

The Impact of Ultra-processed Foods on Dietary Patterns in Developed Countries and the Development of Obesity and Cardiovascular Disease

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Abstract: On the basis of NOVA classification system based on the scope and purpose of food processing, ultra-processed foods (UPF), modified by a series of complex industrial processing, refer to a group of convenient, ready-to-eat, hyper-palatable foods that add varieties of food additives and generally contain high dose of sugar, salt and fat, and low dose of protein, dietary fiber and micronutrients. In this field, many articles from other researchers mentioned that dietary UPF exposure was associated with at least one adverse health outcome. In adults, these risks include overweight, obesity, and cardiometabolic risks; cancer, type 2 diabetes and cardiovascular disease; irritable bowel syndrome, depression and frailty; and all-cause mortality. In children and adolescents, including cardiometabolic risk and asthma. In this paper, evidence was collected to prove that that excessive consumption of ultra-processed foods is related to chronic disease by comparing multiple data points from other credible research articles.

1. Introduction

Since the very beginning of human evolution, hunting and gathering have been the major means for human to obtain foods. This foraging lifestyle means complete dependence on chance: if you find food sources, you would be able to survive, but unfortunateness may starve you to death. Risks that threaten life may exist even if you have access to foods, for they may be toxic. After almost 19,000 years of hunter-gather lifestyle, the first Neolithic Revolution at around 12,000 years ago marked the start of agriculture [1]. The relatively short time span of agriculture has clearly changed human diet pattern rather rapidly and drastically. Nowadays, access to foods that are not only safe but also delicious at any point of time is no longer rare. Some may argue the relative assurance of this new relationship between human and food sources: at least in most regions, we no longer need to fear toxicity of foods, nor do we starve to death. The safeness of modern food sources is secured indeed in these two perspectives. However, while availability of food no longer put risks on human, the diet pattern in the past century may be negatively impacting human in a new way – chronic diseases, with its effect most obviously seen in developed countries. The diet pattern referred here is characterized by containing higher portion of ultra-processed foods (UPF) with each passing decade. It is worth mentioning that processed food is different from “ultra-processed food”. Most foods are processed because their crude forms for many reasons. UPF, however, despite sharing the same feature with processed foods as being palatable, are high in fat, salt, sugar and are depleted in dietary fiber, protein, various micronutrients, and multiple other bioactive compounds [2]. The characterizations of UPF show their potential harm to human in causing diet-related non-communicable diseases, especially under the condition of overconsumption. Acknowledging these negative impacts, it may be ponderous to see how prevalent overconsumption of UPF is. They are convenient and satisfying, which make them favorable to recent generations who are mostly work-centered. In the United States, it is recorded

that UPF products have made up almost 60% of its total food supply [3]. The number is only rising. This drastic shift from hunter-gatherer diet to high UPF content diet corresponds to the change in major causes of death: depending on the specific hunter gatherer group, they may have as high as 85% of total death from respiratory and gastrointestinal diseases, the incidence rate of chronic diseases such as diabetes has risen sharply in the high UPF diet prevalent in developed countries, hypertension, coronary heart diseases, and so on, all of which can lead to death potentially [4]. Therefore, it is vital to determine how UPF is impacting dietary pattern, and thus disease development, in developed countries which are at front of UPF-consumption.

2. Effects of super processed foods on dietary structure in developed countries

Nowadays, as society becomes more and more developed, people's dietary patterns have changed dramatically with the development of the food processing industry and global trade. Unlike the dietary patterns of a hundred years ago when most raw ingredients were used, the dietary patterns of modern developed countries tend to favor processed foods and convenient ultra-processed foods. The changing dietary patterns in developed countries are good evidence to indicate the position of ultra-processed foods occupy in currently developed countries. Thus, we use the NOVA definition of UPF to distinguish the UPF and other food products in order to better understand and analysis the impact of UPF on dietary patterns in developed countries.

2.1 NOVA definition of ultra-processed food

NOVA is a kind of food classification and considered as the most useful method. NOVA classified all food products into four categories. The NOVA group 1 refers to foods that are unprocessed and minimally processed, like vegetables, fruits, and nuts. The term "unprocessed food" usually refers to fresh natural food that has not been processed by humans. Minimally processed food refers to the products going through the preservative measures to extend the shelf life of the food and simple processing to remove unwanted parts. The NOVA group 2 refers to processed culinary ingredients, like oil, sugar, and salt. These food products are obtained from the foods in NOVA group 1 by some industrial means. The goal of producing processed culinary ingredients is to better cook and season the first group of foods. The NOVA group 3 includes processed foods, like breads, noodles, canned foods, and cheeses. Such foods are often more artificially processed. They are created by combining group 2 foods with group 1 foods to increase the shelf life and palatability of group 1 foods. The final group of foods in NOVA group 4 is UPF, like carbonated soft drinks, chocolates and candies, cookies, and other ready-to-eat foods. The ingredients used in these foods include ingredients used in industry and are not normally used in homemade foods, like high fructose syrup, flavor enhancers, and industrial emulsifiers. Typically, this kind of food needs to go through more complex processing to achieve its mass production, long durability, and palatable purpose. In this way, the NOVA group 4 (UPF) is the category of food products that people should pay the most attention to [3].

2.2 Current dietary pattern in developed countries

Snacks and ready-to-eat foods (UPF) became progressively convenient and appealing choices as societies became more urbanized, the food industry systems developed, and the increased available incomes. Since the 1980s, dominating international economic policies aimed at enabling capital flows and rapid trade expansion has shaped national food systems. International and global trade agreements have grown in importance since the 1990s, resulting in the proliferation of multinational food manufacturing, retail, "fast food" chains, and related companies. Nowadays, consumption patterns have evolved in tandem with the nature of what is consumed. UPF are commonly consumed as snacks or ready-to-eat foods at nearly any time and location, especially for office workers and young people, considerably reducing the time required to prepare and cook raw food materials. Besides, in countries such as the United States, Mexico, Canada, Brazil and China, snack foods consume up to a quarter of calories. Snack food consumption in China has increased every two years since 2000. These data indicate UPF are gradually replacing raw food materials to dominate the global food system. Monterio

and et al. conduct a study about trends in the purchase and sales of UPF in high- and middle-income countries, especially in Canada and Brazil [4]. Time varying dietary contribution data of over processed products estimated from repeated national household food expenditure surveys in Canada and Brazil, the percentage of UPF in the total calories of purchased food in Canada increased from 24.4% in 1938 to 54.9% in 2001. Brazil, on the other hand, increased from 18.7% in 1987 to 26.1% in 2003(**Figure 1**). According to the study, UPF accounted for more than half of all food calories consumed in Canada, and more than a quarter in Brazil around the early 2000s. They conclude that consumption of ready-to-eat snacks in high-income nations may remain stable, whereas soft drink consumption may have peaked. Overall, the trend showed UPF have replaced or are gradually replacing staple foods in high- and middle-income countries [6]. Moreover, Steele and et al. investigated the caloric contribution of UPF in the US diet and their nutrient composition. Their results showed that in one-fifth of the energy contribution of UPF, the contents of protein, fiber, vitamins A, C, D and E, zinc, potassium, phosphorus, magnesium and calcium in the American diet decreased significantly, while the contents of carbohydrates, added sugar and saturated fat increased. They used a nutrient-balanced-pattern PCA-derived factor score to conclude an inverse dose-response connection between UPF quintiles and total dietary quality. This study also indicated reducing the amount of UPF in daily diet is a sensible and effective method to improve the diet quality in the US [6].

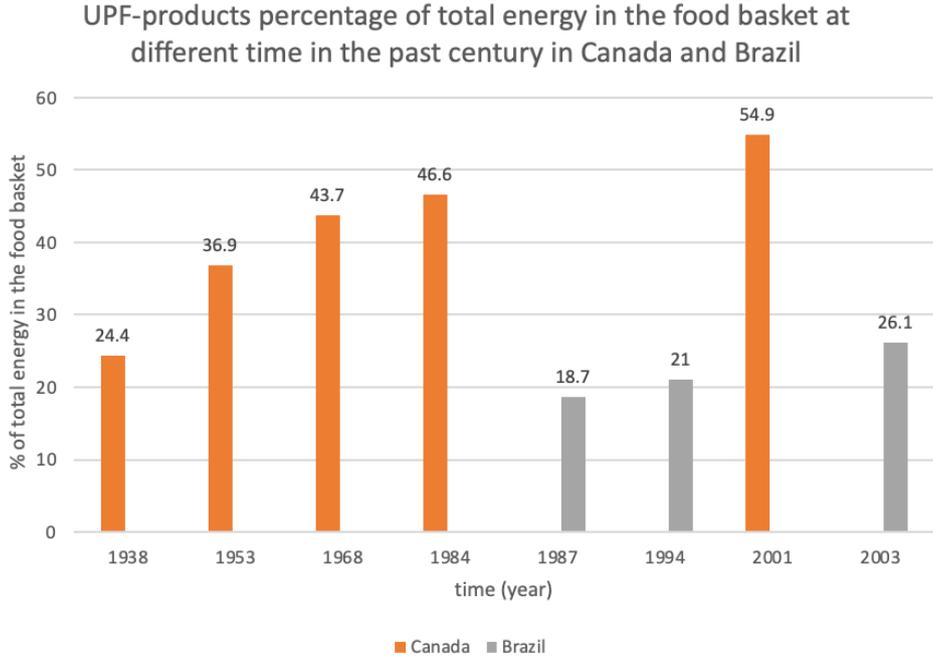


Figure 1: UPF-products percentage of total energy in the food basket at different time in the past century in Canada and Brazil.

2.3 The impact of ultra-processed food on disease development

After understanding the relationship between UPF and dietary patterns, researchers know that over consumption of UPF is enough to influence a person's diet. However, there is also a strong link between diet and human health. Therefore, we discussed the relationship between super processed food and disease development by discussing how super processed food affects people's health. In addition, the link between diet and chronic disease is strong [4]. Therefore, we analyzed and compared experimental data from different countries and researchers to find out how ultra-processed foods affect the risk of chronic diseases.

2.4 Global leading cause of death

The top 10 global leading causes of deaths in 2019, in order of causing the most deaths to causing the least, was ranked by World Health Organization (WHO): ischemic heart disease (16% of the world's total deaths); stroke (11% of the world's total deaths); chronic obstructive pulmonary disease (6% of the world's total death); lower respiratory tract infection; Neonatal status; Trachea, bronchus

and lung cancer; Alzheimer's disease and other dementia; Diarrhea; Diabetes; kidney disease [8]. According to this data, the top three leading causes of deaths were all non-communicable chronic diseases (NCD) [8]. Moreover, in all ten leading causes of deaths, seven of them were NCD, and those seven leading causes of death accounted for 80 percent of the top 10 death and the 44 percent of the total death [8]. According to WHO, all cause of death can be classified into three groups: communicable, noncommunicable and injuries [8]. However, in 2019, all non-communicable diseases alone accounted for 74 per cent of global deaths [8]. Thus, the public should not ignore the mortality of chronic diseases just because they are not as sudden as injuries or as transmissible as communicable diseases. The etiology of chronic diseases is complex and multifactorial, and age, family history, gene, body weight, the level of physical activity, the habit of smoking and drinking alcohol, and diet are all possible risk factors [9]. Furthermore, the risk factors that can be modified, like diet, are the ones that can best impact the public health [9].

2.5 Trends between consumption of over processed foods and chronic disease risk

In this way, diet should be given more attention as a factor that can influence the risk of chronic disease [9]. However, UPF plays an important part in the diet of developed countries, and some studies have shown that consuming UPF can influence people's dietary patterns [2]. Therefore, the relationship between UPF and chronic diseases is important because UPF is not only a big influence factor in diet but also can greatly change the risk of chronic diseases in people [3, 10]. Recently, Latin American countries include avoiding UPF as their 'golden rule' in the national dietary guidelines [11]. Moreover, current national Brazilian dietary guidelines also put "avoid ultra-processed products" in their four main recommendations [12]. As the dangers of overconsuming UPF begin to be recognized, the need to understand the relationship between UPF and people's health becomes even more important.

Some studies have shown that UPF usually provides more calories and contains more fat, added sugar and sodium than unprocessed or minimally processed foods and processed cooking ingredients [13,14]. Besides, the WHO also claimed that the UPF consumption was associated with dietary patterns that contain unhealthy fat and low dietary fiber [3]. However, the risk factors of many chronic diseases are associated with the characteristics of UPF [15]. Diabetes is a chronic disease that cannot be neglected. During the 2021 pandemic, the prevalence of diabetes ranged from 7.3% in China to more than 30% in Europe. Type I diabetes is due to autoimmune problems, but type II diabetes has more complex causes [16]. According to research, the trend of consuming more and more UPF may associate with the epidemic of type II diabetes [17]. As mentioned before, UPF usually contain more fat (including saturated fat), added sugar, and salt [13,14]. These components usually contribute to a higher risk of type II diabetes. In a UK-based cohort, researchers tracked whether participants who ate different amounts and types of UPF had diabetes for more than five years. The results showed a 44 percent increased risk of developing type II diabetes from participants with the lowest UPF intake to those with the highest UPF intake. Moreover, after calculation, researchers found each 10-percentage point increase in UPF intake was associated with a 12 percent increase in the risk of type II diabetes [17]. This result is similar to the result of another perspective study which suggested that for every 10-percentage point increase in UPF consumption, the hazard ratio for T2D morbidity was 1.13 [18]. These two studies had similar follow-up time, and the participants consumed similar amount of UPF, but the type of UPF vary widely [17, 18]. In this way, the over consumption of UPF (no matter what kind of UPF products) can lead to a higher risk of developing type II diabetes. Besides, the obesity and overweight can also cause diabetes, and the UPF consumption is not only directly related to the risk of type II diabetes but also related to obesity and overweight [17].

Globally, the prevalence of UPF and obesity is rising [19]. Obesity has now been brought to the attention of researchers in many countries and is being sought for solutions. The study has shown that consuming UPF increase the energy and fat intake of participants leading to weight gain [20]. A cohort study in Brazil with 3.8 years follow-up time, a cohort study in Spain with 8.9 years follow-up time, a cohort study in UK with 5.6 years follow-up time, and a 1-year study in Australia using a complex, stratified, multistage probability random cluster sampling method all showed the similar results that support the previous conclusion [19, 21, 22, 23]. Thus, the fact that so many other researchers are

looking at this issue suggests a strong link between UPF and obesity. UPF and obesity (and other chronic diseases that may be associated with obesity) deserve people's attention. In order to better understand the relationship between chronic diseases, especially obesity, and excessive consumption of UPF, we collected and organized the results of other academic studies and hoped to better understand the specific relationship and mechanisms between them.

3. Effect of eating super processed food on obesity risk

A search found seven studies on UPF intake and obesity, including five cross-sectional studies in Canada, France, Australia, and the United States (**Table 1**). A cross-sectional study conducted by Priscila Pereira Machado et al. in Australia showed that UPF intake was positively correlated with the prevalence of obesity (**Table 1**). In the multivariable regression analysis, those in the highest quintile of UPF consumption had significantly higher BMI (0.97 kg/m²; 95% CI 0.42, 1.51) and WC (1.92 cm; 95% CI 0.57, 3.27) and higher odds of having obesity (OR = 1.61; 95% CI 1.27, 2.04) and abdominal obesity (OR = 1.38; 95% CI 1.10, 1.72) compared with those in the lowest quintile of consumption [19]. Also, Juul et al. the results of a cross-sectional study conducted in the United States Intake was positively correlated with the prevalence of overweight and obesity in adults (**Table 1**). The posterior or values were 1.48 (95% CI = 1.25 ~ 1.76) and 1.53, respectively (95 % CI = 1.29 ~ 1.81) [23].

Rauber et al. findings demonstrate that among British adults, high consumption of over processed foods is closely related to the high risk of a variety of obesity indicators. Results 947 incident cases of overall obesity (BMI 30 kg/m²) and 1900 incident cases of abdominal obesity (men: WC 102 cm, women: WC 88 cm) were identified during follow-up (**Table 1**) [24]. Beslay et al. observed a positive association between UPF intake and gain in BMI (Time x UPF=0.02 for an absolute increment of 10 in the percentage of UPF in the diet, P<0.001) (**Table 1**). UPF intake was associated with a higher risk of overweight (n= 7,063 overweight participants; hazard ratio (HR) for an absolute increase of 10% of UPFs in the diet = 1.11, 95% CI: 1.08-1.14; P<0.001) and obesity (n=3,066 incident obese participants; HR= 1.09(1.05-1.13); P<0.001) [25]. Nardocci et al. found UPF make up almost half (45%) of the daily calories consumed by Canadian adults (**Table 1**). UPF consumption is positively associated with obesity [26]. Furthermore, except for one Brazilian [27] report that UPF was negatively correlated with obesity, the other five reports found that UPF was positively correlated with obesity.

Table 1: The impact of ultra-processed food intake on obesity in different countries

Author	Country	Research Methods	People Accounting		Effect Size	95% CI
Machado	Australia	cross-sectional study	7411	Obesity	OR=1.61	1.27-2.04
Juul	America	cross-sectional study	15977	Obesity	OR=1.48	1.25-1.76
Rauber	UK	24-h recall and repeated measures	22659	Overall obesity	HR=1.79	1.06-3.03
				Abdominal obesity	HR=1.35	1.25-1.45
Beslay	French	cross-sectional study	110260	Obesity	HR=1.09	1.08-1.14
Nardocci	Canada	cross-sectional study	19363	Obesity	OR=1.32	1.05-1.57

4. Effect of eating super processed food on the risk of cardiovascular disease

As mentioned before, the characteristics of UPF is associated with many risk factors of chronic diseases [16]. In addition to obesity, cardiovascular disease is also a chronic disease with several risk factors directly related to nutrient intake, like higher saturated fat and trans-fat intake [28], lower polyunsaturated fat intake [29], high energy intake [30], and lower dietary fiber intake may result a higher risk of cardiovascular disease [31]. In this way, the relationship between the UPF intake and the risk of cardiovascular disease and the possible mechanisms between this relationship should be further explored to better understand the effects of consuming UPF.

4.1 Relationship between intake of super processed food and risk of cardiovascular disease

In a prospective cohort study on 1,236,049.2 person-years follow-up of 13.5 years, Guo-Chao Zhong et al. the highest incidence rate of all cardiovascular diseases (CVD) was found in the highest UPF intake group. In the fully adjusted model, participants with the highest and lowest quintiles of UPF consumption had a higher risk of dying from cardiovascular disease (HR=1.50; 95% CI, 1.36-1.64) and heart disease (HR=1.68; 95% CI, 1.50-1.87). Subgroup analysis showed that the risk of increased mortality of UPF in women was significantly higher than that in men (all Pinter action < 0.05) [32].

4.2 The possible mechanism

The underlying physio-pathological interrelationships between atherosclerosis formation and cardiovascular disease progression are complex and involve multiple pathways. Metabolic, proinflammatory, prothrombotic, prooxidation, and endothelial dysfunction co-exist and reinforce each other [33]. Most cardiovascular risk factors play a role in triggering endothelial dysfunction and injury and maintaining the pro-inflammatory molecular environment before thrombosis. Through the complex network of these factors and molecular feedback loop mechanisms, the formation of atherosclerosis escalates and continues, eventually leading to various cardiovascular events.

The higher energy density and oral sensory properties of UPF (i.e., softer, less fibrous and easier to chew) also allow for higher energy intake in a shorter period of time. Experimental studies show that the increase of eating speed leads to the increase of energy intake, which may be due to the delay of satiety signal [20].

Excessive sodium in the diet increases the risk of hypertension, which is a major risk factor for cardiovascular disease and stroke [34]. The mechanism of the association between increased sodium intake and hypertension is complex and not fully understood. Several pathways have been involved, including renal sodium homeostasis disorders, extrarenal sodium therapy, direct effects on vascular walls, systemic and local neurohormonal pathways, and salt sensitive phenotypes. Metabolic, hemodynamic, and inflammatory changes lead to volume dilation, water retention, endothelial stiffness, increased peripheral resistance, and subsequent elevated blood pressure.

5. Conclusion

Growth of international and global trade agreements have led to proliferation of multinational food manufacturing, retail, “fast food” chains, and related companies. This results in ubiquitous consumption of UPF in the form of snacks or ready-to-eat foods, which are most convenient and therefore favorable by students and workers. UPF is displacing raw foods gradually in terms of dominating global food system. The consumption of UPF is kept relatively high in developed countries. In addition, soft drink consumption in these countries have escalated. As a result of this consumption pattern, intake of valuable macronutrients such as fiber, protein, and multiple micronutrients are being compressed by the expansion of sugar and fat intake. It can be concluded that UPF is having an increasingly dominating role in dietary pattern in developed countries.

Non-communicable diseases are outweighing communicable diseases and injuries as the leading causes of death in a worldwide scale. Although etiology can be complexed, one of the controllable and important risk factors of multiple NCDs is diet. High intake of UPF is associated with high risk of cardiovascular disease and type II diabetes. Mechanisms behind this associations may be due to

characteristics of UPF that trigger body signals in unusual ways and the accumulation of excess fat. However, exact mechanisms of how dietary intakes impact development of NCDs are not thoroughly determined yet. Additionally, obesity is one crucial medical condition that is not only positively correlated with UPF, but also positively identified with increased risk of various NCDs. In conclusion, dietary pattern of increasing consumption of UPF is negatively impacting individual's health. Developed nations which are experiencing high UPF intake among population should take reaction in reinforcing reduction in this type of product for a healthier general population.

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