023), China	Cross-sectional study (Multiplicity Cohort Study), 2022	1370 children and adolescents (7–16 years)	Measurement: 142-item FFQ, not validated Operationalization:	Measurement: height and weight based on birth records	Model: generalized linear model and logistic regression	BMI in kg/m² (β , 95% CI) Q1: reference Q2: 0.07 (–0.65 to 0.78)	

(Continues)

TABLE 1 (Continued)

B: Cross-sectional studies	
Madalosso et al. (2023), Brazil	<p>Cross-sectional (Estudo de Riscos Cardiovasculares em Adolescentes-ERICA), 2013–2014</p> <p>36,952 adolescents (12–17 years)</p> <p>UPF intake (% of total kcal/day) categorized into Q</p> <p>Operationalization: BMI and BMI z-scores based on age and sex BMI growth curves for Chinese children and adolescents</p> <p>Categorization into underweight, normal weight, overweight, and obesity based on the Working Group for Obesity in China (WGOC) cutoffs</p> <p>Covariates: age, sex, family income, maternal education, maternal BMI, physical activity, total energy intake, breastfeeding, gestational age at delivery, and delivery mode</p> <p>BMI z-scores (β, 95% CI) Q1: reference Q2: 0.01 (–0.25 to 0.26) Q3: 0.09 (–0.16 to 0.35) Q4: 0.11 (–0.14 to 0.37) P-trend: 0.746</p> <p>Overweight/obesity (OR, 95% CI) Q1: reference Q2: 1.01 (0.57 to 1.80) Q3: 1.27 (0.73 to 2.22) Q4: 1.03 (0.58 to 1.82) P-trend: 0.763</p>
Asgari et al. (2022), Iran	<p>Cross-sectional, 2017–2018</p> <p>788 children (6 years)</p> <p>Measurement: 24-h dietary recall, not validated</p> <p>Operationalization: UPF intake (% of total kcal/day) categorized into T</p> <p>Model: Poisson regression</p> <p>Covariates: sex, age, school type, geographic region, skin color, physical activity, screen time, tobacco/cigarette, and power consumption</p> <p>Measurement: weight and height measured by trained staff</p> <p>Operationalization: BMI z-scores based on WHO criteria and categorization: <ul style="list-style-type: none"> • Normal (BMI z-score $\leq +1$) • Overweight (BMI z-score $> +1$ and $\leq +2$) • Obesity (BMI z-score $> +2$) </p> <p>Measurement: weight, height, and mid-upper arm circumference measured by trained staff</p> <p>Operationalization: BMI z-scores based on WHO criteria and categorization: <ul style="list-style-type: none"> • Obesity (BMI z-score $> +2$) • Overweight (BMI z-score $> +1$ and $\leq +2$) • Normal (BMI z-score > -1 and $< +1$) • Underweight (BMI z-score < -1) • Wasting (BMI z-scores < -2) </p> <p>Measurement: 168-item semiquantitative FFQ (assessing consumption during the previous year) completed by mothers, validated</p> <p>Operationalization: T of UPF intake (g/day)</p> <p>Model: logistic regression</p> <p>Covariates: energy intake, socioeconomic status, and physical activity</p> <p>Obesity (OR, 95% CI): T1: reference T2: 1.57 (0.57 to 4.26) T3: 0.97 (0.31 to 3.01)</p> <p>Overweight/obesity (OR, 95% CI): T1: reference T2: 0.82 (0.56 to 1.18) T3: 0.86 (0.59 to 1.25)</p>

TABLE 1 (Continued)

B: Cross-sectional studies							
Ashraf et al. (2022), Canada	Cross-sectional (Guelph Family Health Study - GFHS), 2017–2020	267 children (1.5–5 years)	Measurement: 3-day food diary completed by parents or caregivers, not validated Operationalization: UPF intake (% of total kcal/day)	Measurement: weight, height, WC, and percent FM (by bioelectrical impedance analysis) measured by trained staff Operationalization: BMI z-scores based on WHO criteria	Model: generalized estimating equations Covariates: age, sex, annual household income, ethnicity, and highest level of parental education	BMI z-scores (β , 95% CI): –0.002 (–0.008 to 0.004) WC in cm (β , 95% CI): 0.013 (–0.007 to 0.033) Weight in kg (β , 95% CI): –0.001 (–0.01 to 0.01) FM in % (β , 95% CI): 0.01 (–0.03 to 0.05) Note: β per 1% kcal/day increase of UPF	
Crisóstomo et al. (2022), Brazil	Cross-sectional (Population-based health survey in the municipalities of Teresina and Picos, Piauí [ISAD-PI]), 2018–2019	120 adolescents (10–19 years)	Measurement: 24-h dietary recall using multiple-pass method (repeated in the 40% of sample within 2 months), not validated Operationalization: UPF intake (% of total kcal/day)	Measurement: weight, height, and WC measured by trained staff Operationalization: BMI z-scores (based on WHO criteria) and WC (according to sex and age cut-offs of Taylor et al., 2000) ³⁰	Model: linear regression Covariates: sex, age, education, alcohol consumption, smoking status, and total diet energy in kcal	BMI z-scores (β , 95% CI): –0.04 (–0.06 to –0.01) WC z-scores (β , 95% CI): –0.07 (–0.11 to –0.02)	
de Souza et al. (2022), Brazil	Cross-sectional, (School Policy and Cardiovascular Risk: A Multi-Country Study), 2017	576 adolescents (10–17 years)	Measurement: 99-item FFQ assessing consumption during the previous 6 months, validated Operationalization: Q of UPF intake (g/day)	Measurement: weight, height, and WC measured by trained staff Operationalization: • Overweight: BMI > 85th percentile (according to BMI z-scores based on WHO criteria) • Central obesity: WC > 80th percentile (according to sex and age cut-offs of Taylor et al., 2000) ³⁰ • Central obesity: WHHR ≥ 0.5	Model: Poisson regression Covariates: age, sex, and socioeconomic status	Overweight (PR, 95% CI): \leq Q3: reference >Q3: 1.58 (1.07 to 2.34) Central obesity [based on WC] (PR, 95% CI): \leq Q3: reference >Q3: 2.48 (1.41 to 4.36) Central obesity [based on WHHR] (PR, 95% CI): \leq Q3: reference >Q3: 2.09 (1.11 to 3.92)	
Neri et al. (2022), United States	Cross-sectional (National Health and Nutrition Examination Survey - NHANES), 2011–2016	3587 adolescents (12–19 years)	Measurement: two 24-h dietary recalls (first in person and second by telephone), not validated Operationalization: UPF intake (% of total g/day and as % of total kcal/day), as continuous or categorized into T	Measurement: weight, height, WC, and SAD measured by trained staff Operationalization: age- and sex-specific categories for BMI, WC, and SAD based on US Centers for Disease Control and Prevention	Model: logistic regression Covariates: age, sex, race/ethnicity, educational attainment of household head, physical activity, being on special diet for weight loss, and total calories	UPF operationalized as % of total g/day Overweight/obesity (OR, 95% CI): T1: reference T2: 1.21 (0.90 to 1.63) T3: 1.45 (1.02 to 2.06) P-trend: 0.040 Continuous*: 1.06 (1.00 to 1.12)	

(Continues)

TABLE 1 (Continued)

B: Cross-sectional studies

2000 growth charts.	Central overweight/obesity (OR, 95% CI):
Category: Overweight/obesity:	T1: reference
• BMI \geq 85th percentile	T2: 1.36 (0.99 to 1.86)
• Central overweight/obesity: WC \geq 85th percentile	T3: 1.52 (1.06 to 2.18)
• Visceral overweight/obesity: SAD \geq 85th percentile	P-trend: 0.026
	Continuous*: 1.07 (1.01 to 1.13)
	Visceral overweight/obesity (OR, 95% CI):
	T1: reference
	T2: 1.48 (1.14 to 1.91)
	T3: 1.63 (1.19 to 2.24)
	P-trend: 0.005
	Continuous*: 1.07 (1.02 to 1.13)
	*Note: Per 10% g/day increase of UPF
	UPF operationalized as % of total kcal/day
	Overweight/obesity (OR, 95% CI):
	T1: reference
	T2: 1.01 (0.75 to 1.35)
	T3: 1.22 (0.83 to 1.78)
	P-trend: 0.291
	Continuous*: 1.55 (0.60 to 4.02)
	Central overweight/obesity (OR, 95% CI):
	T1: reference
	T2: 1.17 (0.81 to 1.71)
	T3: 1.17 (0.79 to 1.74)
	P-trend: 0.437
	Continuous*: 1.56 (0.60 to 4.06)
	Visceral overweight/obesity (OR, 95% CI):
	T1: reference
	T2: 1.29 (0.92 to 1.80)
	T3: 1.41 (0.99 to 2.01)
	P-trend: 0.057
	Continuous*: 2.26 (0.95 to 5.40)
	**Note: Per 10% g/day increase of UPF

TABLE 1 (Continued)

B: Cross-sectional studies	
Nascimento et al. (2021), Brazil	<p>Cross-sectional (Health at the School: Situational Diagnosis in High School), 2016</p> <p>327 adolescents (14–19 years)</p> <p>Measurement: multiple-pass 24-h dietary recall (note: to correct for intrapersonal variability, a second 24-h dietary recall was applied to 40% of the population during a 2-month interval), not validated</p> <p>Operationalization: T of UPF intake (% total kcal/day)</p> <p>Model: logistic regression Covariates: sex, age, income, and type of school</p> <p>Measurement: weight, height, and WC by trained staff</p> <p>Operationalization: BMI z-scores based on WHO criteria and categorization:</p> <ul style="list-style-type: none"> Obesity: > +2 BMI z-score Central obesity (based on WC): percentile ≥ 90 Central obesity (based on WHtR): ≥ 0.50 <p>Obesity (OR, 95% CI): T1: reference T2: 0.93 (0.46 to 1.90) T3: 0.67 (0.31 to 1.45)</p> <p>Central obesity (based on WC) (OR, 95% CI): T1: reference T2: 1.73 (0.62 to 4.84) T3: 0.47 (0.11 to 1.96)</p> <p>Central obesity (based on WHtR) (OR, 95% CI): T1: reference T2: 1.08 (0.52 to 2.23) T3: 1.68 (0.77 to 3.66)</p>
Oviedo-Solis et al. (2022), Mexico	<p>Cross-sectional, (Mexican National Health and Nutrition Surveys), 2006 and 2016</p> <p>8074 children (5–11 years) and 6482 adolescents (12–19 years) in 2006; 2934 children and 2118 adolescents in 2016</p> <p>Measurement: semiquantitative FFQs (101 items and 140 items in 2006 and 2016, respectively) reported by study participants ≥ 12 years of age or mothers of study participants <12 years of age, validated</p> <p>Operationalization: UPF intake (total kcal/day)</p> <p>Model: logistic regression Covariates: survey year, energy NOVA groups (energy partition model), age, socioeconomic status, indigenous status, place of residence, regions, screen time, and sex</p> <p>Measurements: weight and height measured by trained staff</p> <p>Operationalization: BMI z-scores based on WHO criteria and categorization:</p> <ul style="list-style-type: none"> Overweight: BMI z-score > +1 Obesity: BMI z-score > +2 <p>Child overweight/obesity (OR, 95% CI): No: reference Yes: 1.09 (1.02 to 1.16)</p> <p>Adolescent overweight/obesity (OR, 95% CI): No: reference Yes: 1.04 (0.98 to 1.10)</p> <p>Note: OR per 200 kcal/day increase of UPF</p>
Bleiweiss-Sande et al. (2020), US	<p>Cross-sectional, 2017–2018</p> <p>131 children (6–12 years)</p> <p>Measurement: three 24-h dietary recalls collected on nonconsecutive days (including two weekdays and one weekend day) for children <10 years of age completed by parents or caregivers, not validated</p> <p>Operationalization: UPF intake (% of total kcal/day)</p> <p>Model: linear regression Covariates: sex, participation status in the School Breakfast Program and National School Lunch Program</p> <p>Measurement: weight and height measured by trained staff three times at baseline</p> <p>Outcomes: BMI z-scores based on US Center for Disease Control and Prevention 2000 growth charts</p> <p>BMI z-score (β, 95% CI): 0.0006 (–0.0068 to 0.0080)</p> <p>Note: β per 10% kcal/day increase of UPF</p>
Oliveira et al. (2020), Brazil	<p>Cross-sectional (Grow up with Health in Vitória de Santo Antão), 2018–2019</p> <p>164 children (7–10 years)</p> <p>Measurement: three 24-h 195-item dietary recalls carried out on three nonconsecutive days (including one on the weekend) completed with children over an interval of less than 4 weeks, not validated</p> <p>Model: linear regression Covariates: age, sex, and total caloric intake</p> <p>Measurement: weight, height, and WC measured by trained staff</p> <p>Operationalization:</p> <ul style="list-style-type: none"> BMI z-scores based on WHO criteria Central obesity (WC \geq 90th percentile for age and sex or WHtR \geq 0.5) <p>BMI z-score (β, 95% CI): –0.004 (–0.057 to 0.048)</p> <p>WC in cm (β, 95% CI): –0.037 (–0.167 to 0.092)</p> <p>WHtR (β, 95% CI): 0.001 (–0.001 to 0.001)</p>

(Continues)

TABLE 1 (Continued)

B: Cross-sectional studies		Operationalization: UPF intake (% of total kcal/day)	Measurement: weight, height, WC, FM percentage (by BOD POD), muscle mass, and android fat (by DEXA) measured by trained staff	Model: linear regression Covariates: sex, education, socioeconomic classification according to the Brazilian Association of Research Companies, total dietary energy intake, dieting to lose weight, physical activity, alcohol consumption, smoking, and number of hours spent sleeping/night	Note: β per each 10% increase of UPF (kcal/day)
Viola et al. (2020), Brazil	Cross-sectional, (Determinants Throughout the Life Cycle of Obesity, Precursors of Chronic Diseases, Human Capital and Mental Health - RPS Cohorts Study), 1997–1998	1525 adolescents (18–19 years)	Measurement: semiquantitative 106-item FFQ assessing consumption during the previous year (adapted for adolescents of Sao Luis), not validated Operationalization: T of UPF intake (% of total kcal/day)	Model: linear regression Covariates: sex, education, socioeconomic classification according to the Brazilian Association of Research Companies, total dietary energy intake, dieting to lose weight, physical activity, alcohol consumption, smoking, and number of hours spent sleeping/night	BMI z-score (β , 95% CI): –0.01 (–0.03 to –0.01) WC in cm (β , 95% CI): –0.02 (–0.05 to 0.01) Android fat in kg (β , 95% CI): –0.02 (–1.06 to 1.08) Muscle mass in kg (β , 95% CI): –0.04 (–0.06 to –0.02) LMI in kg/m² (β , 95% CI): –0.01 (–0.02 to –0.01) Note: β per each 1% increase of UPF (kcal/day)
Melo et al. (2017), Brazil	Cross-sectional, missing timeframe	249 adolescents (14–19 years)	Measurement: 84-item FFQ, validated Operationalization: daily frequency of UPF intake grouped into two groups (i.e., “less than weekly” or “weekly or more”)	Model: Poisson regression Covariates: age and sex	Overweight/obesity (PR, 95% CI) Less than weekly: reference Weekly or more: 0.76 (0.47 to 1.22) High WC z-score (PR, 95% CI) Less than weekly: reference Weekly or more: 0.94 (0.51 to 1.72)
Louzada et al. (2015), Brazil	Cross-sectional (subsample of National Household Budget Survey), 2008–2009	7534 adolescents (10–19 years)	Measurement: Two 24-h dietary recalls spanning 1 week, not validated Operationalization: Qntls of UPF intake (% of kcal/day)	Model: linear regression (for BMI) and logistic regression (for overweight or obese) Covariates: age, sex, race, region, urban status, smoking, physical activity, Qntls of years of education, per capita household income, consumption of fruits, vegetables, and beans (each in % of total energy intake from nonultraprocessed food),	BMI in kg/m² (mean difference, 95% CI): Qnt1: reference Qnt2: 0.01 (–0.33 to 0.31) Qnt3: 0.34 (–0.12 to 0.81) Qnt4: 0.40 (–0.17 to 0.97) Qnt5: 0.84 (–0.16 to 1.85) P-trend: 0.08 Overweight/obesity (OR, 95% CI): Qnt1: reference Qnt2: 1.05 (0.78 to 1.41)

TABLE 1 (Continued)

B: Cross-sectional studies

and the interaction between sex and income	QntI3: 1.12 (0.77 to 1.61) QntI4: 1.15 (0.74 to 1.77) QntI5: 1.52 (0.75 to 3.07) P-trend: 0.25
Obesity (OR, 95% CI):	
QntI1: reference	
QntI2: 0.96 (0.55 to 1.68)	
QntI3: 1.74 (0.82 to 3.73)	
QntI4: 1.90 (0.88 to 4.09)	
QntI5: 2.74 (0.78 to 9.60)	
P-trend: 0.05	
Note: Effect modification by age and sex	

Abbreviations: BMI, body mass index; CI, confidence interval; FFQ, food frequency questionnaire; FM, fat mass; FMI, fat mass index; LMI, lean mass index; NWO, normal-weight obesity; OR, odds ratio; PR, prevalence ratio; Q, quartile; QntI, quintile; RR, risk ratio; SAD, sagittal abdominal diameter; T, tertile/tercile; WC, waist circumference; WHO, World Health Organization; WHR, waist-to-height ratio.

two studies additional anthropometric measures (i.e., sagittal abdominal diameter [SAD] and mid-upper arm circumference),^{45,48} and six studies compositional measures related to fat.^{32,33,35,43,46,52} The corresponding outcomes calculated based on these measurements greatly varied across studies (e.g., BMI z-scores, overweight/obesity based on BMI, central obesity based on WC/SAD, and body composition indices such as FMI), with most reporting a combination of different outcomes. Among studies that reported BMI z-scores, 15 of them reported this outcome measure according to the World Health Organization reference standards,^{31,34,38–40,42–47,49–52} while two studies used age and sex standardization based on the study sample,^{35,37} two studies the US Centers for Disease Control and Prevention 2000 growth charts,^{41,48} one study British references,³² and one study Chinese references.⁵³

3.2 | Quality assessment results

The NOS scores for the cohort and cross-sectional studies included in the present systematic review can be found in Tables S2 and S3, respectively. Most studies ($n = 12$) were assessed to be of “fair quality,”^{32,34,35,37,41–46,49,50} while the rest of the studies ($n = 11$) were classified as “high quality.”^{31,33,36,38–40,47,48,51–53} Explanatory Note S2 provides a detailed description of the quality assessment results.

3.3 | Narrative synthesis

3.3.1 | Results by BMI z-scores

Five out of the eight cohort studies reported BMI z-scores as a measure of overweight/obesity, yielding inconsistent findings—that is, one study reported positive associations,³² two studies mixed findings,^{34,37} and two studies null associations with UPF consumption.^{31,35} The largest prospective cohort to date (i.e., 9025 seven-year-old children residing in the United States), when assessing growth trajectories up to 24 years, found that the trajectories of BMI z-score were significantly greater among those with the highest consumption of UPF.³² Specifically, when UPF consumption was operationalized as percent of total grams per day and categorized into QntIs, those in QntI5 increased their BMI z-scores by an additional 0.01 ($\beta = 0.01$, 95% CI: 0.003 to 0.01) per year in comparison with those in QntI1. Similar results were obtained when UPF consumption was operationalized as percent of total kilocalories per day ($\beta = 0.01$, 95% CI: 0.005 to 0.01).

Among those that reported mixed findings, Vedovato et al.'s prospective cohort of 1175 four-year-old children residing in Portugal found that for every 100 kcal/day UPF consumed at 4 years of age, BMI z-scores at 10 years of age significantly increased by 0.028 ($\beta = 0.028$, 95% CI: 0.006 to 0.051); in contrast, no association was found at the 7 years of age follow-up period.³⁴ Likewise, a more recent US prospective cohort analysis of 595 children reported that compared with low UPF consumption (i.e., 300 kcal/day), high UPF

intake (i.e., 1300 kcal/day) was associated with a 1.2 higher BMI z-score at 36 months for 3-year-olds ($\beta = 1.2$, 95% CI: 0.5 to 1.9) and a 0.6 higher BMI z-score for 4-year-olds ($\beta = 0.6$, 95% CI: 0.2 to 1.0).³⁷ However, this association was not statistically significant for 5-year-olds or in the overall model.

Finally, among those that reported null findings, Vilela et al. did not find any association between UPF consumption (in grams per day) and BMI z-scores in a Portuguese cohort of 3034 children aged 7 years and followed up to 10 years of age.³⁵ Similarly, Bawaked et al. constructed a child lifestyle score by summing five lifestyle behaviors (i.e., physical activity, sleep time, television time, plant-based foods, and intake of UPF in grams per day) in a Spanish cohort of 1480 children aged 4 years and did not find any association.³¹

Results from the seven cross-sectional studies that reported BMI z-scores do not support a positive association with UPF intake, with five reporting null findings^{41,42,44,46,53} and two reporting inverse associations.^{43,50} In terms of the latter two studies, both conducted in adolescent Brazilian populations, they found that for every 1% increase in the contribution of UPF to total kilocalories per day, there was a decrease of 0.01 ($\beta = -0.01$, 95% CI: -0.03 to -0.01)⁴³ or 0.04 ($\beta = -0.04$, 95% CI: -0.06 to -0.01)⁵⁰ in BMI z-scores.

3.3.2 | Results related to overall overweight/obesity based on BMI

One cohort study³⁸ and nine cross-sectional studies have explored the association between UPF consumption and overall obesity/overweight based on BMI.^{39,40,44,45,47-49,51,53} All but two studies utilized World Health Organization cutoffs to determine overall obesity/overweight outcomes. One exception was the study conducted by Neri et al., where obesity was defined as a BMI \geq 85th percentile according to US Centers for Disease Control and Prevention 2000 Growth Charts⁴⁸; the second exception was the study conducted by Hou and Qui, who categorized BMI based on the Working Group for Obesity in China cut-offs.⁵³

Only 2 of these 10 studies found a positive association between UPF and overweight/obesity.^{47,48} In particular, Neri et al. in their cross-sectional study of 3587 adolescents aged 12-19 years from the United States found that those with the highest consumption of UPF (T3, based on percent of total grams per day) had 45% higher odds (OR = 1.45, 95% CI: 1.02 to 2.06) of overweight/obesity compared with those in T1.⁴⁸ They also found a 10% increment in the proportion of UPF consumption associated with increased risk for overweight/obesity (OR = 1.06, 95% CI: 1.00 to 1.12). A smaller cross-sectional study carried out on 576 Brazilian adolescents aged 10-17 years yielded similar results, namely, that the highest level UPF consumption in grams per day (i.e., \geq Qntl3) was associated with a 58% higher PR (PR = 1.58, 95% CI: 1.07 to 2.34) of overweight/obesity compared with the lowest level of consumption (i.e., \leq Qntl3).⁴⁷

Mixed findings were reported in the cross-sectional study carried out by Oviedo-Solís et al.⁴⁹ The authors found that for each 200 kcal/

day of increased UPF consumption, the odds of having excess weight were 9% higher in children (OR = 1.09, 95% CI: 1.02 to 1.16), while null results were reported in adolescents. The remaining seven studies, mostly focused on Brazilian populations,^{38-40,44,51} reported null findings on the relationship between UPF consumption and overweight/obesity in children,^{38,45} adolescents,^{39,40,44,51} or both children and adolescent populations.⁵³

3.3.3 | Results related to central obesity

Eleven studies assessed the association between UPF consumption and central obesity by measuring WC,^{31,32,35,40,42-44,46-48,50} WHtR,^{42,44} and SAD.⁴⁸ Among them, four studies focused on children,^{31,35,42,46} six on adolescents,^{40,43,44,47,48,50} and one on both children and adolescents (i.e., those between 7 and 17 years of age).³²

Five of the seven studies that analyzed UPF consumption continuously found null associations between UPF consumption and WC or WHtR.^{31,35,42,43,46} Only the large prospective cohort study of Chang et al. found that trajectories of WC increased by an additional 0.17 (95% CI, 0.11-0.22) cm/year³²; in contrast, a small Brazilian study involving 120 adolescents reported an inverse association ($\beta = -0.07$, 95% CI: -0.11 to -0.02).⁵⁰

Among the four studies that analyzed the outcome categorically, two reported null findings^{40,44} and the other two reported strong positive associations.^{47,48} In particular, when comparing T3 of UPF consumption (percent of total grams per day) to T1, Neri et al. found there was 52% higher odds (OR = 1.52, 95% CI: 1.06 to 2.18) of abdominal obesity/overweight (based on WC) and 63% higher odds (OR = 1.63, 95% CI: 1.19 to 2.24) of visceral obesity/overweight based on SAD.⁴⁸ They also found that a 10% increment in the proportion of UPF consumption was associated with an increased risk of both central overweight/obesity measure (OR = 1.07, 95% CI: 1.01 to 1.13) and visceral overweight/obesity measure (OR = 1.07, 95% CI: 1.02 to 1.13). Consistent with this finding, de Souza et al. found positive associations for central obesity, albeit the estimates were less pronounced. This was observed when central obesity was based on WC (PR = 2.48, 95% CI: 1.41 to 4.36), as well as WHtR (PR = 2.09, 95% CI: 1.11 to 3.92).⁴⁷

3.3.4 | Other excess adiposity measures

Other adiposity indicators, such as weight (in kilograms), weight-for-age z-scores, and normal-weight obesity (NWO), were examined in few studies. Chang et al. reported positive associations between UPF and weight, when UPF consumption was both operationalized as percent of total grams per day ($\beta = 0.20$, 95% CI: 0.11 to 0.28) and percent of total kilocalories per day ($\beta = 0.14$, 95% CI: 0.06 to 0.22).³² Instead, the cross-sectional study of 267 Canadian children conducted by Ashraf et al. reported null results.⁴⁶ Gyimah et al. in their cohort study of 125 two-year-old Ecuadorian children similarly found that UPF consumption (number of times per day categorized into T) was

not associated with weight-for-height z-scores.³⁶ More recently, Cota et al. carried out a cross-sectional study which assessed the association between UPF consumption (in percent of kilocalories per day categorized into T) and NWO phenotype in 364 school-aged Brazilian children.⁵² They defined NWO as individuals with normal weight who were assessed to have a high amount of body fat. This study revealed that increased UPF consumption was associated with higher prevalence of NWO, both among normal-weight children ($PR_{T2vsT1} = 1.9$, 95% CI: 1.1 to 3.4; and $PR_{T3vsT1} = 1.8$, 95% CI: 1.01 to 3.1) and those with excess weight ($PR_{TvsT1} = 2.0$; 95% CI, 1.2 to 3.3); albeit null findings were reported for children with excess weight in the highest UPF consumption category.

3.3.5 | Results by body composition indicators

Three prospective cohorts^{32,33,35} and two cross-sectional studies^{43,46} have assessed the association between UPF and body composition indicators. Different measurement instruments were used to assess body composition, including the BOD POD™ digital scale,^{33,43} DEXA,³² and bioelectrical impedance analysis.^{35,46} Among them, two prospective studies reported positive associations.^{32,33} After a 5-year follow-up, Costa et al. reported that a 100-g increase in UPF consumption was associated with an FMI increase of 0.05 kg/m² (95% CI: 0.04 to 0.06).³³ In the same vein, when assessing growth trajectories from 7 to 24 years, Chang et al. observed increases of 0.03 kg/m² in FMI ($\beta = 0.03$, 95% CI: 0.01 to 0.05) and of 0.15 kg in FM ($\beta = 0.15$, 95% CI: 0.08 to 0.21) per year in children in the highest Qntl of UPF (based on percent of total grams per day) compared with the lowest Qntl. Null associations were reported for total fat in percent, lean mass in kilograms, or LMI in kilograms per square meter; and similar results were observed when UPF was operationalized as percent of total kilocalories per day.³² In contrast, the cross-sectional study by Viola et al. focused on Brazilian adolescents reported an inverse association between UPF (percent of total kilocalories per day, categorized into T) and LMI in kilograms per square meter ($\beta: -0.01$, 95% CI: -0.02 to -0.01).⁴³

4 | DISCUSSION

This systematic review provides an overview of the limited and heterogeneous evidence regarding UPF consumption and excess adiposity in children and adolescents. Of the 23 studies that met the inclusion criteria, only one cohort study³³ and three cross-sectional studies^{47,48,52} reported consistent positive associations in children^{33,52} or adolescents.^{47,48} And of the remaining 19 studies, one reported inverse associations,⁵⁰ five mixed results,^{32,34,37,43,49} and 13 null findings.^{31,35,36,38–42,44–46,51,53}

The five studies that reported mixed results varied according to (a) the type of outcome assessed or (b) the time of exposure to UPF. Regarding the former, Chang et al. found positive associations between UPF (both as percent of total grams per day and as percent

of total kilocalories per day) and BMI z-score, BMI, FMI, weight, WC, and FM, but not for percent of total fat, LMI, or lean mass³²; Viola et al. reported inverse associations for BMI and LMI and null findings for WC and android fat.⁴³ Regarding the latter, Vedovato et al. found positive associations among children with exposure at 4 years of age, but not at age 7³⁴; Heerman et al. found positive associations for exposures at 3 and 4 years, but not at 5 years of age³⁷; and Oviedo-Solis et al. found positive associations among children, but not among adolescents.⁴⁹

Our results align with four other previous systematic reviews conducted on children and adolescents.^{17–20} The first study, by Costa et al., found that while some studies found a positive association between high UPF consumption and excess body fat, there was a lack of association in others.¹⁷ The researchers noted that methodological issues may explain the mixed findings and pointed to a need to use a standardized UPF classification system that considers the level of food processing. Subsequent systematic reviews on this topic sought to address this study limitation by restricting their synthesis to studies using the NOVA classification system to assess exposure to UPF^{18–20}; nevertheless, these reviews also noted mixed associations with several adiposity indicators. Even with more recently published studies included in our updated systematic review, existing research findings are still very heterogeneous, making it difficult to draw firm conclusions on the linkages between UPF consumption and excess adiposity among pediatric populations. Conversely, the existence of these linkages is more to the well-established for adult populations.^{14,16,56} Overall, current available evidence indicates that only longitudinal studies with long follow-up periods provide some level of consistency in supporting the relationship between high consumption of UPF and several adiposity indicators in pediatric populations. A notable example is the study conducted by Chang et al.,³² which reported null findings when examining associations between UPF consumption and excess adiposity at baseline. However, it is important to point out that in their linear growth curve models, higher UPF consumption was associated with greater increases in adiposity from childhood to early adulthood.

From a research standpoint, the present systematic review emphasizes the need to expand and homogenize investigations regarding the impact of UPF consumption on weight outcomes in children and adolescents. This includes standardizing how UPF consumption and excess adiposity are measured in this population. Although the utilization of the NOVA classification system serves as an initial starting point to better measure UPF consumption, it is imperative to consistently operationalize measurement units across studies (e.g., grams vs. kilocalories and absolute vs. relative intakes) to ensure uniformity. A good practice, already followed by some studies,^{32,48} may involve presenting results as relative amount of total grams and kilocalories, both as continuous and categorical variables. Researchers have also suggested that the implementation of the NOVA classification system could be enhanced by incorporating tools that are specifically validated for its application.⁵⁷ Moreover, the measurement and operationalization of excess adiposity varies considerably across studies. This issue is not novel, as it has been previously pointed out that

there are dissimilarities in terminology and measurement approaches employed to examine excess adiposity in children, which can create confusion within research.⁵⁸ It is also worth noting that the adequacy of BMI as a measure of health and excess adiposity has been increasingly questioned,^{59,60} especially in diverse populations of children.^{61,62} Within this context, it is unsurprising there have been recent calls to stop using BMI due to its potential for stigmatization and inadequate reflection of health.^{63,64} Furthermore, there is a need to conduct studies that encompass diverse populations, as existing research focused on the relationship between UPF consumption and excess adiposity in young populations has primarily been carried out in Brazil. This limitation may result in a restricted geographic representation and dietary patterns that differ from other countries. Multicenter studies involving multiple countries offer an opportunity to generalize findings to specific regions and better enhance global applicability.

Several limitations present in the included studies must be considered when interpreting our findings. First, most of them were cross-sectional studies, making it difficult to establish causal relationships and examine associations over time. While some of these limitations are addressed by the longitudinal cohort studies included in the review, they do not consider potential changes in dietary patterns that may contribute to changes in adiposity trajectories. Additionally, the assessment of UPF exposure primarily relied on food frequency questionnaires or food records that were not originally designed to capture detailed information on food processing (and were not always validated to the study population), potentially leading to UPF misclassification.⁵⁷ Moreover, studies relying on caregiver reports of child dietary intake are prone to misreporting and social desirability bias, which may introduce additional measurement errors. Another significant limitation pertains to the lack of adjustment for relevant confounding factors in certain studies, such as physical activity (or energy expenditure), dietary patterns, and socioeconomic status. As previously mentioned, it is important to acknowledge that most studies were conducted in children or adolescents from Brazil, limiting the generalizability of the results to other regions.

The present systematic review was also subject to a few limitations. First, findings may be affected by publication bias. While we made a concerted effort to be thorough in the selection of search terms used for conducting the systematic review, it is possible that given the vast terminology on excess adiposity, some keywords may have been overlooked. In addition, the heterogeneity of the studies encompassed variations in age range, outcome assessment, and operationalization/categorization of UPF consumption, which made it difficult to synthesize the results and, thus, prevented us from carrying out a meta-analysis which may have offered stronger evidence on this topic.

Nonetheless, this study represents, to date, the most comprehensive and updated synthesis of observational studies examining the risk of excess body weight resulting from UPF intake in children and adolescents. It provides an extensive overview of the existing literature on this topic, highlights study limitations that warrant improvement, and identifies research gaps and opportunities for future investigation.

5 | CONCLUSION

The existing scientific literature investigating the association between high consumption of UPF and excess adiposity measures in children and adolescents remains limited and heterogeneous. Consequently, drawing definitive conclusions within this population continues to be a challenge. Given that methodological issues may lie behind some of these inconsistencies, future studies should adopt longitudinal designs with sufficiently extended follow-up periods, account for relevant confounding factors, employ validated and standardized measurement tools to assess dietary exposure, ensure consistent operationalization of variables, and encompass diverse geographic contexts. Addressing such current research constraints may shed better insights necessary to inform current and forthcoming policy and practice interventions aimed at mitigating the increasing prevalence of overweight and obesity in childhood and across the life course.

AUTHOR CONTRIBUTIONS

B. R. and M. So. conceptualized the initial study and M. Sa. guided the search strategy. B. R., M. So., and A. M. extracted the data and independently appraised all guidelines. Any discrepancies were resolved by M. Sa. B. R. and M. So. synthesized the results and B.R. drafted the original version of the manuscript. All authors contributed to the interpretation and presentation of the data and assisted with the preparation of the final version of the article. All authors have read and approved the article for publication.

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CONFLICT OF INTEREST STATEMENT

No conflicts of interest are declared by the authors.

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