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Ultra-processed Food Intake and Obesity: What Really Matters for Health – Processing or Nutrient Content?

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Abstract

Purpose of Review—The aim of this narrative review was to summarize and critique recent evidence evaluating the association between ultra-processed food intake and obesity.

Recent Findings—Four of five studies found that higher purchases or consumption of ultra-processed food was associated with overweight/obesity. Additional studies reported relationships between ultra-processed food intake and higher fasting glucose, metabolic syndrome, increases in total and LDL cholesterol, and risk of hypertension. It remains unclear whether associations can be attributed to processing itself or the nutrient content of ultra-processed foods. Only three of nine studies used a prospective design, and the potential for residual confounding was high.

Summary—Recent research provides fairly consistent support for the association of ultra-processed food intake with obesity and related cardiometabolic outcomes. There is a clear need for further studies, particularly those using longitudinal designs and with sufficient control for confounding, to potentially confirm these findings in different populations and to determine whether ultra-processed food consumption is associated with obesity independent of nutrient content.

Keywords

food processing; ultra-processed food; processed food; overweight; obesity

Introduction

To identify dietary factors associated with increased risk of weight gain and obesity, investigators have traditionally focused on nutrients, foods, or dietary patterns [1]. An emerging line of inquiry explores the role of food processing [1-5]. In recent decades, global

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food systems have undergone marked changes due to advances in food processing and technology that have resulted in greater availability, affordability, and marketing of highly processed foods [6-8]. Increasingly sophisticated processing methods have altered food structure, nutritional content, and taste [8-11]. Traditional diets that feature whole or minimally processed foods and emphasize home-cooking and food preparation are being replaced by diets comprised of industrially processed and prepared food products [3-5]. Almost all foods consumed in modern societies can be considered “processed foods,” but these processed foods vary greatly in the type and purpose of processing used in their production [2-5]. To study the effect of food processing on nutritional quality and health, a classification of foods that distinguishes between different levels of processing is needed [3-5]. The most widely used system for studying food processing, the NOVA classification scheme, has been recognized as a specific, coherent, and comprehensive framework for assessment of food processing levels [3, 5, 12].

The NOVA system classifies foods into 4 groups according to the nature, extent, and purpose of industrial food processing used in their production [2-4, 13, 14]. *Unprocessed/minimally processed foods* are defined as parts of plants or animals that have not been industrially processed or have been altered in ways that do not add any new substance (such as fats, sugar, or salt) but may involve removal of parts of the food [3-5]. Examples include fruits or vegetables, fresh or frozen meat, eggs, milk, and rice or other grains [4]. *Processed culinary ingredients* are substances extracted from unprocessed foods, such as oil and sugar, or obtained from nature, such as salt [2, 4, 5]. Culinary ingredients are typically not consumed alone but are used in combination with unprocessed and minimally processed foods in cooking to make dishes and meals [2, 4]. *Processed foods* are produced by adding salt, oil, sugar, or other culinary ingredients to minimally processed foods [4]. Processed foods remain recognizable as modified versions of unprocessed foods and include items such as canned fruits or vegetables, salted nuts, cured or smoked meats, and cheese [4]. At the highest end of the processing spectrum, *ultra-processed foods* are defined as multi-ingredient industrial formulations and include sugar sweetened beverages (SSBs), packaged breads, cookies, savory snacks, candy, ice cream, breakfast cereal, and pre-prepared frozen meals [4, 15].

Classification of foods and beverages by degree of food processing can potentially provide novel insight into dietary factors that contribute to obesity risk by identifying an entire class of foods with poor nutritional quality, rather than focusing on individual nutrients or specific food items [16-20]. Many scholars hypothesize that increased consumption of ultra-processed food is a major driver of the obesity epidemic [2, 7, 21-23]. However, very limited research has directly examined the relationship between ultra-processed food consumption and obesity or related chronic non-communicable disease. Several studies have examined evidence for specific types of ultra-processed foods, for example finding higher consumption of SSBs, fast food, potato chips, fried potatoes, or sweets is associated with higher risk of weight gain or obesity [24-27]. Evidence also supports an inverse association between consumption of specific unprocessed/minimally processed foods, such as whole grains, fruits, and vegetables, with weight gain [24, 28-30]. The relationship between the consumption of foods aggregated by degree of processing and obesity is a more recent topic of investigation with research only emerging in the past 5-10 years. A 2009 systematic review of epidemiological evidence of associations between diet and excess weight gain or obesity found no studies that examined food production, preservation, processing, or preparation [31].

The aim of this narrative review was to summarize and critique the evidence evaluating the association between ultra-processed food intake and obesity. Specifically, this paper reviews current ultra-processed food consumption levels in children and adults in various countries across the globe, evaluates current studies that assess the relationship between ultra-processed food intake and obesity or obesity-related cardiometabolic outcomes, discusses potential mechanisms that explain these hypothesized relationships, and identifies future research needs.

Ultra-processed food consumption levels

Ultra-processed food purchasing and consumption patterns have been described in several countries [4], with studies in Brazil [17, 32-35], Chile [16, 36], Colombia [37], Indonesia [38], Kenya [39], multiple European countries [9, 40], France [41], Norway [42, 43], Sweden [44], Australia [45, 46], New Zealand [47], USA [19, 20, 48, 49], Canada [18, 50, 51], and the UK [15, 40, 52].

The majority of energy intake among individuals in high-income countries comes from ultra-processed foods and beverages. Ultra-processed products contributed 61-62% of calories in packaged food and beverage purchases from retail food stores by households in the US between 2000 and 2012 [20], 55% of calories purchased in Canada in 2001 [50], 51% of calories purchased in the UK in 2008 [40], and 49% of sales expenditures at food retailers in Norway in 2013 [42]. In terms of dietary intake, ultra-processed products provided 58% of energy intake for children and adults in the US [19], 48% in Canada [51] and 36% in France [41]. Consumption of highly processed foods (defined as foods that have been industrially prepared and require no/minimal domestic preparation apart from heating and cooking) among middle-aged adults in 10 European countries ranged from 61% of energy intake in Spain to 78-79% in the Netherlands and Germany in 1995-2000 [9]. Processed/ultra-processed food accounted for 56% of home food expenditures among Australian households in 2010 [46] and 84% of packaged foods available in New Zealand supermarkets in 2013 [47].

Ultra-processed food purchases and consumption remain somewhat lower in middle-income countries. In Brazil in 2008-2009, ultra-processed products contributed 25% of calories purchased [32] and 21.5% of total energy intake for adolescents and adults [33]. Among school-aged children in Colombia, 34% of energy intake came from processed and ultra-processed foods in 2011 [37]. Ultra-processed foods provided 29% of total energy intake among Chileans in 2010 [36]. In Europe, the contribution of ultra-processed products to household food purchases ranged from 18% of calories purchased in Croatia (2004), 20% in Slovakia (2003), and 21% in Hungary (1991) to 26% in Lithuania (2004) and 33% in Latvia (2004) [40]. Data from lower middle-income and low-income countries is sparse; ultra-processed foods contributed 16% of energy intake in Indonesia in 2014 [38], and 10% in small towns in Kenya in 2012 [39].

Is Ultra-Processed Food Consumption Associated with Obesity and Related Cardiometabolic Outcomes?

Methods

To address this research question, we reviewed English-language studies examining the relationship of ultra-processed food intake with obesity or related cardiometabolic outcomes that were published in peer-reviewed journals through August 2017. For the reasons described above, we focused on articles about ultra-processed or highly processed foods, rather than the broader class of "processed foods." We conducted electronic searches of PubMed and Scopus databases, manually searched the reference lists of identified articles, and searched for publications citing the identified articles using Google Scholar. Because of the limited number of studies examining ultra-processed foods and health, we included studies on food consumption as well as food purchases, and no restrictions were imposed on the study population age or geographic location.

Of the 10 studies [52-61] examining the relationship between ultra-processed foods and obesity or related disease, 3 evaluated data for all age groups [53-55], 3 focused on pediatric populations [57-59], and 4 studied only adults [52, 56, 60, 61]. Evidence was available from several countries across the world, with most studies in Brazil [54, 55, 57-59], and additional evidence from 2 studies in Spain [56, 61], 1 in the UK [52], 1 in Canada [60], and 1 in Guatemala [53]. Two early studies evaluated food and beverage purchases [53, 54], while most evaluated self-reported dietary intake assessed by food frequency questionnaire (FFQ) [56, 57, 61], 24-hour dietary recalls [58-60], or food records [52, 55]. Almost all investigations defined ultra-processed foods using the NOVA classification system developed by Monteiro and colleagues [54-56, 58, 60, 61]. However, 2 studies used an original iteration of this classification that combined processed and ultra-processed foods into a single category [52, 57]. Two investigations defined highly processed foods using methods unique to the individual study [53, 59]. The majority of studies were cross-sectional [52-55, 57, 59, 60] while only 3 employed a more rigorous longitudinal design [56, 58, 61]; no randomized controlled trials were identified.

Ultra-processed food and obesity

Descriptions of the 5 studies that examined the association between ultra-processed food consumption and obesity are shown in Table 1. In the earliest study, Asfaw examined the association between household highly processed food purchases and individual-level BMI among 21,803 adults and children aged 10 years and older in Guatemala using data from the 2000 Living Standard Measurement Survey [53]. Highly processed foods were defined as food items that have undergone secondary processing into a readily edible form, such as pastries, cookies, crackers, ice cream, candy, processed meat, breakfast cereal, soft drinks, and prepared meals [53]. Highly processed food purchases were collected at the household level and could not be attributed to individual household members, while weight, height, and demographics were assessed at the individual level. Using instrumental variables techniques to control for endogeneity, Asfaw found that the share of household food expenditures on highly processed foods was significantly associated with higher BMI and increased likelihood of being obese [53].

The first investigation using the NOVA food processing classification examined the association between household purchases of ultra-processed foods and the prevalence of obesity in Brazil using data from the 2008-2009 Household Budget Survey [54]. In cross-sectional analyses, Canella et al. found that mean BMI z-score and the prevalence of obesity were significantly higher among children and adults living in household strata with the highest compared with the lowest ultra-processed food purchases [54]. Building upon these initial findings, a cross-sectional study by Louzada and colleagues used data from the 2008-2009 Brazilian Dietary Survey to examine the association between ultra-processed food consumption and obesity among 30,243 adolescents and adults [55]. Being in the highest compared to lowest quintile of ultra-processed food consumption was associated with significantly higher BMI and odds of being obese [55].

Adams and White examined the association between ultra-processed food intake and body weight among 2,174 adults using data from the 2008-2012 UK National Diet and Nutrition Survey [52]. In contrast to other studies, investigators used Monteiro's original 3-level processing classification, which groups processed food and ultra-processed food together into a single category [52]. Processed/ultra-processed food intake was not associated with BMI or with the likelihood of being overweight/obese or being obese [52]. One possible explanation for this lack of association is the aggregation of processed foods, including items like canned fruit or salted nuts, with ultra-processed foods. Notably, higher intake of less-processed foods (unprocessed/minimally processed and processed culinary ingredients, collectively) was associated with lower likelihood of being overweight/obese [52].

Only one study has used a prospective study design to examine the association between ultra-processed food intake and incident obesity. Mendonca and colleagues investigated this association in a prospective Spanish cohort, the Seguimiento Universidad de Navarra (SUN) study, including 8451 middle-aged university graduates [56]. Investigators examined the relationship between baseline ultra-processed food intake and risk of incident overweight/obesity during a median of 8.9 years of follow-up [56]. Adults in the highest quartile of ultra-processed food consumption had a significantly higher risk of developing overweight/obesity than those in the lowest quartile [56]. This study provides the strongest evidence to-date to support the hypothesis that ultra-processed food consumption is related to increased risk of weight gain and obesity. There is a critical need for further studies with similar designs to replicate and potentially confirm these findings in different populations, locations, and contexts and in population-based samples with greater generalizability.

Ultra-processed food and cardiometabolic outcomes

Five studies have investigated the relationship between ultra-processed food consumption and obesity-related cardiometabolic outcomes (Table 2), including metabolic syndrome [57, 59, 60], blood lipids [58], and hypertension [61]. Rinaldi and colleagues examined the association between processed food intake and components of the metabolic syndrome among 147 overweight or obese children aged 6-10 y in Brazil [59]. Processed foods were defined as “industrialized” foods [59]. In cross-sectional analyses, processed food consumption was associated with higher fasting glucose, but was not associated with metabolic syndrome or other metabolic syndrome components [59]. Tavares et al. examined the cross-sectional association between ultra-processed food intake and metabolic syndrome using data from 210 adolescents in metropolitan Brazil from the Cardiometabolic, Renal, and Familial (CAMELIA) study [57]. This study used Monteiro's original classification system, which groups processed foods and ultra-processed foods together into a single category [57]. In contrast to the findings of Rinaldi, processed/ultra-processed food intake was significantly associated with prevalence of metabolic syndrome [57]. In addition, in a cross-sectional study including 811 Eeyouch adults in Canada, Lavigne-Robichaud and colleagues found that higher ultra-processed food consumption was associated with increased likelihood of having metabolic syndrome, low HDL cholesterol, and elevated fasting plasma glucose; however, ultra-processed food intake was not associated with elevated triglycerides, waist circumference, or blood pressure [60].

Two longitudinal studies have examined the relationship of ultra-processed food intake and cardiometabolic risk. Rauber and colleagues investigated whether ultra-processed food consumption at age 3-4y was associated with changes in blood lipid concentrations from preschool- to school-age in a cohort of 345 preschoolers from low-income families in Brazil [58]. Ultra-processed food intake at preschool-age was associated with greater increases in total cholesterol and LDL cholesterol, but not with changes in triglycerides or HDL cholesterol [58]. Mendonca and colleagues examined the association between ultra-processed food consumption and incident hypertension among 14,790 Spanish university graduates participating in the SUN study [61]. This prospective study found that adults in the highest compared with lowest tertile of ultra-processed food consumption had higher risk of developing hypertension [61].

Processing or Nutrient Content?

Hypothesized mechanisms through nutrient content

Researchers propose several potential mechanisms that might explain the relationship between ultra-processed food consumption and risk of weight gain and obesity. Ultra-processed products tend to be energy-dense and high in saturated and trans fat, added sugar, and sodium [5]. Consumption of these products may promote excess energy intake because of their high energy density, as regulation of food intake controls volume consumed rather than calories consumed [62, 63]. Many ultra-processed foods are high in refined carbohydrates that can alter insulin response and promote shuttling excess nutrients away from oxidation towards storage in adipose tissue [53, 55, 64]. Some researchers suggest that the high refined carbohydrate or fat content of ultra-processed foods may produce changes in reward neurocircuitry, leading to addictive-like eating behaviors and overconsumption [5, 65, 66].

Across several countries, consistent evidence indicates that ultra-processed food and beverage products have less favorable nutrient content than minimally processed foods. In the US, for example, households' ultra-processed food purchases had significantly higher saturated fat, sugar, and sodium content compared with less-processed food purchases [20], and ultra-processed foods consumed by Americans had significantly higher added sugar content than less-processed foods [19]. Ultra-processed foods consumed by children and adults in Brazil and in Canada were significantly higher in free sugar content [33, 51], saturated and trans fat content [33], sodium density [51] and energy density [33, 51] and lower in fiber [33, 51], vitamin D, potassium, and magnesium densities [33, 34, 51] compared to less-processed foods.

Very limited research has directly compared whether processing or nutrient content is more strongly related to increased risk of obesity. Such research is needed to determine whether a focus on processing is more advantageous than other food classifications or measures, such as dietary quality indexes or nutrient profiling scores, for uncovering relationships between diet and health. To the best of our knowledge, only one study has made such comparisons; in the study among Eeyouch adults in Canada, ultra-processed food consumption was more strongly related to metabolic syndrome than either the Alternate Healthy Eating Index (aHEI-2010) or the Food Quality Score [60]. Studies are also needed to directly compare whether consumption of ultra-processed food is more strongly associated with obesity than consumption of products with poor nutrient profiling scores from front-of-pack labeling systems, such as the UK traffic light label or Australian Health Star Rating. Future research should explore whether these typologies could be combined, for example to identify foods that are both ultra-processed and receive a low nutrient profiling score, to best identify foods related to increased obesity risk.

Other potential mechanistic links to obesity

Several unique non-nutritional features of ultra-processed foods have been proposed as potential mechanistic links through which these products may promote obesity independent from their nutrient content [5]. These foods are typically rated as highly palatable, packaged with large portion sizes, and persuasively marketed, which may promote overconsumption [54, 55, 67-71]. Physical and structural characteristics of ultra-processed foods may result in lower satiety potential and higher glycemic response [72]. Ultra-processed products, which tend to be convenient and ready-to-consume with minimal preparation, may alter eating patterns, promoting shifts toward snacking and eating while engaged in other activities (e.g., eating while watching television) [5, 54, 55]. These eating behaviors promote rapid eating rate and inattentive eating that can interrupt digestive and neural mechanisms that signal satiation and satiety, possibly leading to overconsumption [58, 73-75].

Little research has examined whether ultra-processed foods have effects on health independent of their nutrient content. Louzada and colleagues found that associations between ultra-processed food intake and obesity remained significant even after adjustment for saturated fat, trans fat, added sugar, and fiber intake [55]. Authors suggest that nutrient composition is not able to explain the influence of ultra-processed foods on obesity risk [55]. Likewise, Mendonca and colleagues found that the association between ultra-processed food consumption and hypertension persisted even after adjustment for sodium intake, fruit and vegetable intakes, or Mediterranean dietary pattern score [61]. Tavares et al found that, whereas processed/ultra-processed food intake was associated with prevalence of metabolic syndrome, no associations were found for carbohydrate, fat, protein, and fiber intakes [57]. Moreover, associations with obesity and related health outcomes have not been observed for processed foods, which typically do not exhibit the same characteristics of convenience and palatability as ultra-processed foods. Household purchases of processed foods were not associated with BMI or obesity among Brazilians [54]. Processed food intake by preschoolers was not associated with 4-year changes in lipid profiles [58]. These findings suggest that ultra-processed foods may promote adverse health outcomes, independent of nutrient content. However, further studies are needed to evaluate the hypotheses relating to palatability, satiating potential, and convenience in order to determine whether ultra-processed foods have unique characteristics beyond poor nutrient content that affect health.

Future Research Needs

Universal definition of ultra-processed food

The lack of a universally accepted definition of ultra-processed foods and classification scheme for food processing has limited the amount of prospective epidemiologic evidence examining the role of food processing in the development of obesity [54]. The NOVA classification system based on the degree and purpose of processing was formally outlined and described less than 10 years ago by Monteiro and colleagues [2]. Further, that classification has undergone revision and refinement over time, notably a shift from 3 to 4 levels of processing; the split of the original Group 3 (referred to as “ultra-processed”) into Groups 3 and 4 (“processed foods” and “ultra-processed foods”) can potentially lead to misinterpretation of research utilizing this classification [3, 4, 76].

Refined dietary assessment methods

Another key reason for the limited research examining the relation between ultra-processed food and health is the lack of instruments specifically designed to assess food processing [9, 18]. Researchers underscore the shortcomings of traditional dietary assessment methods for measuring consumption of highly processed foods [9]. Most FFQs and 24-hour dietary recalls are not designed to collect sufficient details that allow distinction of foods based on processing and rarely address food processing in data collection [18].

Further, many existing studies acknowledged the use of a dietary assessment methods not designed for assessment of food processing as an important study limitation [18, 33, 36, 49, 55, 56, 61, 77]. The lack of specificity of FFQ food item questions may lead to misclassification of ultra-processed foods that could potentially attenuate or bias associations between these foods and health outcomes [78]. This limitation extends to household expenditure surveys, which distinguish relatively few items [50]. Several studies using 24-hour dietary recalls also acknowledge that only limited information indicative of food processing is collected and collected inconsistently for different food items [36, 49]. Misclassification is particularly likely for foods such as pizza, mixed dishes, cookies, or other baked goods, which could be either culinary preparations or ultra-processed pre-prepared products [33]. Overall, the lack of food purchase and dietary assessment methods specifically designed to collect information about food processing level is a major barrier to further understanding of the relationship between ultra-processed food consumption and obesity.

Stronger study designs

While studies consistently indicate a relationship between ultra-processed food consumption and obesity, the majority of studies are cross-sectional, which are limited by the potential for reverse causality. Further, all studies are observational, and because obesity is a multifactorial disease with many related lifestyle contributors, residual confounding is likely. In particular, several studies were unable to adjust for physical activity [52, 54, 57-60], smoking [52-54], or alcohol intake [53-56]. The study by Asfaw was the only research to-date to control for potential endogeneity of highly processed food consumption, whereby individuals who consume high levels of these foods may differ systematically from individuals with lower consumption in unmeasured or unobservable ways that are also related with obesity [53]. In particular, individuals who frequently consume ultra-processed foods may have different taste preferences, less nutrition knowledge, may be less health conscious, or may have more financial and time constraints than individuals who consume ultra-processed food less frequently [53]. Supporting this hypothesized endogeneity, Mendonca and colleagues found that adults with the highest consumption of ultra-processed foods tended to have less healthy lifestyles – lower physical activity, more tv time, and low adherence to the Mediterranean dietary pattern [61].

Further, there is wide variability in the nutrient content of ultra-processed products [20]. The types of foods that are ultra-processed (e.g., baked goods, savory snacks) tend to have poor nutritional profiles; however, ultra-processed foods with more favorable nutrient content (e.g., whole-grain packaged bread, unsweetened breakfast cereals) are available, suggesting that processing itself may not be a causal determinant of the nutritional quality of foods [79-81]. Individuals with higher consumption of ultra-processed food may be more likely to select products with less healthful nutritional profiles, potentially contributing to the relationship with obesity.There is also wide variability in the nutrient content of foods prepared at home from minimally processed foods and processed culinary ingredients, due to variation in the types of foods that are home-cooked and the methods used to prepare them [82, 83]. Many foods (including bread, grain-based desserts such as cookies, or mixed dishes such as lasagna or soup), can be purchased as ultra-processed products or prepared at home from less-processed ingredients. For any given food item, it remains unknown whether the ultra-processed version necessarily has lower nutritional quality than its home-cooked counterpart. Although limited, evidence suggests that home-cooked foods and home recipes are not consistently higher in nutritional quality, and may even be worse, than ultra-processed alternatives [83-87]. Some researchers propose that the type of food and its ingredients might be more important determinants of nutritional quality than whether the food is industrially-prepared or home-prepared [79, 83-85]. There is a need for experimental research as well as randomized controlled trials to examine the causal effect of consuming ultra-processed foods on weight gain independent from differences in nutrient content or the types of foods consumed.

Conclusion

Overall, evidence suggests that consumption of ultra-processed foods may be associated with increased risk of obesity as well as metabolic syndrome prevalence, increases in total and LDL cholesterol, and risk of hypertension. However, the limited number of prospective studies and the limited number of studies investigating each outcome preclude any strong conclusions about the impact of ultra-processed food consumption on obesity and related cardiometabolic outcomes. There is a clear need for further studies, particularly those using longitudinal designs and with sufficient control for confounding by lifestyle factors, to examine the association between ultra-processed food consumption and obesity. If confirmed using stronger study designs and in diverse populations and settings, these associations between ultra-processed food consumption and adverse health outcomes can provide critical insight into the etiology of obesity and can help inform development of targeted public health programs and policies to control and treat obesity among children and adults worldwide.

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• Of importance

•• Of outstanding importance

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Abbreviations

BMI	body mass index
FFQ	food frequency questionnaire
HDL	high-density lipoprotein
LDL	low-density lipoprotein
SSB	sugar-sweetened beverage

Table 1

Studies examining the relationship between ultra-processed food purchases or intake and obesity

Authors, Journal, Date	Study population	Study Design	Dietary assessment	Exposure	Outcome	Adjustment variables	Results[a]		
							BMI	OW/OB	OB
Asfaw Health Econ 2011 [53]	Guatemala: nationally representative sample of individuals ≥10 y (n=21,803)	Cross-sectional	Household food/beverage expenditures (% expenditures): 2-week record	Highly processed: items that have undergone secondary processing into a readily edible form	BMI; overweight/obesity, obesity (self-report[b])	Partially processed food (% expenditures), age, sex, education, household expenditure, occupation, time spent in high physical activity, urban/rural, region, food prices, food away-from-home expenditure	+	+	+
Canella et al. PloS One 2014 [54]	Brazil: nationally representative sample of households (n=550 strata with 55,970 households)	Cross-sectional (study unit: geographic strata of households)	Household food/beverage purchases (kcal/d per capita): 7-d records	Ultra-processed: NOVA definition	BMI or BMI-for-age z-score; overweight/obesity, obesity (measured)	Stratum-level processed food purchases (kcal), culinary ingredient purchases (kcal), % children, % elderly, % female, income, region, urban/rural, food away-from-home expenditure	+	+	+
Louzada et al. Prev Med 2015 [55]	Brazil: nationally representative sample of individuals ≥10 y (n=30,243)	Cross-sectional	Food/beverage consumption (% kcal): 2 24-hr food records	Ultra-processed: NOVA definition	BMI; overweight/obesity, obesity (measured)	Age, sex, race, education, income, interaction of sex and income, smoking status, physical activity, urban status, region; intake of fruit, vegetables, or beans (% kcal)	+	+	+
Adams & White Int J Behav Nutr Phys Act 2015 [52]	UK: national sample of adults ≥18 y (n=2,174)	Cross-sectional	Food/beverage consumption (% kcal): 3-4 d diet record	Processed + ultra-processed: original NOVA definitions[c]	BMI; overweight/obesity, obesity (measured)	Age, sex, occupational social class, alcohol intake (% kcal)	NS	NS	NS
Mendonca et al. Am J Clin Nutr 2017 [56]	Spain: sample of middle-aged university graduates (n=8,451)	Prospective cohort (median 9y follow-up)	Food/beverage consumption (servings/d): FFQ	Ultra-processed: NOVA definition	Overweight/obesity (self-report)	Age, sex, education, smoking, physical activity, siesta sleep, tv time, marital status, snacking, fruit/vegetable intake, following special diet, baseline BMI		+	

[a]Blank cell in Results column indicates outcome was not assessed in given study.

[b]Overweight and/or obesity categorized using BMI calculated from self-reported weight and height.

[c]Study used the original version of the NOVA classification published by Monteiro and colleagues, which categorized degree of processing into 3 groups: Group 1 (unprocessed/minimally processed), Group 2 (processed culinary ingredients), and Group 3 (“ultra-processed” foods). The current, more refined version of the NOVA classification split Group 3 into Group 3 (processed foods) and Group 4 (ultra-processed foods). Thus, “ultra-processed” foods in this study included processed foods and ultra-processed foods as defined in the current version of NOVA.

BMI, body mass index; FFQ, food frequency questionnaire; NS, not significant; OW/OB, overweight or obesity; OB, obesity

Table 2

Studies examining the relationship between ultra-processed food intake and obesity-related cardiometabolic outcomes

Authors, Journal, Date	Study population	Study Design	Dietary assessment	Exposure	Adjustment variables	Results[a]								
						WC	BP	Htn	Glc	Chol	HDL	LDL	TG	MetS
Tavares et al. Public Health Nutr 2012 [57]	Brazil: adolescents 12-19 y (n=210)	Cross-sectional	Food/beverage consumption (g/d): FFQ	Processed + ultra-processed: original NOVA definitions	Smoking, family history of hypertriglyceridemia, and total energy									+
Rauber et al. Nutr Metab Cardiovasc Dis 2015 [58]	Brazil: 3-4 y old children from low-income families (n=345)	Prospective cohort (4y follow-up)	Food/beverage consumption (% kcal): 2 24-hr recalls	Ultra-processed: NOVA definition	Sex, group status in RCT, birth weight, family income, maternal schooling, BMI z-score and total energy intake at age 7-8y					+ [b]	NS	+	NS	
Rinaldi et al. Diabetol Metab Syndr 2016 [59]	Brazil: 6-10y children with overweight/ obesity (n=147)	Cross-sectional	Food/beverage consumption (% kcal): 3 24-hr recalls	Processed: “industrialized foods”[c]	Age, sex, school	NS	NS		+		NS		NS	NS
Lavigne-Robichaud et al. Public Health Nutr 2017 [60]	Canada: Eeyouch adults aged ≥18y (n=811)	Cross-sectional	Food/beverage consumption (% kcal): 1 24-hr recall	Ultra-processed: NOVA definition	Age, sex, smoking, area of residence (coastal/inland), total energy intake, alcohol intake	NS		NS	+		+ [d]		NS	+
Mendonca et al. Am J Hypertens 2017 [61]	Spain: middle-aged university graduates (n=14,790)	Prospective cohort (mean 9y follow-up)	Food/beverage consumption (servings/d): FFQ	Ultra-processed: NOVA definition	Age, sex, smoking, physical activity, tv time, following special diet, baseline BMI, alcohol, use of analgesics, family history of htn., high chol.; total energy, olive oil, fruit/vegetable intakes			+						

[a] Blank cell in Results column indicates outcome was not assessed in given study.

[b] Outcomes were change in lipid concentrations between ages 3-4 and 7-8 y.

[c] Processed foods were defined only as “industrialized” food. Examples provided were chips, microwave popcorn, cookies, sugar-based breakfast cereal, nuggets, noodles, frozen food, cake mix, pudding mix, chocolate drinks.

[d] Associated with higher likelihood of low HDL cholesterol.

BMI, body mass index; BP, blood pressure; Chol, total cholesterol; FFQ, food frequency questionnaire; Glc, fasting glucose; HDL, high-density lipoprotein cholesterol; Htn, hypertension; LDL, low-density lipoprotein cholesterol; MetS, metabolic syndrome; NS, not significant; RCT, randomized controlled trial; TG, triglycerides; WC, waist circumference