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Review

Ultra-Processed Food Consumption and Obesity: A Narrative Review of Their Association and Potential Mechanisms

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Obesity is a major global health concern, with diet playing a crucial role in its development and treatment. Ultra-processed foods (UPFs) have become prevalent in diets due to changes in the food environment. These foods are energy-dense; high in fat, sugars, or salt; and low in fiber, protein, vitamins, and minerals, raising concerns about their effects on health. In addition to traditional research focused on nutrients, food, and dietary quality, growing evidence has linked UPF consumption to obesity. Therefore, this study provides a comprehensive review of the levels and trends of UPF consumption, current epidemiological evidence on the association between UPF consumption and obesity, and UPFs' potential role in the etiology of obesity and weight gain. Additionally, this study reviews strategies for reducing UPF consumption and outlines future studies of the link between UPF consumption and obesity.

Key words: Diet, Food, Processed, Food handling, Humans, Obesity, Overweight

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INTRODUCTION

Obesity is a major global health concern. Numerous studies have indicated that obesity leads to a wide range of chronic diseases, including diabetes mellitus, cardiovascular diseases, cancers, and musculoskeletal disorders.[1,2] In addition to this disease burden, the socioeconomic impact of obesity are also significant, with direct costs reflecting the treatment of obesity-related diseases and indirect costs reflecting productivity losses from premature death and inpatient care.[3,4] Despite ongoing efforts to prevent and manage obesity and weight gain, the global prevalence of overweight and obesity continues to rise.[5-7] By 2030, it is projected that more than half of the world's adult population (approximately 3.3 billion people) will be overweight or obese.[6]

Diet plays a key role in obesity development and treatment. The protective or harmful effects of various dietary factors have been studied, including nutrient and food intake and dietary patterns.[8-10] Based on current evidence, health professionals recommend a nutritionally balanced diet that includes reduced energy intake, high consumption of fruits and vegetables, and low intake of fat, sugar, and sodium to promote healthy weight management.[11]

During the past three or four decades, global diets have shifted dramatically. Traditional diets based on various unprocessed and minimally processed foods have been largely replaced by highly processed foods, with ultra-processed foods (UPFs) now dominating modern food systems.[12,13] UPFs are typically energy-dense; high in fat, sugars, or salt; and low in fiber, protein, vitamins, and minerals. These obesogenic characteristics have led to increased interest in the association between UPF consumption and obesity and other health outcomes.[14-18]

This study provides a comprehensive review of the status and trends of UPF consumption, current epidemiologic evidence on the association between UPF consumption and obesity, and the potential mechanisms by which UPFs might influence weight gain and obesity. Additionally, the study outlines strategies for reducing UPF consumption and promoting healthier choices and identifies future research needs in this area.

WHAT ARE UPFs?

UPFs are industrially formulated food products prepared mostly or entirely with industrial ingredients, such as substances derived from natural foods and additives, with few or no whole foods.[19] These foods include sugary drinks, sweets, chocolates, snacks, candies, breakfast cereals, breads, cakes, ice cream, pre-prepared pizza, ramen, and other ready-to-eat foods.

Brazilian researchers first introduced the concept of ultra-processing; in 2009, Monteiro et al.[20] drew attention to the issue of food processing, which had received relatively little attention in the field of nutrition and health. Food processing involves any intentional alteration to food from the time of origin to the time of consumption.[19,21] Almost all foods are processed before being consumed; the difference is just the extent. Thus, Monteiro et al.[19,22] proposed a novel food classification system called NOVA (not an acronym) according to the nature, extent, and purpose of food processing. NOVA is the most widely accepted food classification system worldwide for assessing UPF consumption among populations and investigating the association between UPF consumption and health outcomes.[19,22,23]

Within NOVA, foods are classified into four categories: (1) unprocessed or minimally processed foods, (2) processed culinary ingredients, (3) processed foods, and (4) UPFs. ‘Unprocessed or minimally processed foods’ retain their natural state or have undergone minimal changes, such as the removal of inedible parts, drying, grinding, or freezing, primarily for storage or cooking convenience. ‘Processed culinary ingredients,’ such as oils, fats, sugar, and salt, are extracted from original foods or nature through processes such as pressing, centrifuging, refining, extracting, or mining. ‘Processed

Table 1. The NOVA food classification system and its four food groups

NOVA groups	Definition	Examples
Group 1. Unprocessed or minimally processed foods	‘Unprocessed foods’ are edible parts of plants (seeds and fruits) or animals (muscle, eggs, and milk), after separation from nature. ‘Minimally processed foods’ are natural foods altered by processes that include removal of inedible or unwanted parts and drying, crushing, grinding, fractioning, filtering, roasting, boiling, non-alcoholic fermentation, pasteurization, refrigeration, chilling, freezing, placing in containers, and vacuum-packaging.	Fresh, squeezed, chilled, frozen or dried fruits and vegetables; grains, corn; legumes; starchy roots and tubers; fungi; meat, poultry, fish and seafood, whole or in the form of steaks, fillets and other cuts, or chilled or frozen; eggs; milk, pasteurized or powdered; fresh fruit or vegetable juices; pasta made with flours, nuts, and other oilseeds; fresh or dried spices; plain yoghurt; tea and coffee; and drinking water
Group 2. Processed culinary ingredients	‘Processed culinary ingredients’ are substances derived from group 1 foods or from nature by processes that include pressing, refining, grinding, milling, and drying.	Oils; butter; lard; sugar; molasses; honey; starch; and salt
Group 3. Processed foods	‘Processed foods’ are made by adding salt, oil, sugar, or other substances from group 2 to group 1 foods.	Bottled vegetables; canned fish; fruits in syrup; cheeses; salted or sugared nuts and seeds; salted or pickled meat and vegetables; and freshly made breads
Group 4. Ultra-processed foods	‘Ultra-processed foods’ are not modified foods but formulations made mostly or entirely from substances derived from foods and additives, with few if any intact group 1 ingredients.	Ready-to-eat products such as soft drinks; sweet or savory packaged snacks; candies; ice cream; breakfast cereals; energy bars; energy drinks; sugary milk drinks; sugary yoghurt; sugary fruit juice; and instant sauce Pre-prepared products needing little or no cooking, such as instant soups, noodles, and desserts; prepared pizza and pasta; and fish and chicken nuggets

The NOVA food classification system and its four groups, as described above, are a summary of previous research.[19,22,23] foods' are industrial products mainly prepared by adding processed culinary ingredients to unprocessed or minimally processed foods. The goal in the production of these foods is to preserve the food for a longer period and make it more palatable. Canned fish, fruits in syrup, and bottled pickles are included in this food category. The final category, UPFs, contains products prepared via advanced industrial processes such as fractioning whole foods into substances, and chemical modifications such as hydrogenation, extrusion, mould, use of food additives, and packaging with synthetic materials. This is why these foods are called UPF. The processes used in UPF production are intended to make them highly profitable, hyper-palatable, and easily consumed anywhere, anytime. Table 1 provides more details about the four NOVA food classification groups.

WHAT QUANTITY OF UPFs IS CONSUMED?

UPF consumption is generally presented as the contribution (%) of energy from UPFs to the total energy obtained from all types of foods or as the proportion (%) of UPFs eaten to the total quantity of food consumed. Its contribution to total energy intake has been widely used in epidemiological studies. UPF consumption levels and trends have been mainly analyzed using survey data, including individual dietary surveys and household food purchase surveys. They have also been inferred from food supply and sales information.

UPF consumption varies across countries due to differences in conditions that can affect food consumption, such as food systems, food supplies, consumer purchasing power, and socioeconomic status. Generally, high-income countries, particularly in Europe, North America, and Australasia, report high UPF consumption. Based on national dietary survey data, UPF contribution to total energy intake was 57.5% in the United States (US),[24] 56.8% in the United Kingdom (UK),[25] 46.8% in Canada,[26] and 42.0% in Australia.[27] A study of national household budget surveys (not dietary surveys) from 19 European countries reported similar findings, showing that the average household availability of UPFs exceeded two-fifths of the total purchased dietary energy in many European countries, including Belgium, Germany, Finland, Ireland, and the UK.[28] Supermarket sales data also reflect this trend; a Norwegian study found that UPFs accounted for 58.8% of foods purchased from food retailers.[29] In contrast, middle- and low-income countries, specifically Brazil, Mexico, and Columbia, and countries in other regions, specifically South Korea, report low UPF consumption, accounting for 29.6%,[30] 30.0%,[31] 15.9%,[32] and 26.1% of total energy intake,[33] respectively.

Within countries, UPF consumption also varies by sociodemographic characteristics. By age, younger individuals, particularly adolescents, consume more UPFs than older adults.[24,25,32-38] Socioeconomic status, represented by variables such as income, education, and residence, strongly influence UPF consumption; however, the patterns vary by national economic status. In high-income countries such as the US, UK, and France, low-income and less-educated individuals tend to consume more UPFs than those with higher socioeconomic status.[34,35,38] In contrast, in middle- and low-income countries, those with higher education and income and those living in urban areas consume more UPFs than their lower-income and rural counterparts.[32,36,37,39,40]

WHAT ARE THE TRENDS IN UPF CONSUMPTION?

During the past several decades, the UPF market has expanded considerably, and UPF purchases and consumption have increased dramatically worldwide,[33,41-44] accompanying economic improvement, industrialization of food systems, advances in food processing technology, globalization, and changes in distribution.[12-14]

In Canadian Household Food Budget Surveys, the dietary energy availability of ready-to-consume ultra-processed products increased from 28.7% to 61.7% between 1938 and 2011.[41] Mexican household surveys show that the daily energy contribution of purchased UPFs doubled from 10.5% in 1984 to 23.1% in 2016.[43] In a study that analyzed dietary data from the Korean National Health and Nutrition Examination Surveys, the share of UPFs in Korean daily energy intake increased notably from 23.1% in 2010–2012 to 26.1% in 2016–2018, and that increasing trend was consistently observed in all subgroups characterized by sex, age, education, income, and residence.[33]

This global shift toward greater UPF consumption is expected to continue, though the rate of expansion varies across countries and regions.[12-14,45] In high-income countries and regions of Europe, North

America, and Australasia, a wide range of UPFs is still sold, but total sales growth is projected to slow due to increasing consumer awareness of UPF health effects and policies promoting healthier choices.[13,14] Conversely, in countries with historically lower UPF sales, including middle- and low-income countries and Asian and African countries, sales are projected to increase rapidly.[13,45] The burden of UPF consumption is expected to become an even more pressing public health issue.

IS UPF CONSUMPTION LINKED TO OBESITY?

With UPF classification available since the development of the NOVA system, evidence from various study designs, such as population- or individual-level observation studies and intervention studies, has been reported during the past decade and revealed an association between UPF and obesity/weight gain.

Evidence from observational studies

Ecological studies

Numerous studies of national-level aggregated statistics, such as food availability, food sales, and obesity prevalence, have inferred that UPF consumption has potential effects on obesity (Table 2). A study of 19 European countries indicated that countries with greater national household availability of UPFs had higher obesity prevalence than those with lower availability.[28] Another study of 14 countries (12 Latin American countries, Canada, and the US), showed a strong, positive association between UPF sales *per capita* and obesity prevalence.[46] In that study, a time-series analysis showed that annual changes in UPF sales were significantly associated with annual changes in body mass index (BMI) between 2000 and 2013. Similar findings were observed in Sweden, where a study comparing trends in UPF availability and national obesity prevalence from 1960 to 2010 revealed a sharp increase in *per capita* UPF availability and a doubling of obesity prevalence during the same period.[42] However, caution is needed when interpreting those studies due to limitations of the ecological data analyzed (i.e., food sales and availability do not equal actual consumption) and the study designs, such as ecological fallacies.[28,42,46]

Cross-sectional studies

More robust evidence has emerged from individual-level studies linking UPF intake to obesity (Table 3).[26,30,47-51] In the US, National Health and Nutrition Examination Surveys showed that adults consumed an average of 56% of their energy from UPFs, ranging from ≤36.5% (the lowest quintile) to ≥74.2% (the highest quintile).[47] Those in the highest quintile of UPF consumption had 53% and 62% higher odds of obesity and abdominal obesity, respectively, than those in the lowest quintile, with a significant linear trend in obesity measures across UPF consumption quintiles. Similar findings were reported in Canadian and Australian adults, whose diets were dominated by UPFs.[26,48] Such associations were also observed in populations with relatively low UPF consumption. For example, a Brazilian dietary survey showed that Brazilian adolescents and adults consumed approximately one-third of their total energy from UPFs, ranging from ≤6.0% (lowest quintile) to ≥56.0% (highest quintile). Even in that population, those in the highest quintile had significantly higher odds of obesity and higher BMI than those in the lowest quintile, even after adjusting for sex, age, socio-demographic characteristics, and health-related behaviors.[30] These cross-sec-

Table 2. Summary of ecological studies investigating the association between ultra-processed foods and obesity

Author (year)	Country	Subjects	Dietary assessment	Exposure	Outcome	Results
Juul et al. (2015)[42]	Sweden	≥18 yr	Household budget surveys	*Per capita* consumption	Obesity prevalence	UPF consumption increased by 142% between 1960 and 2010. During the same period, adult obesity increased from 5% to 11%.
Pan American Health Organization (2015)[46]	14 countries in the Americas	≥18 yr	UPF sales data	Sales *per capita*	Obesity prevalence	Countries in which sales of UPFs are higher had higher prevalence of obesity and mean body mass.
Monteiro et al. (2018)[28]	19 European countries	-	Household budget surveys	Household availability	Obesity prevalence	Each percentage increase in household UPF availability led to a 0.25% rise in obesity prevalence.

UPF, ultra-processed food.

Table 3. Summary of cross-sectional studies investigating the association between ultra-processed foods and obesity

Author (year)	Country	Subjects	Dietary assessment	UPF consumption	Outcome	Results
Louzada et al. (2015)[30]	Brazil	30,243 (≥ 10 yr)	Food records	% energy (Q1 ≤ 13.0, Q5 ≥ 44.0)	Excess weight* Obesity	OR $_{Q5\ vs.\ Q1}$: 1.26 (0.95–1.69) OR $_{Q5\ vs.\ Q1}$: 1.98 (1.26–3.12)
Juul et al. (2018)[47]	USA	15,997 (20–64 yr)	24-hr recall	% energy (Q1 ≤ 36.5, Q5 ≥ 74.2)	BMI ≥ 25.0 kg/m² Obesity Abdominal obesity	OR $_{Q5\ vs.\ Q1}$: 1.48 (1.25–1.76) OR $_{Q5\ vs.\ Q1}$: 1.53 (1.29–1.81) OR $_{Q5\ vs.\ Q1}$: 1.62 (1.39–1.89)
Silva et al. (2018)[49]	Brazil	8,977 (35–64 yr)	FFQ	% energy (Q1 < 16.0, Q5 > 29.0)	Overweight Obesity Abdominal obesity	OR $_{Q4\ vs.\ Q1}$: 1.31 (1.13–1.51) OR $_{Q4\ vs.\ Q1}$: 1.41 (1.18–1.69) OR $_{Q4\ vs.\ Q1}$: 1.41 (1.20–1.66)
Machado et al. (2020)[48]	Australia	7,411 (≥ 20 yr)	24-hr recall	% energy (Q1 ≤ 21.7, Q5 ≥ 62.1)	Obesity Abdominal obesity	OR $_{Q5\ vs.\ Q1}$: 1.61 (1.27–2.04) OR $_{Q5\ vs.\ Q1}$: 1.38 (1.10–1.72)
Nardocci et al. (2021)[26]	Canada	13,608 (≥ 19 yr)	24-hr recall	% energy (T1 ≤ 38.5, T3 ≥ 58.7)	Obesity	OR $_{T3\ vs.\ T1}$: 1.31 (1.06–1.60)
Sung et al. (2021)[50]	South Korea	7,364 (19–64 yr)	24-hr recall	% energy (Q1 ≤ 12.5, Q4 ≥ 39.1 in M) (Q1 ≤ 9.6, T3 ≥ 33.5 in F)	Obesity Abdominal obesity	OR $_{Q4\ vs.\ Q1}$: 1.51 (1.14–1.99) in F OR $_{Q4\ vs.\ Q1}$: 1.64 (1.24–2.16) in F
Shim et al. (2023)[51]	South Korea	6,894 (30–64 yr)	FFQ	% energy (T1 ≤ 13.9, T3 ≥ 28.4 in M) (T1 ≤ 9.0, T3 ≥ 21.2 in F)	Obesity Abdominal obesity	OR $_{T3\ vs.\ T1}$: 1.24 (1.07–1.45) OR $_{T3\ vs.\ T1}$: 1.34 (1.14–1.57)

*BMI ≥ 25.0 kg/m² for adults and BMI-for-age z-scores from the World Health Organization references ≥ +1 and +2 for adolescents.
UPF, ultra-processed food; OR, odds ratio; BMI, body mass index; FFQ, food frequency questionnaire; M, male; F, female.

tional studies suggest that UPF consumption contributes to obesity regardless of consumption levels. However, those studies measured UPF consumption on a specific day using a single-day 24-hour recall, and the measured UPF consumption might not be representative of the participants' usual long-term diets. Positive associations have been consistently found between UPF consumption and various obesity measures, such as obesity, abdominal obesity, BMI, waist circumference, and percentage body fat, in studies that have assessed usual UPF consumption through food frequency questionnaires;[49,51,52] however, those results were based on cross-sectional analyses. Thus, those findings cannot infer causality, and reverse causality cannot be excluded.

Prospective cohort studies

Since the late 2010s, cohort studies have assessed the effects of UPF consumption on obesity risk (Table 4).[53-58] A cohort study of Spanish adults with a mean age of 38 years found that, after nearly 9 years of follow-up, those in the highest quartile of UPF consumption had a 26% higher risk of developing overweight or obesity than those in the lowest quartile.[53] In a 6-year study of Spanish adults aged ≥ 60 years, higher UPF consumption was associated with incident abdominal obesity.[54] Similar effects of UPF consumption on obesity measures have been reported in studies of the UK Biobank and the French NutriNet-Santé cohort.[56,57] A prospective analysis of British adults aged 40–69 years found that individuals in the highest quartile of UPF consumption had a 79% and 30% higher risk of developing obesity and abdominal obesity, respectively, and a higher risk of a 5% or more increase in BMI, waist circumference, and body fat percentage than those in the lowest quartile during a 5-year follow-up period.[56] The French NutriNet-Santé cohort study assessed French adults aged ≥ 18 years without obesity at baseline between 2009 and 2019.[57] In that cohort, BMI increased in all UPF consumption quartiles over time, and those with higher UPF consumption experienced greater BMI gains and higher risks of overweight and obesity during follow-up than those with lower UPF consumption. These associations were independent of baseline BMI and remained significant after adjusting for potential confounders such as socioeconomic characteristics and health behaviors, including physical activity, smoking, alcohol use, and other dietary factors. Moreover, UPF consumption was associated with visceral fat deposition and other adiposity markers among older adults with cardiometabolic risk. In the PREvención con DIeta MEDiterránea Plus (PREDIMED-Plus) trial, a prospective study of Spanish adults aged 55–75 years with overweight/obesity and metabolic syndrome,

Table 4. Summary of prospective cohort studies investigating the association between ultra-processed foods and obesity

Author (year)	Country/cohort name	Subjects	F/U duration	Dietary assessment	UPF consumption	Outcome	Results
Mendonça et al. (2016)[53]	Spain/SUN study	8,461 (37.6 yr)*	8.9 yr	FFQ	Servings/day (Q1: 1.5, Q4: 6.1)†	BMI ≥ 25.0 kg/m^2	HR $_{Q4\ vs.\ Q1}$: 1.26 (1.10–1.45)
Sandoval-Insausti et al. (2020)[54]	Spain/Seniors-ENRICA-1 study	652 (≥ 60 yr)	6 yr	Dietary history	% energy (T1 ≤ 12.4, T3 ≥ 22.5 in M) (T1 ≤ 10.5, T3 ≥ 19.3 in F)	Abdominal obesity	OR $_{T3\ vs.\ T1}$: 1.62 (1.04–2.54)
Beslay et al. (2020)[57]	France/NutriNet-Santé cohort	110,260 (≥ 18 yr)	4.1 yr	Dietary records	% g	BMI ≥ 25.0 kg/m^2 Obesity	Per 10% increase in UPF consumption HR: 1.11 (1.08–1.14) HR: 1.09 (1.05–1.13)
Rauber et al. (2021)[56]	UK/UK Biobank	22,659 (40–69 yr)	5 yr	24-hr recall	% energy (Q1 ≤ 26.3, Q4 ≥ 72.2 in M) (Q1 ≤ 24.7, Q4 ≥ 71.1 in F)	Obesity Abdominal obesity Increase in BMI‡ Increase in WC‡ Increase in body fat‡	HR $_{Q4\ vs.\ Q1}$: 1.79 (1.06–3.03) HR $_{Q4\ vs.\ Q1}$: 1.30 (1.14–1.48) HR $_{Q4\ vs.\ Q1}$: 1.31 (1.20–1.43) HR $_{Q4\ vs.\ Q1}$: 1.35 (1.25–1.45) HR $_{Q4\ vs.\ Q1}$: 1.14 (1.03–1.25)
Konieczna et al. (2021)[58]	Spain/ PREDIMED-Plus trial	1,485 (55–75 yr)	-	FFQ	% g	Visceral fat Android-to-gynoid fat ratio Total fat mass	Per 10% increase in UPF consumption β: 0.09 (0.05–0.13) β: 0.05 (0.00–0.09) β: 0.09 (0.06–0.13)
Rudakoff et al. (2022)[55]	Brazil/1978/1979 birth cohort study	1,021 (23–25 yr)	-	FFQ	% g	BMI (kg/m^2) Body fat (%) Lean mass (%)	Per 10% increase in UPF consumption β: 0.04 (0.01 to 0.07) in F β: 0.08 (0.04 to 0.13) in F β: –0.07 (–0.11 to –0.03) in F

*Mean age; †Mean of each quartile; ‡Increase ≥ 5% from baseline to follow-up.

F/U, follow-up; UPF, ultra-processed food; SUN, Seguimiento Universidad de Navarra; FFQ, food frequency questionnaire; BMI, body mass index; HR, hazard ratio; ENRICA-1, Study on Nutrition and Cardiovascular Risk in Spain-1; M, male; F, female; OR, odds ratio; WC, waist circumference; PREDIMED-Plus, PREvención con DIeta MEDiterránea Plus.

dietary intake was assessed using a food frequency questionnaire, and regional adiposity and total fat mass were measured at baseline, 6 months, and 12 months using dual-energy X-ray absorptiometry.[58] That study found a higher increase in UPF consumption was associated with greater accumulation of visceral fat, android-to-gynoid fat ratio, and total fat mass after controlling for potential confounders.

In addition, UPF consumption appeared to affect weight regain in patients who underwent metabolic and bariatric surgery. Metabolic and bariatric surgeries are well-established treatments for severe obesity that reduce dietary intake by decreasing gastric capacity and absorption through intestinal bypass, which results in body weight loss and improvement in comorbid conditions.[59,60] However, body weight loss typically occurs rapidly post-surgery, followed by gradual weight regain.[61] To maintain long-term weight reduction, dietary habit changes focused on obesity management and healthy eating are essential. A recent 5-year follow-up study of patients who underwent Roux-en-Y gastric bypass revealed that patients' dietary energy and macronutrient intake had decreased significantly at 3 months post-surgery but gradually increased, returning to preoperative levels by 60 months.[60] Similarly, UPFs' contribution to total energy intake returned to the preoperative level by 60 months post-surgery. That study indicated that maintaining successful weight loss in patients who have undergone metabolic and bariatric surgery might require dietary education focused on the degree of food processing and healthier consumption choices.

Meta-analyses of observational studies

As such epidemiological evidence has accumulated, meta-analyses have been performed to combine the results of those studies and estimate the overall effect of UPF consumption on obesity. A meta-analysis of 12 cross-sectional and two prospective studies showed that higher UPF consumption in adults was associated with increased risks of overweight (odds ratio [OR], 1.36; 95% confidence interval [CI], 1.23 to 1.51), obesity (OR, 1.51; 95% CI, 1.34 to 1.70), and abdominal obesity (OR, 1.49; 95% CI, 1.34 to 1.66) compared with lower UPF consumption.[17] Another systematic review of nine cross-sectional studies and one cohort study found a significant association between UPF consumption and obesity (pooled effect size, 1.26; 95% CI, 1.13 to 1.41).[18] Those meta-analyses consistently show a positive relationship between UPF consumption and weight gain or obesity. However, many of the included studies were cross-sectional, limiting the ability to determine whether UPF affects obesity independent of overall diet quality. Another review of prospective cohort studies provided a deeper understanding of the role of dietary quality and patterns in mediating the association between UPF consumption and obesity, reporting that the adverse effects of UPFs on weight gain and obesity persisted even after adjusting for dietary quality and patterns.[62]

Evidence from clinical studies

Randomized controlled trials

Several years ago, the results of an inpatient randomized controlled trials that addressed the effects of UPFs on energy intake and body weight change were published.[63] In that trial, 20 adults were randomly assigned to consume either ultra-processed or unprocessed diets for 2 weeks each, with both diets matched for nutritional content, including calories and macronutrients. Participants were allowed to eat *ad libitum*. Interestingly, participants consumed approximately 500 kcal more energy on the ultra-processed diet than they did on the unprocessed diet, leading to increases in both body weight and fat mass during the ultra-processed diet period. Weight and fat mass decreased during the unprocessed diet phase. These results suggest that reducing UPF consumption could help prevent obesity and support healthy weight maintenance.

HOW DOES UPF CONSUMPTION CAUSE OBESITY?

A better understanding of the mechanisms linking UPFs to weight gain and obesity will be useful for developing policies and strategies to control and treat obesity. Several mechanisms have been proposed to explain the association between UPF and obesity (Fig. 1). These explanations can be broadly classified into two categories. One focuses on the poor nutritional features of UPFs and the other focuses on food processing.[64-66]

Nutritional aspects of UPFs

UPFs have less favorable nutrient profiles than less processed or unprocessed foods: they are often higher in energy density, saturated fatty acids, refined carbohydrates, sugars, and salt while being

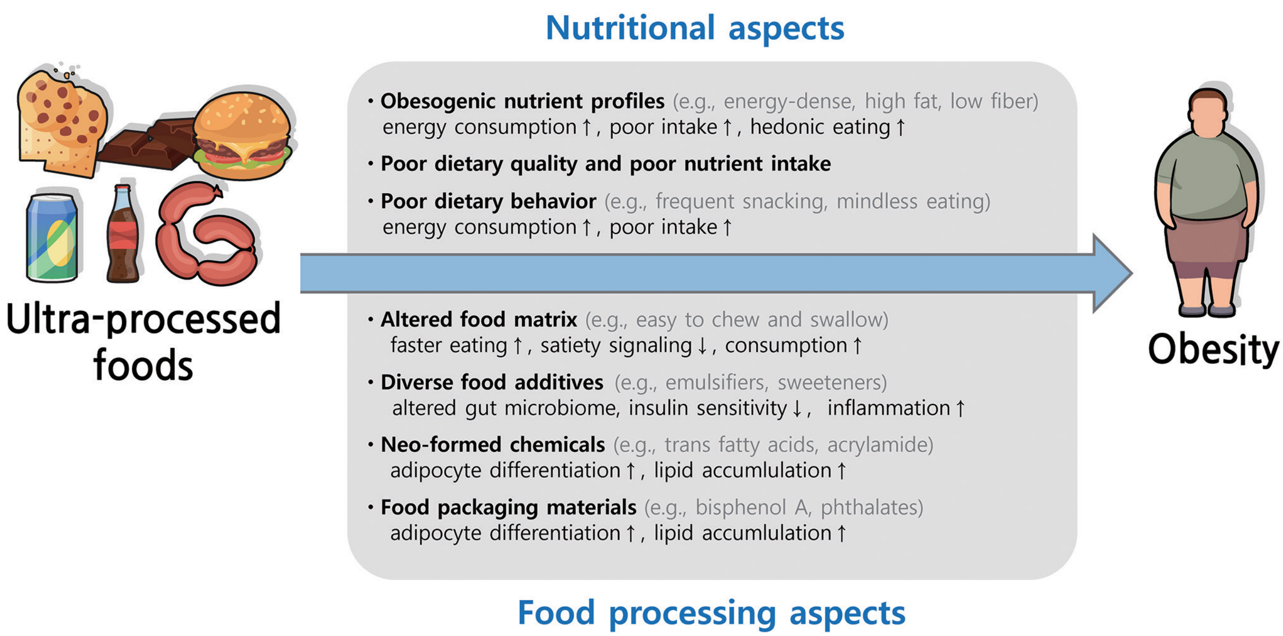

Figure 1. Plausible mechanisms underpinning the link between ultra-processed food consumption and obesity.

lower in protein, fiber, minerals, and vitamins.[19,23] These foods are also designed for convenience, making them easy to consume while doing something else (i.e., walking or gaming), encouraging mindless eating and overconsumption.[22,63,64] Therefore, higher UPF consumption is strongly associated with greater energy intake, poorer dietary quality, and worse nutritional intake—all factors known to drive obesity.[24,64,67-69] These results indicate that the nutritional aspects of UPF consumption play a key role in the pathogenesis of obesity. However, nutrition is not the sole explanation for the effect of UPF on obesity. Recent studies have found that a strong association between UPF consumption and diverse adiposity indicators remains even after adjusting for potential confounders (e.g., sex, age, socioeconomic characteristics, and health behaviors) and diverse dietary factors (e.g., dietary energy and nutrient intake, specific food consumption, and overall dietary quality). Thus, the link between UPF and obesity appears to be only partially explained by dietary factors,[52,58,62] suggesting that food processing plays a key role in the pathogenesis of obesity.

Food processing aspects of UPFs

The explanations supporting the importance of food processing focus on the altered food matrix, chemical properties, and nutritional content of the UPFs. First, the physical and structural alterations that occur during food processing increase the ease of chewing and swallowing, leading to faster eating and affecting satiety, glycemic response, and gut microbiota composition and function.[70,71] Studies indicate that the more highly processed is a food, the more delayed is its satiety signaling,[72] which could promote overconsumption. Furthermore, even with the same nutritional composition, foods processed to different degrees can elicit different physiological responses.[72] For instance, whole apples provide more satiety than applesauce or juice, and adding dietary fiber to apple juice does not improve satiety to the level of a whole apple.[73] These matrix changes can also affect nutrient bioaccessibility and absorption kinetics, influencing gut microbiota composition, metabolism, and growth.[70] Second, UPFs contain various food additives, including preservatives, antioxidants, stabilizers, dyes, color stabilizers, flavors, flavor enhancers, and sweeteners. Food additives are widely consumed in modern diets.[74] Some recent studies suggest that certain additives, such as emulsifiers and sweeteners, can alter the gut microbiome, impair insulin sensitivity, and promote inflammation and obesity.[57,75] Third, neo-formed chemicals are involved in obesity etiology. Among these chemicals, the most well-known are trans fatty acids, formed when processing liquid oils into solid fats, and acrylamide, produced when root vegetables containing asparagine (e.g., potatoes) are cooked at high temperatures with starchy foods.[76,77] One study found that rats fed a diet rich in trans fatty acids had significantly greater visceral and hepatic fat mass than controls, suggesting that trans fats affect nutrient metabolism in the liver, adipose tissue, and skeletal muscle.[57,76] Another study showed that acrylamide accelerated adipocyte differentiation and promoted lipid accumulation in mice, suggesting that acrylamide can upregulate adipogenesis.[77] Fourth, higher UPF consumption was associated with increased exposure to chemicals from food packaging materials, such as bisphenols and phthalates.[78,79] A recent review demonstrated that these toxic food contaminants, which have endocrine-disrupting properties, can modify dietary habits and promote adipocyte differentiation and adipogenesis.[80] However the long-term human health effects of UPF constituents (additives, neo-formed chemicals, and contaminants) need further investigation because most studies are based on animal models and focus on individual compounds. The combined effects of various additives on human health remain unknown.[80]

WHAT EFFORTS ARE BEING MADE TO REDUCE THE CONSUMPTION OF UPFs?

The growing evidence linking UPF consumption to adverse health effects has prompted efforts to reduce intake and encourage healthier choices. Strategies include establishing food-based national dietary guidelines, educating the public on the benefits of less processed foods, restricting UPF sales, and providing food labeling information.[32,42]

In 2014, Brazil introduced the new Brazilian Dietary Guideline.[81] Unlike conventional nutrient-based guidelines, it emphasizes the benefits of natural and minimally processed foods and freshly prepared meals. Following Brazil, many countries (e.g., Canada, France, Uruguay, Ecuador, and Peru) have revised their national dietary guidelines and recommend reduction of UPF consumption.[26,56,57,82-86] Additionally, regulations to restrict food marketing and taxation policies have been implemented. Many countries, recognizing that children and adolescents are particularly vulnerable to UPF consumption, have restricted advertising during children's TV viewing times, banned UPF sales within schools, and prohibited the promotion of UPFs at school events.[16,87] Taxation has also been a key strategy for discouraging UPF consumption. For instance, the UK, Mexico, and South Africa have imposed taxes on sugar-sweetened beverages and packaged foods to promote healthier choices.[16,88] Furthermore, front-of-package warning labels intended to help consumers identify and avoid UPFs have been introduced in many countries.[88] Despite that progress, efforts remain largely focused on reducing UPF consumption at the individual level. Regulatory and policy actions targeting the food industry face industry resistance and a lack of sufficient funding and leadership to enforce strict regulations.[13,88]

WHAT ARE FUTURE RESEARCH NEEDS?

Although growing evidence links UPF consumption to obesity, several research gaps and limitations remain to be addressed. First, although the NOVA food classification by Monteiro et al.[19,22] has been widely applied in epidemiological studies, it is controversial. As mentioned above, the NOVA system classifies foods into four categories based on the nature, extent, and purpose of their processing rather than on their specific nutrient or chemical properties. The 'purpose of processing' requires subjective interpretation and could facilitate food misclassification.[64,89] To improve classification consistency, some studies asked several researchers to independently classify foods and resolve disagreements by discussion.[47,57,67] More rigorous approaches (e.g., discovery of biomarkers reflecting UPF consumption) are needed to enhance credibility. Second, the UPF category comprises heterogeneous food-processing techniques and nutritional compositions.[90] Although many UPFs have unhealthy nutritional profiles, not all are nutritionally poor. Therefore, future studies should focus on understanding the consumption patterns and individual effects of specific UPF subcategories on obesity and other health outcomes. That research will help refine the concept of UPF. Third, dietary assessment methods must be refined. When characterizing and classifying food processing, many variables must be collected: for dishes, ingredient lists and preparation methods; for foods produced in industrial settings, brand and product name, ingredients, preparation methods, and location of purchase or consumption.[91] Traditional dietary assessment tools, such as dietary recall and food frequency questionnaires, do not collect sufficiently detailed information to classify foods according to the NOVA classification, which has led to the misclassification of UPFs in many studies.[64,89] Fourth, many early studies did not account for covariates that could affect the relationship between UPFs and obesity. Recent studies have adjusted for dietary quality or dietary factors (e.g., total energy intake, specific nutrients, or food intake) along with other covariates (e.g., physical activity and socioeconomic status) to address the distinct effects of UPFs on obesity[53,54,57] and have shown that the link between UPF consumption and obesity is only partially mediated by dietary quality.[52] Future research should continue to account for all known covariates to better isolate the independent effects of UPF consumption on obesity. Finally, research is needed on the reasons for consuming UPFs and the factors that hinder the reduction of UPF consumption to identify reduction strategies.

CONCLUSION

As the global diet has shifted rapidly, UPFs have become a dominant part of human food consumption. During the past several decades, the purchase and consumption of UPFs have increased worldwide, and those trends are expected to continue, albeit with regional variation. Numerous observational and experimental studies have shown that UPF consumption is strongly associated with diverse adiposity indicators in a dose-dependent manner. The effects of UPFs on weight gain and obesity risk could be due to the nutritional aspects of these foods, the characteristics of the food processing, or both. The reported association is independent of other dietary factors, including dietary quality, which only partially explained the relationship between UPF consumption and obesity. Further studies are needed to overcome the limitations of previous studies and elucidate the role of UPFs in the etiology of obesity. Nevertheless, the current evidence seems sufficient to recommend reducing UPF consumption as part of obesity prevention and treatment strategies.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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