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Examining the relationship between ultra-processed food consumption and obesity: A comprehensive review

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Abstract. This research investigates the relationship between the consumption of ultra-processed foods (UPFs) and obesity by analyzing seven studies, including both cross-sectional and longitudinal designs. The NOVA classification framework is employed to distinguish foods based on their degree of processing, with particular attention given to the adverse health outcomes associated with UPFs, which are characterized by high sugar, fat, and salt content, and low nutritional value. This review also explores potential mechanisms by which UPFs contribute to obesity, including their nutrient composition, impact on satiety, and behavioral factors related to their consumption. The findings indicate that measures should be taken to reduce UPF consumption and encourage healthier dietary habits to combat the global obesity epidemic.

Keywords: Ultra-Processed Foods (UPF), Obesity, NOVA Classification, Food Processing, Dietary Intake.

1. Introduction

Recently, the structure of the global food supply has undergone significant changes. The proportion of processed foods has been increasing. Studies have shown that the level of food processing is linked to adverse health outcomes [1]. Traditional food classification methods often group foods by plant and animal species or nutrient content, potentially grouping foods with different levels of industrial processing and health effects. For example, "cereals and products" includes both whole grains and sweetened breakfast cereals in industrial packaging. The NOVA classification is classified by processing degree and purpose of food processing, and UPF are a category within the NOVA classification. As global UPF consumption increases, these foods are becoming more integral to daily diets, coinciding with the rising morbidity of overweight and obesity [2]. This is a summary of how eating ultra-processed foods (UPF) is connected to being overweight.

2. Obesity

Obesity is recognized as a chronic and multifaceted condition, which the World Health Organization (WHO) defines as "excessive fat deposits that can be harmful to health" [3]. To assess an individual's obesity and general health status, body mass index (BMI) is frequently employed as a standard measurement. According to WHO criteria, a BMI between 25 and 29.9 means that a person is overweight,

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and a BMI of 30 or higher means obese. Approximately two billion adults around the world are overweight (BMI ⩾ 25 kg/m2) [3]. Recently, the morbidity of obesity and overweight has increased rapidly due to the changes in people's lifestyles and eating habits. The FAO Panel on Nutrition says that the global population of overweight and obese individuals will reach 3.28 billion by 2030. This means that about one in three people worldwide will be overweight or obese [4].

According to a survey in 2015 across 195 countries, the number of adults and children who are obese is 603.7 million and 107.7 million, respectively. Approximately 4 million people die from overweight and obesity-related diseases, resulting in 120 million disability-adjusted life years (DALYs) lost [5]. In China, the 2015 report on nutrition and chronic diseases indicated that the adult overweight and obesity rates were 30.1% and 11.9%, respectively, in 2012, an increase of 7.3% and 4.8% from 2002 [6]. Overweight and obesity are key causative factors for several chronic noncommunicable diseases, including hypertension, type 2 diabetes, cardiovascular diseases, and cancer. These conditions have emerged as a pressing global public health challenge, impacting both physical and mental health, while simultaneously exacerbating the economic burden on nations [7].

3. Ultra-processed food (UPF)

3.1. NOVA classification

In recent years, the NOVA classification system has gained widespread use in evaluating the extent of food processing. The concept of "ultra-processed foods" was first introduced by Monteiro et al. in 2009 [8] Among various methods of classifying food by processing degree, the NOVA classification is the most organized, thorough, and commonly used way to sort food based on how it is processed [9]. The NOVA classification system categorizes foods based on the physical, chemical, and biological processes that raw materials undergo before consumption or preparation. It classifies foods into four distinct groups according to the level and purpose of processing [10]: minimally processed foods (MPF), processed culinary ingredients (PCI), processed foods (PF), and ultra-processed foods (UPF). The NOVA classification, along with examples of representative food products for each category, is provided in Table 1.

Table 1. Classification according to the NOVA system and examples of typical foods.

NOVA group	definition	Representative foods
MPFs: Minimally processed foods	Foods obtained without industrial processing or only removing the inedible parts of food, or by drying, refrigerating, freezing, boiling, pasteurizing, etc., without adding salt, sugar, oil, and other condiments	Fruits, vegetables, eggs, legumes, fresh and frozen meats, fresh fruit juices, milk (fresh or treated), plain yogurt (fresh or treated), seeds and nuts without extra sugar or salt, rice and other cereals, etc.
PCIs: Processed culinary ingredients	Obtained by industrial processing methods such as pressing, refining, centrifugation, etc., and often used in combination with the first type of food to cook dishes	Sugar, salt, vegetable oil, lard, butter, honey, cream, starch, etc.
PFs: Processed foods	Made by canning, bottling, and other preservation methods	Bacon, canned fish, canned fruit, pickles, nuts and seeds with sugar and salt, fresh and unpackaged bread and cheese, beer and wine, among others
UPFs: Ultra-processed foods	Ready-to-eat foods made by a series of complex industrial processing progress and food additives such as spices, pigments, flavor enhancers, and emulsifiers	Sweets, chocolates, ice cream, biscuits, sweet cereals, packaged breads, pastry cakes, Chinese dim sum, fries, potato chips, pizza, sugary drinks, fruity yogurt, tahini, bean paste, sausages, burgers, hot dogs and other processed meats, bagged sweet or savory snacks, heated ready-to-eat foods, infant formula, distilled spirits, etc.

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3.2. UPFs

Recently, there has been growing interest in examining the relationship between ultra-processed foods (UPFs) and health, as categorized by the NOVA classification. UPF has undergone A range of industrial processes, formulated from a variety of different industrial ingredients. It usually doesn't have whole food materials and often has a lot of sugar, salt, fat, but not much protein, fiber, or vitamins [11]. Globally, the consumption of ultra-processed foods (UPFs) is on the rise, with UPF-derived energy now accounting for over 50% of total energy intake in high-income nations such as the United States and the United Kingdom [12, 13]. Increased UPF consumption can reduce the intake of unprocessed foods or MPFs such as fruits and vegetables, leading to a decline in diet quality [14]. As a result, this trend contributes to an elevated risk of various chronic diseases related to diet. Evidence from numerous studies indicates that UPF intake is a causative factor for obesity, hypertension, type 2 diabetes, and other diseases. Its health effects cannot be ignored [15-17].

4. The connection between UPF intake and obesity

Following a preliminary information gathering, the authors examined seven studies investigating the link between ultra-processed food (UPF) consumption and overweight and obesity. This review encompassed four cross-sectional studies [18-21], with the remaining studies being longitudinal or cohort studies conducted in various regions, including North America (United States and Canada), Europe (United Kingdom and Spain), South America (Brazil), and China. Of these seven studies, three investigated UPF intake using dietary reviews [18, 20, 22], two used food frequency questionnaires [21-23], and two employed multi-day non-weighing dietary records [19-22]. All seven studies focused on adults. Overweight and obesity were assessed using World Health Organization standards, and all studies utilized the NOVA classification for food group categorization.

4.1. Related conclusions

According to a cross-sectional study conducted by Juul et al. in US, there exists a significant connection between BMI, waist size, and UPF consumption. Higher consumption of ultra-processed foods (UPFs) was linked to overweight and obesity, with adjusted odds ratios (OR) of 1.48 (95% CI = 1.25-1.76) and 1.53 (95% CI = 1.29-1.81). This connection was found to be more pronounced among women, who exhibited a higher prevalence compared to men. [18].

Results from a cross-sectional study by Nardocci et al. Canada showed that UPF consumption was higher among young adults, men, smokers, people with less formal education, physically inactive individuals, and Canadian-born individuals. UPF intake was likely associated with obesity prevalence, with those having the highest UPF consumption being 32% more possibly to develop obesity (predicted OR = 1.32, 95% CI = 1.05-1.57) [20].

Similarly, a cross-sectional study by Silva et al. in Brazil found a positive correlation between ultra-processed food (UPF) intake and the prevalence of overweight and obesity in adults. After adjustments, the likelihood of being overweight was higher (OR = 1.31; 95% CI = 1.13-1.51), as was the likelihood of being obese (OR = 1.41; 95% CI = 1.18-1.69) [21].

A longitudinal cohort study by Pan et al. in China found that higher long-term UPF consumption was significantly linked to an elevated risk of developing metabolic syndrome (MetS) and its components. Specifically, individuals with high UPF intake faced a 17% greater risk of developing MetS. Additionally, the risks for central obesity and elevated triglycerides were increased by 33% (HR: 1.33, 95% CI: 1.18-1.51) and 26% (HR: 1.26, 95% CI: 1.08-1.48), respectively [22].

4.2. Possibly related conclusions

In contrast, a cross-sectional study by Adams et al. in the United Kingdom found no association between UPF intake and weight gain. However, it did reveal that higher intake of MPFs and lower intake of UPFs were linked to healthier dietary patterns. This may be because the study uses the original NOVA three-level classification method, which grouped processed foods with UPF, and the classification of food categories may have an impact on the findings; Additionally, the study used a 4-day non-weighing recording method to track food intake, which might not accurately reflect the quantitative differences in food intake among the subjects [19].

A prospective cohort study conducted by Mendonca et al. in Spain, involving 8,451 participants with an average follow-up period of 8.9 years, revealed that individuals in the highest ultra-processed food (UPF) intake group were 26% more likely to be overweight or obese compared to those in the lowest intake group (HR = 1.26, 95% CI = 1.10-1.45). However, the study was conducted among college graduates, a demographic generally characterized by higher levels of education and health awareness. Therefore, caution should be exercised when extrapolating these findings to the general population [23].

Another prospective cohort study by Canhada et al. in Brazil , which included 11,827 participants and had a mean follow-up period of 3.8 years, found that the prevalence of overweight and obesity was 20% higher in the group with the highest UPF intake compared to the group with the lowest intake (RR = 1.20, 95% CI = 1.03-1.40).However, among the people who were overweight at the start, there was no strong link between obesity and other factors, the risk was measured at1.02 (95% CI = 0.85-1.21) [24].

Table 2. Seven studies about the Effect of ultra-processed food intake status on overweight and obesity.

Author	Publication time	Research nation	Type of study	Number of people surveyed	Diet assessment method	Intake of UPF (%)	Effect Size	95 % CI
Juul [18]	2018	USA	Cross-sectional analysis (CSA)	15,977 adults	24-hour recall	⩾74.2% of total energy	BMI ⩾ 25 kg/m²: 48%, BMI ⩾ 30 kg/m²: 53%, Abdominal obesity: 62%	1.48 - 1.76, 1.53 - 1.81, 1.62 - 1.89
Adams [19]	2015	UK	CSA	2,174 adults	Four-day food records	Average of 53% of total energy	OR = 1.01	1.00–1.02
Nardocci [20]	2018	Canada	CSA	19,363 adults	24-hour recall	75.95% of daily total energy	OR = 1.32	1.16–1.51
Silva [21]	2018	Brazil	CSA	8,977 individuals (35-64 years old)	Food Frequency Questionnaire (FFQ)	>29% of total energy	Overweight: 1.31, Obese: 1.41, Increased waist circumference: 1.41	Overweight: 1.13-1.51, Obese: 1.18-1.69, Increased waist circumference: 1.20-1.66
Pan [22]	2023	China	Longitudinal cohort study	5,147 adults	Three continuous 24-hour dietary recalls and weighing household foods and condiments	Divided into four groups based on UPF consumption	Central obesity: HR: 1.33, Raised triglycerides: HR: 1.26	Central obesity: 1.18–1.51, Raised triglycerides: 1.08–1.48
Mendonca [23]	2016	Spain	Prospective cohort study	8,451 middle-aged graduates from Spain universities	FFQ	Divided into four groups based on UPF consumption	Adjusted HR: 1.26	1.10-1.45
Canhada [24]	2019	Brazil	Longitudinal study	11,827 civil servants from Brazilian institutions situated in six cities	FFQ	>30.84% of total energy	Large weight gain: 1.27, Incident overweight/obesity: 1.20, Incident obesity: 1.02	Large weight gain (>90th percentile): 1.07-1.50, Incident overweight/obesity: 1.03-1.40, Incident obesity: 0.85-1.21

5. Potential mechanisms

Several mechanisms through which UPFs might lead to energy overconsumption and weight gain have been proposed. Those include their high levels of nutrients and energy, taking the place of healthy foods, breakdown of food structure, changes in texture and taste, less feeling of fullness, and the presence of various additives [25-27]. Additionally, UPFs can interfere weight regulation mechanisms and are linked to behavioral and environmental factors, including hyper-palatability, aggressive marketing, large portion sizes, low cost, availability, and convenience [28, 29]. There are some researchers claim that UPFs might be addictive, though this remains a topic of debate [30].

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UPFs may contribute to overweight and obesity through various nutrition-related mechanisms. After a series of complex industrial productions, UPFs tends to have the characteristics of high sugar, high fat, high energy, low dietary fiber, etc., with reduced nutritional value and increased energy density [31]. High carbohydrate content in UPFs can stimulate insulin secretion, which promotes the transfer of excess nutrients to adipose tissue and accelerates fat synthesis [32].

Added sugars can lead to an increase in the body's glycemic load, which is directly related to weight gain [33]. The unique and very palatable combination of fats, sugars, and salts in UPFs [34], along with added flavorings, colors, and sweeteners, can mess up the connection between taste and nutrition then promote weight gain through over intake [35]. Modifying food recipes to incorporate low-calorie sweeteners might inaccuracies in signaling nutrient and calorie content to the brain, because sweetness may not reflect calorie content accurately [36]. Artificially sweetened drinks with lower calorie can trigger a stronger brain response and preference compared to higher-calorie drinks with the same sweetness levels [37]. Taste-nutrient relationships are consistent across NOVA food groups according to observational data from Singapore [38]. UPFs exhibit stronger correlations between fat taste and fat content, as well as between salt taste and salt content, but weaker correlations between sweet taste and sugar content compared to MPFs [38]. Besides, UPFs with higher energy density could also amplify food reward mechanisms, impacting gut-brain signaling, flavor-nutrient conditioning, and food preferences [39].

Dietary fiber can affect the composition of intestinal microorganisms, which can affect body weight by affecting the host's energy metabolism and triggering inflammatory responses [40]. High energy density reduces satiety by speeding up gastric emptying, leading to increased energy intake [41]. In addition, UPF may also lead to being overweight and obesity through non-nutritional mechanisms. Studies have shown that the degree of food processing influences food texture and is closely related to the satiety index (SI) and blood glucose response. Higher degrees of food processing are associated with increased glycemic response and reduced SI [42].

UPFs may induce continuous or involuntary eating behaviors due to their appealing taste, palatability, and convenience [43]. For example, when eating snacks during leisure and entertainment time such as watching TV, this kind of eating behavior can affect the response of the nervous and digestive systems' response to satiety [44]. Increased consumption of UPFs can also reduce the intake of unprocessed foods or MPFs, resulting in poor dietary habits and contributing to overweight and obesity [45].

6. Conclusions

Recent changes in the structure of food consumption, especially the increase in UPF consumption, are important factors contributing to obesity. Observational studies have identified a correlation between UPF intake and the prevalence of overweight and obesity. Several mechanisms have been suggested to account for this phenomenon, yet the evidence remains inconclusive. Consequently, there is a need for long-term, high-quality clinical trials to assess the effects of UPFs. The concept of UPFs encourages collective action from individuals and social groups to modify the environment contributing to obesity and empower people to reduce UPF consumption. Concurrently, it is essential to implement policies, regulations, and restrictions on UPFs alongside the development of accessible and sustainable alternatives.

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