REVIEW

Influence of ultra-processed foods consumption during pregnancy on baby's anthropometric measurements, from birth to the first year of life: a systematic review

Cristianny Miranda [1]
https://orcid.org/0000-0002-6962-5784

Rafaela Cristina Vieira e Souza [2]
https://orcid.org/0000-0003-2212-3776

Luana Caroline dos Santos [3]
https://orcid.org/0000-0001-9836-3704

[1-3] Escola de Enfermagem. Universidade Federal de Minas Gerais. Av. Professor Alfredo Balena, 190. sala 324. Belo Horizonte, MG, Brasil. CEP: 30130-100. E-mail: cristiannyms@gmail.com

Abstract

Objectives: to perform a systematic review of studies that investigated the influence of ultra-processed foods (UPF) consumption during pregnancy on child's anthropometric parameters up to one year of life.

Methods: cohort and cross-sectional studies were researched in BVS, Cinahl, Cochrane, Embase, Pubmed, Scopus and Web of Science databases until March 2020, and the main descriptors were: "Pregnant Women", "Ultra-processed foods", "Birth Weight", "Small for Gestational Age", "Infant", "Newborn".

Results: seventeen articles were considered eligible and evaluated the associations between the exposures: ultra-processed dietary patterns; soft drinks, sugar-sweetened beverages, artificially sweetened beverages; fast food, junk food, sweets, snacks and the outcomes: birth weight and its classifications; length and head circumference at birth; birth weight adjustments according to gestational age; weight/age, length/age, body mass index/age and weight/length indices. The results showed: 36 non-significant associations between the exposures and the outcomes; 13 direct associations (outcomes versus ultra-processed dietary patterns, soft drinks, artificially sweetened beverages, sweets, junk food) and 5 inverse associations (outcomes versus ultra-processed dietary patterns, soft drinks).

Conclusions: most of the evaluated literature did not demonstrate the influence of UPF consumption during pregnancy on the newborn's anthropometric measurements up to one year of life and denoted a smaller number of direct and inverse associations between the exposures and the outcomes.

Key words *Ultra-processed foods, Pregnancy, Birth weight, Child, Food consumption*

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Introduction

Despite the importance of food for maternal and child's health, recent changes in the population's eating habits can be observed, mainly regarding the replacement of natural food (*in natura* and minimally processed foods) with ultra-processed foods which have high energy density and low nutritional quality.[1,2] This information is critically given that such replacements happen even during the gestational period, interfering with the nutritional status of the newborn, and later, of the child.[3]

Pesquisa de Orçamentos Familiares (POF/2017-2018)[4] (Research on Family Budget) recently highlighted a relevant increasing share of ultra-processed foods in the total calories determined by household food acquisition, from 12.6% in 2002-2003 to 16.0% in 2008- 2009 and reaching 18.4% in 2017-2018.

On this basis, maternal diet can influence the pre-gestational body mass index (BMI) and excessive gestational weight gain, besides being one of the main factors that interfere with pregnancy outcomes. The maternal metabolic profile may be damaged by an unhealthy diet (rich in saturated fats, sodium and sugar, and low in fiber, vitamins, and minerals), increasing oxidative stress and insulin resistance, and consequently, increasing fat and glucose transfer to the fetus.[5]

Thus, abnormalities in fetal growth patterns can result in newborns small (SGA) or large for gestational age (LGA), with a great impact on the public health system – the high cost of medical and hospital expenses due to prolonged use of neonatal intensive care units, as well as a potential increase in neonatal and infant morbidity and mortality.[6]

The World Health Organization (WHO) considers SGA the newborns with a birth weight below the 10th percentile for gestational age and sex, and LGA those with a percentile higher than 90.[7] It is estimated that babies are born SGA or LGA in 20% out of all births.[8]

SGA newborns present a great risk of hypoxia during delivery, neonatal hypoglycemia, and necrotizing enterocolitis, a serious intestinal infection. Unlikely, the birth of LGA babies is associated with prolonged delivery, excessive maternal bleeding, severe vaginal ruptures, and cesarean section. Also, changes in growth, which start during the gestational period, can negatively affect the baby's health, increasing the risk of future diabetes and cardiovascular diseases, for instance.[8]

In this sense, the first postpartum year accounts for accelerated growth of the child and great biological vulnerability, due to the influence of factors such as birth conditions and extrauterine adaptation, socioeconomic conditions, access to healthcare, housing, sanitation, hygiene, and enough quality and quantity of food. Therefore, monitoring the child becomes essential in this age group, as studies have shown that linear growth deficits that can be fully recovered, begin around the 3rd month of life and continues for two or three years.[9]

Furthermore, this period is inserted in the first thousand days of the baby's life, which starts after conception until the age of two and represents a window of opportunities to improve the individuals health and to implement effective instruments to reduce malnutrition and contribute to the child's healthy growth and development, leading to positive impacts on the adult's health.[10]

Studies have been carried out to clarify the association between the general quality of the diet and birth weight, and the risks of SGA and LGA, even so those associations are not well known.[8] Besides, the influence of an unhealthy maternal diet composed of ultra-processed foods during pregnancy on the baby's weight gain is uncertain,[11] there is still a lack of studies on topics like these in Brazil.

Therefore, considering the importance of assessing the baby's anthropometric measurements to promote child's health, and the increasing prevalence of ultra-processed foods consumption worldwide, this study aimed to conduct a systematic review of articles that investigated the influence of ultra-processed foods consumption during pregnancy on the anthropometric measurements of the baby's first year of life.

Methods

The present study is a systematic review of scientific articles that assess the association between the intake of ultra-processed foods during pregnancy and the baby's anthropometric measurements from birth to one year of life. As a strategy to elaborate the research question - "Is there any scientific evidence in the literature on the influence of ultra-processed foods intake during pregnancy, on the baby's anthropometric measurements from birth to one year of life?" – and to direct the bibliographic search, the anagram PECOS was used, which represents "population", "exposure", "comparison", "outcome" and "design".[12] In the present study, the population refers to the pregnant women, the exposure represents ultra-processed foods intake during pregnancy, the outcome analyzed is the baby's anthropometric measurements from birth to one year of life, and the design of the selected articles are transversal and longitudinal. The selection of the articles was carried out through bibliographic search in the BVS databases (*Biblioteca Virtual em Saúde*/Virtual Library in Health); Cinahl; Cochrane; Embase; Pubmed; Scopus and Web of Science. The terms used were related to the baby's anthropometric measurements (from birth to 1 year), to the ultra-processed foods intake, and to the period of interest – the pregnancy. The search strategy was composed of combinations of the following terms: ((((((((((("Pregnancy" [Mesh]) OR "Pregnant Women"[Mesh])) OR ("Pregnancy"[Title/Abstract] OR "Pregnant Women"[Title/Abstract])))))) AND ((("Ultra-processed"[Title/Abstract] OR "Ultra-processed foods" [Title/Abstract] OR "ultra processed" [Title/Abstract] OR "ultraprocessed"[Title/Abstract] OR "ultra-processed"[Title/Abstract] OR "ready-to-eat" [Title/Abstract] OR "ready-to-consume" [Title/Abstract] OR "industrialized foods" [Title/Abstract] OR "fast-food" [Title/Abstract] OR "fast food" [Title/Abstract] OR "fastfood" [Title/Abstract] OR "junk food" [Title/Abstract] OR "prepared food" [Title/Abstract] OR "candy" [Title/Abstract] OR "ice cream"[Title/Abstract] OR "chocolate" [Title/Abstract] OR "carbonated beverage" [Title/Abstract] OR "soft drink" [Title/Abstract] OR "sweetened beverage" [Title/Abstract] OR "snacks" [Title/Abstract] OR "Sausage" [Title/Abstract] OR "hot dog" [Title/Abstract] OR "Burger"[Title/Abstract] OR "dietary patterns" [Title/Abstract] OR "dietary behaviors" [Title/Abstract] OR "dietary habits" [Title/Abstract] OR "artificially sweetened beverages"[Title/Abstract] OR "cookie"[Title/Abstract] OR "salty snacks"[Title/Abstract] OR "chocolate drink mix" [Title/Abstract] OR "refined grains" [Title/Abstract] OR "sugar-sweetened beverages" [Title/Abstract] OR "ready-to-heat products" [Title/Abstract] OR "cake mixes" [Title/Abstract] OR "biscuits" [Title/Abstract] OR "chips" [Title/Abstract] OR "hamburguer"[Title/Abstract] OR "packaged soups" [Title/Abstract] OR "breakfast cereals" [Title/Abstract] OR "chicken nuggets" [Title/Abstract])))) AND ((((((("Birth Weight" [Mesh]) OR "Infant, Small for Gestational Age"[Mesh]) OR "Infant, Newborn" [Mesh]) OR "Infant" [Mesh])) OR ("Birth Weight" [Title/Abstract] OR "Infant, Small for Gestational Age" [Title/Abstract] OR "Weight by Age" [Title/Abstract] OR "Body Weight" [Title/Abstract] OR "birth weight-for-length" [Title/Abstract] OR "birth weight for length" [Title/Abstract] OR "Weight-for-length" [Title/Abstract] OR "Weight for Length" [Title/Abstract] OR "weight-for-age" [Title/Abstract] OR "Weight for age" [Title/Abstract] OR "length-for-age" [Title/Abstract] OR "Length for age" [Title/Abstract] OR "head circunference" OR "head circunference-for-age" [Title/Abstract] OR "head circunference for age" [Title/Abstract] OR "Large for gestational age"))))))). There were no restrictions on the period of time evaluated, but all works needed to be original studies conducted in human beings. The survey included every article published until March 2020. In addition to the electronic search, the reviewers also performed a manual analysis on the reference list for each study included, to identify those potentially relevant studies that were not found in the initial investigation.

Observational studies - cohort and cross-sectional - published in Portuguese, English, and Spanish were selected for the present review. Eligibility criteria included studies with human beings that assessed the association between the ultra-processed foods intake (exposure) during the gestational period and the baby's anthropometric measurements (outcome) from birth to one year of life.

The exposure variable was the any ultra-processed foods intake as defined in the NOVA classification.[2] Ultra-processed foods are industrial formulations entirely, or for the most part, produced from substances extracted from food (oils, fats, sugar, starch, proteins), derived from food constituents (hydrogenated fats, modified starch), or synthesized in a laboratory to provide products with attractive sensory properties. They are ready-to-eat or ready-to-heat foods, therefore, little or none culinary preparation is needed, making them accessible and convenient. They are usually combined with a sophisticated use of additives to make them durable and hyper-palatable. However, they have very low nutritional quality and tend to limit the *in natura* or minimally processed foods intake.[2]

As an exclusion criteria, for studies that assessed the ultra-processed foods intake in the form of dietary patterns, the pattern should mostly contain ultra-processed foods, as defined in the NOVA[2] classification. The articles that investigated food intake through food indexes (diet quality index) were not taken into consideration, as it would not be possible to discriminate the consumption of ultra-processed foods.

As for the outcomes, the baby's anthropometric measurements at birth and at any time until the end of the first year were evaluated: birth weight and its deviations - low birth weight (<2,500g)[13] and macrosomia (birth weight >4,000g),[14] birth length and head circumference; weight/gestational age and their classifications - small/gestational age (SGA), appropriate/gestational age (AGA) and large/gestational age (LGA) and anthropometric indexes - weight/age (W/A), length/age (L/A), body mass index/age (BMI /A), and weight/length (W/L).

The articles found in the databases through the electronic search were stored in the EndNote® program to organize the references and eliminate duplicates. Then, two independent reviewers made the selection of initial articles after reading the titles, abstracts and keywords. After the initial selection of the articles, the Kappa test was performed to test the agreement between the evaluators, for which the statistical program, Statistical Package for the Social Sciences®(SPSS) version 19.0, was used. Byrt[15] criteria were adopted to classify the result of the concordance test as: slight agreement: 0.21-0.40, fair agreement: 0.41-0.60, good agreement: 0.61-0.80 and very good agreement: 0.81-1.00. The works selected in this stage were read in full and evaluated according to the eligibility criteria. A third reviewer judged whether the chosen articles would be eliminated or excluded in situations where the two reviewers disagreed.

The following data were extracted after the complete analysis of the selected articles: author, country and year of publication; study design; sample size (n) and maternal age (mean in years and standard deviation); method of assessing food consumption and exposure; assessed anthropometric baby's measurements and how these measurements were obtained – taken/self-reported; variables used to control confusion (adjustment variables) and main results.

The general and methodological quality of observational studies was assessed according to STROBE (Strengthening the Reporting of Observational Studies in Epidemiology).[16] The maximum score that can be achieved in this assessment is 22 points, of which 9 points refer to the section "methods" of the studies.

Results

A total of 1551 articles was found, and after removing duplicates (n=509), 1042 titles, abstracts, and keywords remained to be analyzed (Figure 1). The Kappa concordance index found was 0.731, indicating good agreement.[15] Having read the titles, abstracts, and keywords and keeping the eligibility criteria, the reviewers excluded 986 articles, leaving 56 to be read in full (Figure 1).

After the full reading, the reviewer 1 excluded 31 articles, and the reviewer 2 excluded 41 articles. The two reviewers agreed on the selection of 11 studies and disagreed over 18. A third reviewer judged the relevance of the 18 articles on which the two previous reviewers disagreed and decided to exclude 12 of them. Thus, 17 studies were considered eligible for the current review. Figure 1 displays the reasons for exclusions.

Regarding the quality of the studies,16 the total average and the "Methods" section got 17.26 (SD = 1.76) and 7.01 (SD = 0.58) points, respectively.

Table 1 presents the main characteristics and results of the studies assessed, which were published between 1995 and 2019.

Among the selected articles, five were conducted in the United States,[17-21] two in Norway,[8,22] two in Australia,[23,11] and one in Germany,[24] one in Spain,[25] one in Ghana,[26] one in Canada,[27] one in Netherlands,[28] one in New Zealand,29 one in England[30] and one in Brazil[5] (Table 1).

Most of the studies were of prospective cohort design (n=13)[5,8,11,17-22,24,27,28,30] and four were cross-sectional.[23,25,26,29] The sample size ranged from 12725 to 65,9048 women, with seven studies presenting over 1,000 participants[8,18,22,24,27,29,30] (Table 1).

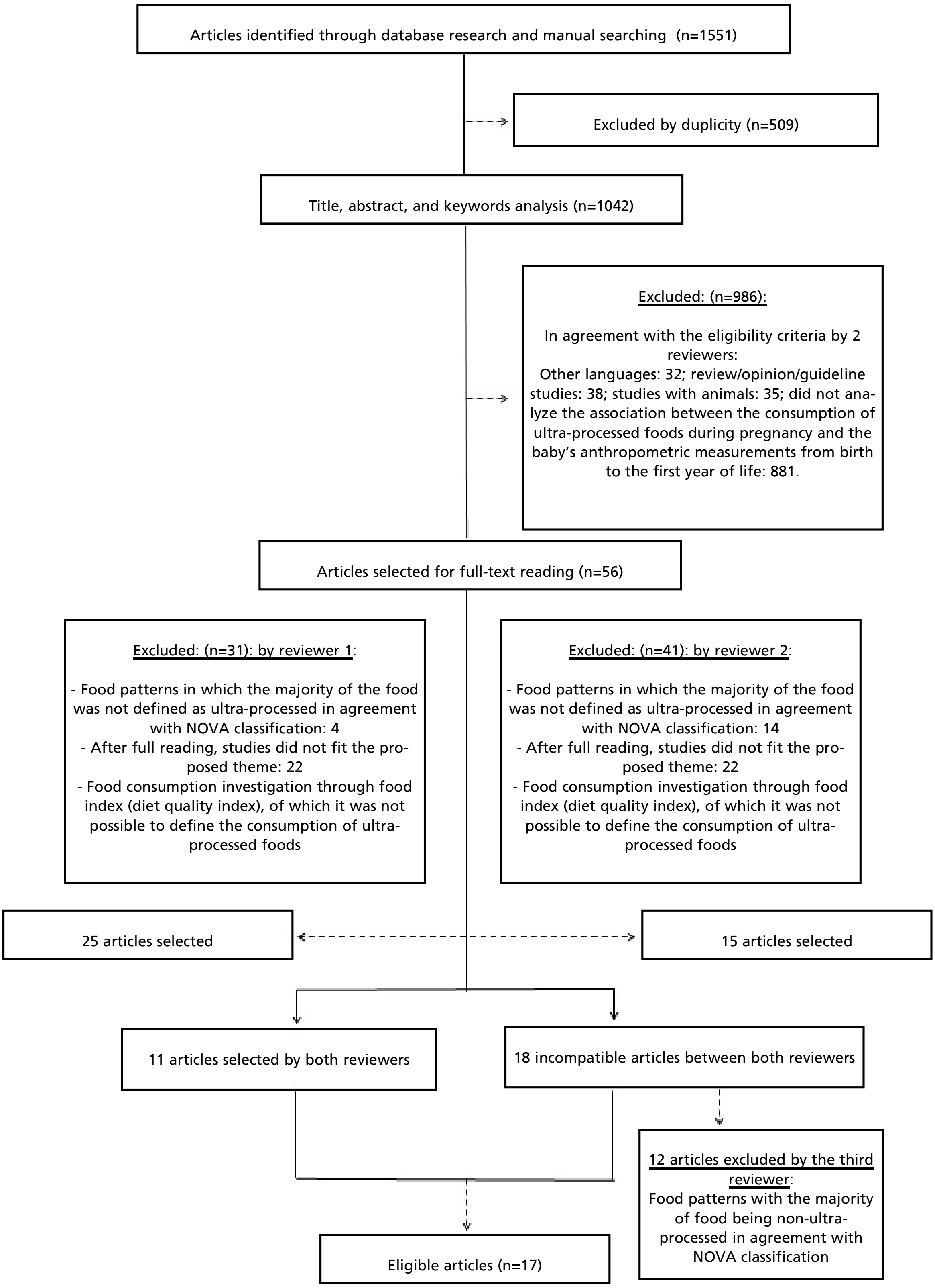
Maternal age was not presented in most part of the articles (n=11). In the others, there was a variation from 24.20 (SD 5.40) years21 to 32.50 (SD 4.60) years27 (Table 1).

It is noteworthy that in eleven[5,8,11,17,19,22,24,26,27-29] of the seventeen articles selected for this review, the mothers in the sample presented some comorbidity before or during pregnancy, such as gestational diabetes, hypertension (including preeclampsia), overweight/obesity, depression, eating disorders (nausea during pregnancy), and chronic illnesses such as chronic hypertension, kidney diseases, and systemic lupus erythematosus. Out of the twelve studies, two were cross-sectional[26,29] and the others were cohort (Table 1).

Besides the use of these variables (maternal comorbidities) in the adjustment of the multivariate model, other treatments were used to remove confounding factors related to these comorbidities such as analysis of variance and chi-square tests,[28] or multivariate analyses[26] to verify whether there was an association between maternal comorbidities and dietary patterns. In Alves-Santos et al. research,[5] a direct acyclic graph used for each outcome was developed to identify a minimal yet sufficient set of covariates to remove confusion from the analysis statistic. Only two studies[19,24] lack information on how these maternal comorbidities variables were considered.

Figure 1

Flow chart illustrating the selection of the articles used for the present systematic review about the association between the consumption of ultra-processed foods during pregnancy and the baby's anthropometric measurements from birth to one year of life.



Food consumption was investigated using mostly the food frequency questionnaire (FFQ). Sixteen studies[5,8,11,17,18,20-30] used this instrument, and one opted for a questionnaire prepared by the authors themselves[19] (Table 1). In the latter, Moss and Harris[19] prepared a questionnaire to assess the weekly intake of fast food, including the frequency of consumption in typical fast-food chains like McDonald's and Kentucky Fried Chicken.

The moment to assess food consumption through the FFQ assigned to mothers varied from the first to the third trimester of pregnancy[8,11,17,18,20,22,24-27,29,30] or it was considered the previous months to pregnancy[5,19,23,28] and in one study, this period was not mentioned.[21]

Regarding the analysis of food consumption (exposure), ten studies carried out using dietary patterns, mostly composed of ultra-processed foods,[5,8,17,18,21,23,26,28-30] five for beverages such as soft drinks, sugar-sweetened beverages (regular pops or soft drinks, and sugar or honey added to tea or coffee) or artificially sweetened beverages (diet soft drinks, soft drinks and artificial sweetener added to tea or coffee)[20,22,24,25,27] and four through investigation on the consumption of "fast food", "junk food" (soft drinks, fast food and/or processed meats and chips) and specific foods such as sweets and snacks.[11,19,20,24]

In the studies that evaluated dietary patterns, the authors described the patterns and wrote phrases indicating that the foods were ultra-processed: "fast food (rich in saturated fat and energy)" [5,17]; "snacks with high sugar/energy content"[26]; "Processed foods low in nutrients and dense in energy, high in saturated and trans fats, sodium and refined sugars"[18]; "Junkfood (unhealthy, energy-dense, low-nutrient diet) associated with increased levels of obesity"[29]; "Processed foods with a high-fat content"[30]; "Foods rich in calories and low in nutrients, high in sodium and sugar".[21] Also, foods such as cakes, sweet pies, and sweets are generally considered to be ultra-processed foods, as noted in the *Pesquisa de Orçamentos Familiares*,[4] keeping in mind that homemade sweets and cakes are consumed by a smaller portion of the population.[4]

The ultra-processed groups included: "high Western" pattern – salty and sweet snacks, desserts, processed meat, sweetened beverages, french fries[8]; "fast food and candies" pattern - fast food and snacks, cakes, cookies, sweets or desserts[5]; "latent class1" pattern - processed meats, french fries, sweets, salty snacks and soft drinks[17]; "non-health conscious diet" pattern - sweetened drink, ice cream, chocolate energy drink, milk drinks and soda[26]; "processed" pattern - processed meat, fast food, snacks, sweets and soft drinks[18] and "high-fat/sugar/takeaway" pattern - ready-to-eat foods, potato chips.[23]

Other ultra-processed patterns included: "energy-rich dietary pattern" - breakfast cereals, margarine, snacks/sweets[28]; "junk food" pattern - ice cream, cookies, cakes, sweetened cereal, crisps, chocolate bars and chocolate energy drink[29]; "processed" pattern - sausages and burgers, chips and crisps and "confectionery" pattern - confectionery, chocolate, sweets, cookies, cakes[30] and "Nutrient Dilute" pattern - salty snacks, cakes, cookies, pastries, gelatine dessert and ice cream.[21]

The most investigated anthropometric measurements in the studies were those at birth, such as birth weight.[8,18,19,21,22,24,26,28,30] Other authors prioritized macrosomia[11,20,22,24] and adjustments of the gestational weight/age index - SGA[8,23,24,25,29] and LGA.[5,8,20,24] In thirteen studies, the measurements were taken - in eleven, they were obtained from hospital records[5,8,11,17,18,22,24,26,28-30] and in two20,27 they were taken by the researchers; in three studies they were self-reported by the mothers[19,21,25] and in one study,[23], such information was not mentioned (Table 1).

The direct association between the consumption of ultra-processed foods and the baby's anthropometric measurements were found in six studies of this present review.[5,8,11,20,25,27]

Englund-Ogge *et al.*[8] identified that the "high prudent" pattern (composed of vegetables, fruits and whole grains) was associated with the lowest birth weight (β=-0.041; CI95%= -0.068 − -0.013) and with fewer chances of LGA (OR=0.84; CI95%=0.75−0.94) when compared to the "high Western" pattern. On the other hand, in the study by Alves-Santos *et al.*[5] the "fast food and candies" pattern was associated with a greater chance of LGA babies (OR=4.38; CI95%=1.32−14.48) and with length at birth > percentile 90 (OR=4.81; CI95%=1.77−13.07). Both studies had a longitudinal design (prospective cohort; Table 1).

In a cross-sectional evaluation, Gomez Roig *et al.*[25] verified a higher consumption of Coke among mothers in the SGA group (p=0.004), while mothers in the AGA group drank more diet Coke (p=0.03). Among mothers of normal weight, Phelan *et al.*[20] reported in a prospective cohort, a higher birth W/A of the baby (β=0.16; p=0.04) in those mothers with a higher intake of soft drinks during pregnancy (Table 1).

The cohort study by Azad *et al.*[27] described a direct association between the daily intake of artifi-

Table 1

Summary of the selected studies for a systematic review which investigated the influence of ultra-processed foods consumption during pregnancy on the baby's anthropometric measurements from birth to one year of life.

Author and year/country	Design	Sample (n)/ Mean age in years (SD)	Method to acess Consumption / Exposure	Anthropometric measurements assessed / Measured/Self-reported	Adjustments of the variables	Main results
Gunther *et al.*,[24] 2019, Germany	Prospective cohort	2,286/NM	FFQ/Soft drinks intake, fast food, sweets and snacks	Birth weight, LBW, weight at birth >4,000g, SGA and LGA/Measured	Pre-pregnancy BMI, age, parity and [a]group assignments.	Up to the 12th gestational week: maternal daily consumption of a glass (200mL) of soda reduced birth weight in 10.90g (CI95%= -18.17–-3.64; *p*=0.003). After the 29th gestational week: reduction of 8.19g (CI95% = -16.26–-0.11; *p*=0.047) for each glass of soda..
Englund-Ogge *et al.*,[8] 2019, Norway	Prospective cohort	65,904/NM	FFQ/Dietary Pattern	SGA, LGA and birth weight /Measured	Maternal age, energy intake, pre-pregnancy BMI, height, parity, smoking, alcohol intake, total family income, level of schooling, chronic diseases and eating disorders (nausea during pregnancy).	"High prudent" pattern: lowest birth weight (β=-0.041; CI95%= -0.068–-0.013), higher chances of SGA (OR=1.25; CI95%= 1.02–1.54) and lower chances of LGA (OR= 0.84; CI95%= 0.75–0.94), compared to "high Western" pattern.
Alves-Santos *et al.*,[5] 2019, Brazil	Prospective cohort	193/NM	FFQ/ Dietary Pattern	LGA and birth length >percentile 90/Measured	Maternal age, smoking, alcohol intake, level of schooling, first-trimester leisure time physical activity.	"Fast food and candies"pattern: higher chances of LGA (OR=4.38; CI95%= 1.32–14.48) and birth lenght >percentile 90 (OR=4.81; CI95%= 1.77–13.07).

continue

AGA = adequate for gestational age; β[a]: adjusted beta; β: beta; BMI= body mass index; BMI/A = BMI/Age; CI= confidence interval; FFQ= food frequency questionnaire; LGA = large for gestational age; LBW = low birth weight; NM = not mentioned; OR = odds ratio; SGA= small for gestational age; W/A= weight by age; Vs= versus

Note: [a]group assignments: 1. Group case: part of the sample received intervention in a previous study for gestational weight control; 2. Control group: no intervention; [b]The Healthy Eating Index is a measurement of dietary quality in agreement with the Dietary Guidelines of 2010 from the United States Department of Agriculture; 12 components address the adequacy of the diet (9 components) and moderation (3 components), the highest score being 100; [c]crown-rump length of the embryo/fetus: it is the estimated length of the embryos and human fetus from the top of its head to the bottom of torso; [d]recruiting clinic –women were recruited at the moment of their first prenatal appointment at one of the six obstetrics clinics, covering a socioeconomic and ethnically diverse population in Providence, Rhode Island, from 2006 to 2008.

Table 1 **continuation**

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Gomez Roig *et al.*,[25] 2017, Spain	Cross-sectional	127 / 31.10 (0.38)	FFQ/Intake of cola-based soft drinks	SGA and AGA/ Measured	Smoking	Higher cola-based soft drinks intake among the mothers of group SGA (p=0.004) and cola-based diet soft drinks among the mothers of group AGA (*p*=0.03).
Grundt *et al.*,[22] 2017, Norway	Prospective cohort	50,280/NM	FFQ/Sweetened carbonated soft drinks	Birth weight and birth weight >4,500g/ Measured	Maternal height, pre-pregnancy BMI, age, parity, level of schooling, income, exercise, smoking, volume of alcohol intake per occasion prior to pregnancy, intake of artificially sweetened beverages, natural birth and baby's birth year, gestational diabetes, glycosuria, preeclampsia and hypertension.	Intake of 100mL of sweetened carbonated soft drinks: reduction of 7.8g (CI95%= -10.3−-5.3) in birth weight and lower chances of birth weight >4,500g (OR=0.94; CI95%= 0.90−0.97).
Martin *et al.*,[17] 2016, United States	Prospective cohort	389/NM	FFQ/ Dietary Pattern	BMI/A z-score/ Measured	Maternal age, race, level of education, income, marital status, parity, smoking and pre-pregnancy BMI, pre-pregnancy diabetes, chronic hypertension, gestational diabetes and pregnancy-induced hypertension.	No association between the "latent class1" pattern (mostly contains ultra-processed foods) on pregnancy and z-score of birth BMI/A, 6 months and 1 year [(β=-0.12 (CI95%= -0.39−0.14); β=0.05 (CI95%= -0.23−0.34); β=0.03 (CI95%= -0.24−0.30, respectively) compared to pattern 2 (mostly contains in natura and minimally processed food).

continue

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Abubakari e Jahn,[26] 2016, Gana	Cross-sectional	578/NM	FFQ/Dietary Pattern	Birth weight/ Measured	Gestational age	Non-healthly conscious diet" pattern: no association with birth weight [OR=1.04; CI95%= 0.65–1.67; p=0.95]
Azad *et al.*,[27] 2016, Canada	Prospective cohort	3,033/ 32.50 (4.60)	FFQ/Artificially sweetened beverages and sugar-sweetened beverages	BMI/A in z-score/ Measured	Maternal BMI, maternal energy intake, points at bhealthy eating index, level of schooling, smoking and gestational diabetes, breastfeeding duration, baby's sex, introduction to solid foods before 4 months old.	Daily intake of artificially sweetened beverages: higher z-scores of BMI/A (β^a=0.22; CI95%= 0.02−0.41) and intake of sugar-sweetened beverages: no association with BMI/A in z-score (β^a=0.07; CI95%= -0.06−0.19), both 1 year, for daily consumers vs non-consumers.
Colón-Ramos *et al.*,[18] 2015, United States	Prospective cohort	1,151/NM	FFQ/Dietary Pattern	Birth weight birth and length W/A, length by age, weight/ length and head circunference/ Measured	Age, race, pre-pregnancy BMI, level of schooling, alcohol intake, gestational weight gain.	"Processed" pattern: no association with birth outcomes (p>0.05).

continue

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Author and year/country	Design	Sample (n)/ Mean age in years (SD)	Method to acess Consumption / Exposure	Anthropometric measurements assessed / Measured/Self-reported	Adjustments of the variables	Main results
Moss and Harris,[19] 2014, United States	Prospective cohort	372/ 24.40 (0.25)	Questionnaire elaborated by the authors/Fast food consumption	Birth weight /Self-reported	Age, race, level of education, wellness feeling, immigrant or not, baby's sex, trimester in which started prenatal, parity, period between the interview and the conception and marital status.	Fast food consumption during pregnancy: no association with birth weight (p=0.93).
Grieger *et al*.,[23] 2014, Australia	Cross-sectional	309/ 26.60 (5.40)	FFQ/Dietary Pattern	LBW, SGA, birth length/NM	Maternal age, maternal BMI, smoking, socioeconomic status, presence of asthma, parity and ethnicity.	"high-fat/sugar/takeaway" pattern: no association with LBW and SGA (p>0.05). Increase of 1 SD in the points of this standard: shorter birth length (β^a=-0.5cm; CI95%= -0.8−-0.1; p=0.004) compared to the other patterns
Wen *et al*.,[11] 2013, Australia	Prospective cohort	368/NM	FFQ/Frequent intake of foods from the "junk food"pattern	Birth weight >4,000g / Measured	Maternal nutritional status (normal weight, underweight, overweight, obesity) and gestational age.	"Junk food" pattern during pregnancy: mothers who did not follow this pattern were less willing to have a newborn weighing >4,000g (OR=0.36; CI95%= 0.14−0.91; p=0.03) compared to those who did.

continue

AGA = adequate for gestational age; β^a: adjusted beta; β: beta; BMI= body mass index; BMI/A = BMI/Age; CI= confidence interval; FFQ= food frequency questionnaire; LGA = large for gestational age; LBW = low birth weight; NM = not mentioned; OR= odds ratio; SGA= small for gestational age; W/A= weight by age; Vs= versus

Note: [a]group assignments: 1. Group case: part of the sample received intervention in a previous study for gestational weight control; 2. Control group: no intervention; [b]The Healthy Eating Index is a measurement of dietary quality in agreement with the Dietary Guidelines of 2010 from the United States Department of Agriculture; 12 components address the adequacy of the diet (9 components) and moderation (3 components), the highest score being 100; [c]crown-rump length of the embryo/fetus: it is the estimated length of the embryos and human fetus from the top of its head to the bottom of torso; [d]recruiting clinic –women were recruited at the moment of their first prenatal appointment at one of the six obstetrics clinics, covering a socioeconomic and ethnically diverse population in Providence, Rhode Island, from 2006 to 2008.

Table 1 **continuation**

Summary of the selected studies for a systematic review which investigated the influence of ultra-processed foods consumption during pregnancy on the baby's anthropometric measurements from birth to one year of life.

Author and year/country	Design	Sample (n)/ Mean age in years (SD)	Method to acess Consumption / Exposure	Anthropometric measurements assessed / Measured/Self-reported	Adjustments of the variables	Main results
Bouwland-Both *et al*.,[28] 2012, Netherlands	Prospective cohort	847/ 31.70 (4.0)	FFQ/Dietary Pattern	Birth weight/Measured	Duration of the last menstrual cycle, maternal age, maternal and paternal height and BMI, baby's sex, parity, level of schooling, smoking, folic acid supplementation, diastolic and systolic blood pressure average, and [c]crown-rump length of the fetus.	"Energy-rich dietary"pattern:no association with birth weight [β=0.02; CI95% = -0.05–0.09)]. .
Phelan *et al*.,[20] 2011, United States	Prospective cohort	363/NM	FFQ/Intake of soft drinks and sweets	W/A, LGA and birth weight >4.000g / Measured	Baby's sex, intervention and control group, gestational age, [d]recruiting clinic, gestational weight gain. The analyses at 6 months old were additionally adjusted by breastfeeding.	Overweight/Obese mothers: higher % of kcal from sweets during pregnancy: higher birth W/A (β=0.19; *p*= 0.004), higher chance of birth weight >4,000g (OR=1.1; CI95%= 1.0–1.2; *p*=0.004), LGA (OR=1.2; 95% CI 1.1–1.3; p=0.002) and higher W/A at 6 months (β=0.30; *p*=0.002). Normal weight mothers: higher intake of soft drinks: higher birth W/A(β=0.16; *p*=0.04).

continue

AGA = adequate for gestational age; β[a]: adjusted beta; β: beta; BMI= body mass index; BMI/A = BMI/Age; CI= confidence interval; FFQ= food frequency questionnaire; LGA = large for gestational age; LBW = low birth weight; NM = not mentioned; OR= odds ratio; SGA= small for gestational age; W/A= weight by age; Vs= versus
Note: [a]group assignments: 1. Group case: part of the sample received intervention in a previous study for gestational weight control; 2. Control group: no intervention; [b]The Healthy Eating Index is a measurement of dietary quality in agreement with the Dietary Guidelines of 2010 from the United States Department of Agriculture; 12 components address the adequacy of the diet (9 components) and moderation (3 components), the highest score being 100; [c]crown-rump length of the embryo/fetus: it is the estimated length of the embryos and human fetus from the top of its head to the bottom of torso; [d]recruiting clinic –women were recruited at the moment of their first prenatal appointment at one of the six obstetrics clinics, covering a socioeconomic and ethnically diverse population in Providence, Rhode Island, from 2006 to 2008.

Table 1 **concluded**

Summary of the selected studies for a systematic review which investigated the influence of ultra-processed foods consumption during pregnancy on the baby's anthropometric measurements from birth to one year of life.

Author and year/country	**Design**	**Sample (n)/ Mean age in years (SD)**	**Method to acess Consumption / Exposure**	**Anthropometric measurements assessed / Measured/Self-reported**	**Adjustments of the variables**	**Main results**
Thompson *et al*.,[29] 2010, New Zealand	Cross-sectional	1,714/NM	FFQ/Dietary Pattern	SGA/ Measured	Gestational age, baby's sex, smoking during pregnancy, pre-pregnancy height and weight, parity, ethnicity and maternal hypertension..	"Junk food" pattern: no association with SGA (OR=1.01; CI95%= 0.88−1.17).
Northstone *et al*.,[30] 2008, England	Prospective cohort	12,053/NM	FFQ/Dietary Pattern	Birth weight/ Measured	Energy intake	"Processed" and "confectionery"patterns: no association with birth weight: [β=0.09; 95% CI - 0.67−0.85) and β= -0.42; CI95%= -1.21−0.38, respectively].
Wolff *et al*.,[21] 1995, United States	Prospective cohort	549/ 24.20 (5.40)	FFQ/Dietary Pattern	Birth weight/Self-reported	NM	Nutrient Dilute" pattern: no association with birth weight (p=0.05).

AGA = adequate for gestational age; β[a]: adjusted beta; β: beta; BMI= body mass index; BMI/A = BMI/Age; CI= confidence interval; FFQ= food frequency questionnaire; LGA = large for gestational age; LBW = low birth weight; NM = not mentioned; OR = odds ratio; SGA= small for gestational age; W/A= weight by age; Vs= versus

Note: [a]group assignments: 1. Group case: part of the sample received intervention in a previous study for gestational weight control; 2. Control group: no intervention; [b]The Healthy Eating Index is a measurement of dietary quality in agreement with the Dietary Guidelines of 2010 from the United States Department of Agriculture; 12 components address the adequacy of the diet (9 components) and moderation (3 components), the highest score being 100; [c]crown-rump length of the embryo/fetus: it is the estimated length of the embryos and human fetus from the top of its head to the bottom of torso; [d]recruiting clinic –women were recruited at the moment of their first prenatal appointment at one of the six obstetrics clinics, covering a socioeconomic and ethnically diverse population in Providence, Rhode Island, from 2006 to 2008.

cially sweetened beverages and the BMI/A of the 1-year-old baby (adjusted β=0.22; CI95%=0.02−0.41) (Table 1). Phelan *et al.*[20] described in a research of the same design, that in overweight/obese mothers, the highest percentage of calories from sweets during pregnancy was associated with higher birth W/A (β=0.19; *p*=0.004) and at 6 months (β=0.30; *p*=0.002), greater chance of birth weight > 4,000g [OR=1.1; CI95%= 1.0 – 1.2; *p*=0.004] and LGA babies [OR=1.2; CI95%= 1.1 – 1.3; *p*=0.002] (Table 1).

In the longitudinal study by Wen *et al.*,[11] mothers who did not follow a "junk food" diet pattern during pregnancy were less likely to have a newborn weighing> 4,000g (OR=0.36; CI95%= 0.14 − 0.91; *p*=0.03) (Table 1), compared to those who followed such a pattern.

The inverse associations with the outcomes have been demonstrated in 4 studies.[8,22,23,24] Grieger *et al.*[23] showed in a cross-sectional evaluation, that an increase of 1 standard deviation in the scores of the "high-fat/sugar/takeaway" pattern was associated with shorter birth length (β[a]=-0.5cm; CI95%= -0.8 − -0.1; *p*=0.004). Likewise, Englund-Ogge *et al.*[8] noted in a prospective cohort, a greater chance of the birth of SGA babies (OR=1.25; CI95%= 1.02 − 1.54) among mothers belonging to the “high prudent” pattern compared to those of the “high western” pattern (Table 1).

In the longitudinal study by Gunther *et al.*,[24] the daily consumption of a glass (200mL) of soft drink by the pregnant woman, before or on the 12th gestational week, reduced birth weight in 10.90g (CI95%= -18.17 − -3.64; *p*=0.003) and, after the 29th week, the reduction was 8.19g (CI95%= -16.26 − -0.11; *p* = 0.047) per glass of soft drink. In the research by Grundt *et al.*,[22] the intake of 100 mL of soft drink was associated with a reduction of 7.8 g (CI95%= -10.3−-5.3) in birth weight and fewer chances of birth weight > 4,500g (OR=0.94; CI95%= 0.90−0.97) (Table 1).

Non-significant associations between the exposures and the outcomes were pointed out in eight studies that investigated the influence of ultra-processed patterns in the baby’s anthropometric measurements, in five cohorts[17,18,21,28,30] and three cross-sections[23,26,29] (Table 1).

Such associations were also highlighted in the studies by Gunther *et al.*[24] in which soft drinks consumption by the mother was not associated with low birth weight (LBW), birth weight > 4,000g, SGA and LGA, and in the studies by Phelan *et al.*[20] in which the intake of soft drinks was not associated with the child's W/A at six months, birth weight >4,000 g and LGA (data not presented in a table). In the study by Azad *et al.*,[27] non-significant association between the exposure and the outcome was also observed between the intake of sugar-sweetened beverages and the BMI/A of the 1-year-old baby (adjusted β=0.07; CI95%= -0.06 − 0.19) (Table 1).

Gunther *et al.*[24] who investigated the consumption of “fast food”, sweets and snacks, during pregnancy, observed that the intake of these foods did not influence with birth weight, LBW, birth weight >4,000g, SGA and LGA, similar to Moss and Harris,19 who did not find any associations between “fast food” consumption and birth weight (*p*=0.93) (Table 1).

The main adjustment variables used in the analyses were maternal age, parity, smoking, level of schooling, pre-gestational BMI, race/ethnicity, baby's sex, gestational age, height, energy intake, alcohol intake, total family income, maternal BMI, gestational weight gain, marital status and breastfeeding (included in the studies which analysis was performed after the baby had been born).

Table 2 presents a summary of the associations (direct, inverse, and non-significant association between the exposure and the outcome) found in the articles that assess the influence of the consumption of ultra-processed foods during pregnancy on the baby's anthropometric measurements from birth to the first year.

In general, it is noted that non-significant association between the exposure and the outcome (n=36) prevailed between the exposures (mostly ultra-processed food pattern; soft drinks, artificially sweetened beverages and beverages sweetened with sugar; “fast food”, “junk food”, sweets and snacks) and the baby's anthropometric measurements.

Thirteen direct associations were found regarding the baby's anthropometric measurements: four when the exposure was ultra-processed dietary patterns; four when the association was with the consumption of soft drinks, artificially sweetened beverages and sugar-sweetened beverages and five when the explanatory variables were the consumption of “fast food”, “junk food”, sweets and snacks (Table 2).

Five inverse associations with the assessed outcomes were mentioned: two when the exposure was ultra-processed dietary patterns, and three when it was the consumption of soft drinks, artificially sweetened beverages and sugar-sweetened beverages (Table 2).

Discussion

The present review showed that the majority of the studies that investigated mostly ultra-processed dietary patterns, the consumption of soft drinks, artificially sweetened beverages and sugar-sweetened beverages and "fast food", "junk food", sweets and snacks, found non-significant association with the baby's anthropometric measurements from birth to one year of life. This result contradicts the hypothesis of the authors of the present review that a high consumption of ultra-processed foods during pregnancy could lead to a greater occurrence of changes in the baby's anthropometric measurements and later, of the child,[3] considering the high energy density and low nutritional quality of those foods.[1] Some hypotheses have been postulated to explain such divergences.

First, it is important to highlight some methodological issues inherent to the studies assessed. Mothers with comorbidities such as gestational diabetes, hypertension, overweight/obesity, depression, and among others, were part of the samples under analysis. Although non-significant associations between the exposures and the outcomes were found in four[18,21,23,30] of the five studies[18,21,23,25,30] that did not mention comorbidities, the presence of any disease or condition during pregnancy can promote an unfavorable gestational evolution, including an increased risk of birth of the newborns with weight deviations.[1]

The main justification for not excluding these mothers from the sample was the use of these variables to adjust the final regression model[8,11,17,22,27-29] and sensitivity analyses to examine the robustness of the results,[17] which suffered minimal[22] or no interference8 from the use of those variables.

Another methodological aspect needs to be considered, which may have influenced the non-significant associations between the exposures and the outcomes identified, concerns the lack of agreement regarding the moment of evaluation of food consumption among the studies. In addition to impairing the comparability of findings among the studies, such inconsistency may have interfered with the results, considering that pregnancy is a period marked by intense physiological, metabolic and endocrine changes. These are responsible for altering nutritional needs, food intake and nutritional maternal status, which are determinants in gestational weight gain, which is directly or indirectly associated with the newborn's and the child's health outcomes in the future.[6]

Nevertheless, it is necessary to consider the characteristics inherent to ultra-processed foods (such as high energy density, low nutritional value, high levels of sugars and caffeine - present mainly in cola-based soft drinks - in addition to fat and saturated fat), which can interfere with the gestational weight gain (including in women who already start pregnancy overweight) and, consequently, in the baby's anthropometric measurements,[5] which can justify the direct and inverse associations found in some studies.

In this sense, diet represents one of the main factors that influence pregnancy outcomes. An unhealthy diet consisting of ultra-processed foods, before and during pregnancy, can increase maternal body weight, increase the risk of birth for LGA babies and impact negatively on the mother and child's health in the short and long term.[5] Thus, in two recent studies, one national[5] and the other international,[8] "fast food and candies" showed a greater chance of LGA and birth length> 90th percentile and the "high Western" pattern showed a greater chance of LGA.

However, in the case of cola-based soft drinks, the relationship between their consumption and the birth of SGA babies remains uncertain.[25] Soft drinks are components of the pattern that provides energy and no specific nutrients. Its high intake can be accompanied by a lower intake of nutritious foods and this could explain the inverse association with birth weight. In addition, the role of soft drinks in this outcome needs to be better clarified, as the literature points out that the consumption of beverages containing sugar can have both an increasing and decreasing effect on birth weight.[24]

Another hypothesis that could justify the inverse association between the intake of sweetened carbonated soft drinks and birth weight and fewer chances of macrosomia would be the rapid sugar absorption provided by these beverages, resulting in glycemic spikes. If they occur frequently, they could induce oxidative stress, inflammation and microvascular endothelial dysfunction impairing blood flow through the placenta, reducing nutrition and fetal oxygenation.[22]

In line with this hypothesis, another possible biochemical mechanism that could be associated would be the presence of pro-inflammatory nutrients in ultra-processed foods, such as fat and saturated fat that would limit the transfer of proper nutrients for the baby[23] through the placenta.

It is important to highlight the presence of mothers with comorbidities in the sample of eleven studies as a limitation of this review. In two of these, the treatment of these comorbidities was not

Table 2

Summary of the associations (direct, inverse and non-significant association between the exposure and the outcome) found in the articles that assessed the intake of ultra-processed foods during pregnancy on the baby's anthropometric measurements baby from birth to one year of life.

		Anthropometric measurements assessed															
Exposures	**Association with the outcomes**	**BW**	**LBW**	**BW >400g**	**BL**	**BL >p90**	**HC**	**SGA**	**AGA**	**LGA**	**Birth BMI/A**	**BMI/A 6 months**	**BMI/A 1 year**	**Birth W/A at birth**	**W/A 6 months**	**Birth W/L at birth**	**Birth W/L at birth**
UP pattern (n=10)	Direct	1				1				2							
	Inverse				1			1									
	NS	6	1		1		1	2			1	1	1	1		1	1
Soft drinks, ASB, SSB (n=5)	Direct							1	1				1	1			
	Inverse	2		1													
	NS		1	2				1		2			1		1		
"*fast food*", "*junk foods*", sweets and *snacks* (n=4)	Direct			2						1				1	1		
	Inverse																
	NS	3	2	2				2		2							

Note: AGA: adequate for gestational age; ASB=artificially sweetened beverages; BL= birth length; BMI/A= body mass index/age; BW= birth weight; HC=head circumference; L/A= length/age; LBW= low birth weight; LGA= large for gestational age; NS=non-significant association between the exposure and the outcome; SGA= small for gestational age; SSB= sugar-sweetened beverages; UP= ultra-processed; W/A= weight/age; W/L= weight/length.

mentioned, so as not to interfere with the results obtained. Also, most of the studies lack information about the mothers' age. The literature points out that age is a factor that can interfere with food consumption and that it is difficult to change eating habits, even during pregnancy and, considering ultra-processed foods, unhealthy dietary practices are more common among adolescents and young adults.[31] The lack of knowledge on healthy eating by pregnant young women is reflected in their food choices, which are influenced by factors such as increased appetite, “desire”, marked taste, and the availability and convenience of food.[32]

Finally, assessing food consumption of an individual or population is complex, due to its variability and the interaction between the various nutrients and food that compose it, in addition to the several possibilities of outcomes of this assessment, whether through dietary patterns, isolated food, food groups or analysis according to the degree of processing as proposed by NOVA.

NOVA is fairly recent and up to this moment, the authors are unaware of studies in the literature in which experts applied it to assess associations between the consumption of ultra-processed foods during pregnancy and the baby’s anthropometric measurements. It is believed that this systematic review is the first to address the association between the consumption of ultra-processed foods during pregnancy and the baby’s anthropometric measurements up to one year of life. Besides, it is noteworthy that a detailed analysis of the selected articles was carried out, concerning the investigated associations, the instruments used in the evaluation of food consumption, the moment to apply these instruments, sample representativeness and adjustment variables used in the studies to minimize confounding factors.

Most of the literature assessed did not show any influence of the consumption of ultra-processed foods during pregnancy on the baby’s anthropometric measurements up to one year of life and pointed to a smaller number of direct and inverse associations between the exposures and analyzed outcomes. However, given the methodological diversity and complexity of the theme, further studies using a standardized food classification such as NOVA, are needed, so as to clarify the role of these ultra-processed products in the baby’s anthropometric measurements.

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Authors' contributions

CM conducted the bibliographic review, conception, analysis and interpretation of the data, and final writing. RCVS participated in the bibliographic review, analysis and interpretation of data and critical review of intellectual content. LCS guided the research, analyzed the results critically, supported the writing, revised the manuscript and approved the final version of the article.

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