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Ultra-processed Foods and Cardiometabolic Health Outcomes: from Evidence to Practice

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Abstract

Purpose of Review Poor diet quality is the leading risk factor related to the overall cardiometabolic disease burden in the USA and globally. We review the current evidence linking ultra-processed foods and cardiometabolic health risk and provide recommendations for action at the clinical and public health levels.

Recent Findings A growing body of evidence conducted in a variety of study populations supports an association between ultra-processed food intake and increased risk of metabolic syndrome, hypertension, type 2 diabetes, overweight and obesity trajectories, and cardiovascular disease. The strongest evidence is observed in relation to weight gain and obesity among adults, as this association is supported by high-quality epidemiological and experimental evidence.

Summary Accumulating epidemiologic evidence and putative biological mechanisms link ultra-processed foods to cardiometabolic health outcomes. The high intake of ultra-processed foods in all population groups and its associated risks make ultra-processed foods an ideal target for intensive health promotion messaging and interventions.

Keywords Dietary guidelines · NOVA · Diet quality · Type 2 diabetes · Cardiovascular disease · Obesity · Processed food

Introduction

Cardiometabolic diseases are an interrelated set of conditions that include cardiovascular diseases (CVD), such as coronary heart disease (CHD), stroke, and hypertension, as well as metabolic diseases, such as type 2 diabetes and obesity, and constitute a major cause of mortality and chronic disability in all parts of the world [1, 2]. Diet plays a pivotal role in cardiometabolic health [3]; in the USA, poor diet is the leading risk factor related to the overall CVD burden and is associated with more than half of US deaths due to CHD and cerebrovascular disease [4, 5]. Globally, 10 million CVD deaths and 207 million disability-adjusted life-years were attributed to suboptimal dietary behaviors in 2017 [6]. The American Heart Association and the American Diabetes Association maintain that a healthy lifestyle, involving a healthy diet, is the most important way to prevent CVD and type 2 diabetes [7, 8].

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Current evidence emphasizes the need to focus on foods and overall dietary patterns, as traditional nutrient-focused metrics have proven insufficient to explain the role of diet in cardiometabolic diseases [9]. In this context, the influence of food processing level on health outcomes is receiving increasing attention in nutrition research. Food processing is not a recent invention; humans have used heat, fermentation, drying, and other processes to avoid spoilage; increase palatability; and ensure microbiological safety of foods since the Neolithic era [10]. Until the nineteenth century, food processing was primarily performed in the home, using traditional methods [10]. Following the industrial revolution, commercial food production rapidly increased and the extent, nature, and purpose of food processing changed [11]. From the 1980s, advances in food science and food technology allowed for the creation of an immense number of edible items made primarily from cheap ingredients and additives, referred to as ultra-processed foods [11, 12].

The NOVA framework (Fig. 1) defines ultra-processed foods as industrial formulations made with no or minimal whole foods that are produced with substances extracted from foods or synthesized in laboratories, such as dyes, flavorings, and preservatives, using processing techniques with no domestic equivalent, such as extrusion or molding [13]. Examples of ultra-processed foods include soft drinks, breakfast cereals, salty snack foods, industrially produced breads, canned/instant soups, and energy bars [13].

Worldwide, diets and food supplies in both high-income and lower-income countries are increasingly based on ultra-processed foods [11]. In the average US diet, ultra-processed foods provide nearly 60% of calories [14]; American children and adolescents have the greatest intakes (>65% of total calories) while older adults have lower intakes (≥60 years, 53% of total calories) [14]. The current dietary exposures to high proportions of ultra-processed foods are unique from an evolutionary perspective and hypothesized to be a driver of the global rise in cardiometabolic diseases [15]. There is convincing evidence that specific ultra-processed products (processed meat, sugar-sweetened beverages) and components of ultra-processed foods (trans fats, sodium) are causally related to CVD and type 2 diabetes [16–20]. Furthermore, a growing body of literature supports the assertion that higher total intake of ultra-processed foods contributes to cardiometabolic diseases [21].

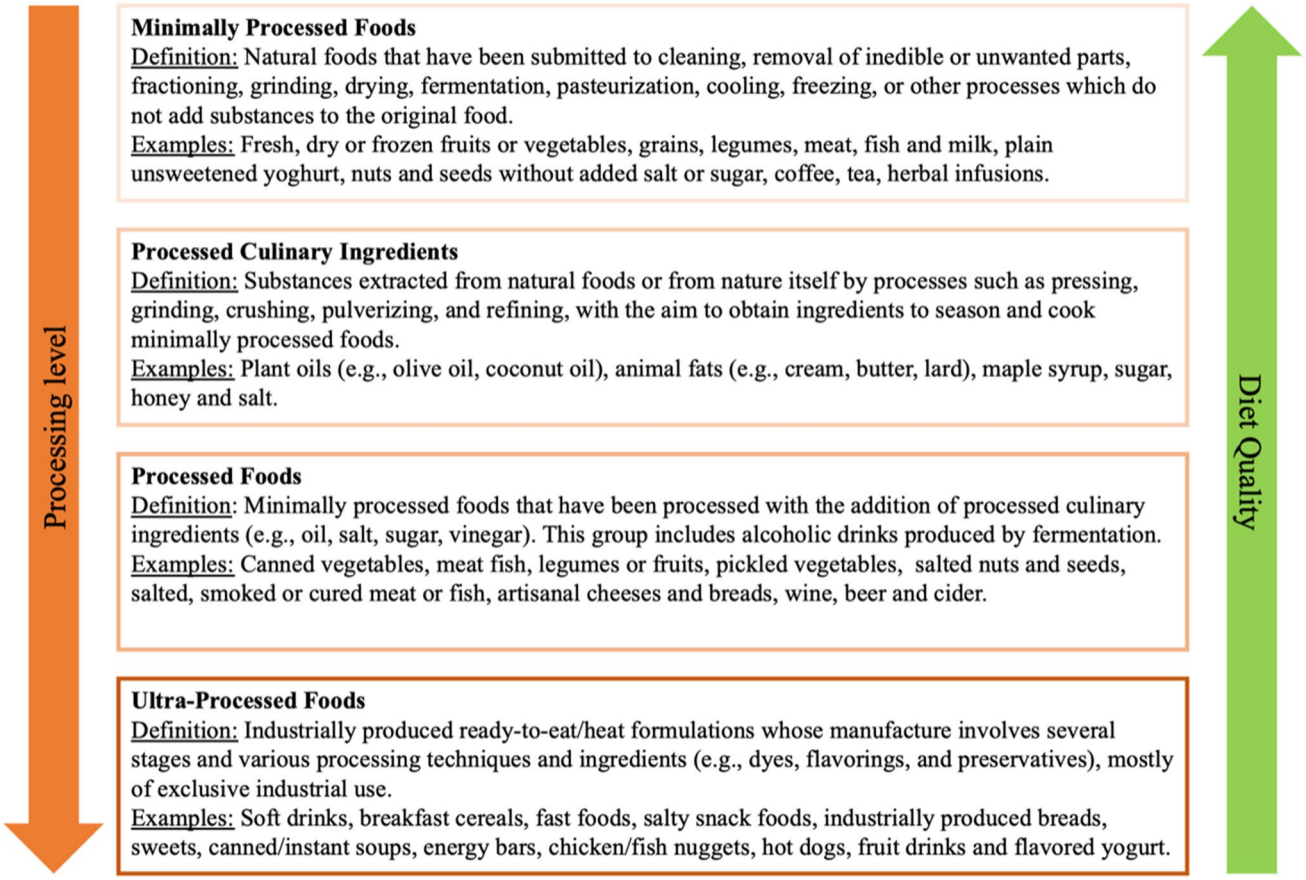

Fig. 1 The NOVA framework and its association with diet quality. NOVA categorizes foods into four mutually exclusive categories based on the extent and purpose of industrial processing. A greater proportion of ultra-processed foods in the diet is associated with lower diet quality [30, 31]

Despite the accumulating epidemiologic evidence linking ultra-processed foods to cardiometabolic health outcomes, the health hazards associated with a broad range of ultra-processed foods (beyond sugar-sweetened beverages and processed meats) are largely unrecognized by clinicians and public health professionals. To address this gap, we discuss recommendations for action at the clinical and public health level, based on the current evidence.

Biological Mechanisms of Action

The biological pathways through which ultra-processed foods may influence cardiometabolic health are not yet fully understood and likely involve synergies between many compounds and characteristics of ultra-processed foods. Processing can alter the nutritional (e.g., macro-and micronutrient content, energy density, glycemic index, and load), physical (e.g., food structure, content of acellular nutrients), and chemical (e.g., presence of artificial sweeteners, additives, and neo-formed contaminants) characteristics of foods in ways that may alter their health effects. Food processing level may also influence dietary behaviors, such as timing and frequency of consumption, portion size, and eating pace, with potential implications for energy intake, diet quality, and cardiometabolic health.

Epidemiological studies have consistently found that diets with a higher proportion of ultra-processed foods have less favorable nutrient profiles than diets containing fewer ultra-processed foods [22–30]. Specifically, diets higher in ultra-processed foods are generally higher in total energy, total fat, saturated fat, trans fat, added/free sugars, and sodium while providing less protein, fiber, and essential vitamins and minerals. The association is particularly pronounced for added sugar. In an analysis of NHANES 2009–2010, 41% of participants (adults and children over the age of one) in the top quintile of ultra-processed food intake consumed > 20% of total energy in the form of added sugars, compared to < 5% of individuals in the bottom quintile [29]. Among a nationally representative sample of US households, grocery purchases of ultra-processed foods were inversely associated with adherence to the US dietary guidelines [31].

While the low nutritional quality of ultra-processed foods likely plays a role, ultra-processed foods may also adversely contribute to cardiometabolic health through mechanisms unrelated to nutritional composition [32]. Notably, the highly degraded physical structure of ultra-processed foods, as well as food additives and neo-formed contaminants produced during processing, may influence absorption kinetics, satiety, glycemic response, and the gut microbiota composition and function, all of which may promote CVD risk [33, 34•, 35–37]. Foods are biologically complex and the food matrix, defined as the naturally occurring constituents and their interactions within a food, influences biological systems [38]. Processing significantly changes the food matrix, for which ultra-processed foods and unrefined whole foods with similar nutritional composition may differentially affect cardiometabolic health outcomes.

Summary of Epidemiological Evidence

Metabolic Syndrome and Its Components

Metabolic syndrome is a cluster of interrelated risk factors for CVD and type 2 diabetes that includes hypertension, dyslipidemia, elevated fasting glucose, and central obesity [39]. High consumption of ultra-processed foods was associated with 28–90% higher odds of metabolic syndrome among adults in the USA ($n = 6{,}385$, adjusted prevalence ratio [APR]:1.28, 95% confidence interval [CI]: 1.09, 1.50 for quintile 5 vs. 1) and Canada ($n = 811$, adjusted odds ratio [AOR]: 1.90, 95% CI: 1.14, 3.17 for quintile 5 vs. 1) [40, 41]. Similarly, Brazilian adolescents with the greatest consumption of ultra-processed and processed foods had a 2.5-fold higher prevalence of metabolic syndrome than those with the lowest consumption (APR: 2.45, $p = 0.012$ [*95%CI not presented*], for quartile 3–4 vs. quartile 1–2) [42]. Greater adherence to a "minimally processed" dietary pattern was associated with lower odds of metabolic syndrome (AOR: 0.18, 95% CI: 0.04, 0.77 for medium/high vs. low adherence) among Lebanese adults ($n = 302$), while a null association was reported for consumption of an ultra-processed dietary pattern in this small study sample [43]. A null association was also observed between intake of "industrialized foods" (e.g., cake/pudding mix, chips, frozen meals, nuggets, sugar-based breakfast cereal, cookies) and metabolic syndrome in another very small study conducted among 6- to 10-year-old children in Brazil ($n = 147$) [44].

Hypertension

Among adults participating in the prospective Spanish Seguimiento Universidad de Navarra (SUN) study ($n = 14{,}790$, mean follow-up of 9 years) and the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil; $n = 8{,}754$, mean follow-up of 4 years), those in the highest tertile of ultra-processed food consumption had 21–23% higher risk of developing hypertension, compared to participants in the lowest tertile) [45, 46]. Intake of liquid ultra-processed foods, e.g., sugar-sweetened beverages (incidence rate ratio: 1.32, 95%CI 1.10, 1.65), but not total or solid ultra-processed foods, was associated with self-reported incident hypertension in the prospective Mexican Teachers' Cohort ($n = 64{,}934$ adult women) [47]. Ultra-processed food intake was not associated with high blood pressure in a small, cross-sectional study of 249 Brazilian adolescents (14–19 years old) [48].

Type 2 Diabetes and Glucose Metabolism

In the prospective French NutriNet-Santé cohort ($n = 104,707$ adults) and the UK Biobank cohort ($n = 21,730$), each 10% absolute increment of ultra-processed foods in the diet was associated with a 12–15% increased risk of incident type 2 diabetes [49, 88]. In the Spanish Seguimiento Universidad de Navarra (SUN) Study ($n = 20,060$), the participants consuming the most ultra-processed foods (top tertile) had a 53% relatively higher hazard of incident type 2 diabetes compared with participants in the lowest intake tertile (HR 1.53; 95% CI 1.06 to 2.22, p-trend: 0.024) [50]. Conversely, no association was observed between ultra-processed food intake at age 4 years and measures of glucose metabolism at age 8 years in a small cohort of Brazilian children ($n = 307$) [51].

Dyslipidemia

One prospective cohort study among older adults (> 60 years) [52] and two prospective analyses among children [53, 54] investigated the association between ultra-processed food intakes and dyslipidemia. In the Seniors-Study on Nutrition and Cardiovascular Risk in Spain (ENRICA) cohort ($n = 1,082$), ultra-processed food intake was associated with incident hypertriglyceridemia and low HDL, but not with high LDL cholesterol [52]. In two analyses of data from a small sample of Brazilian children ($n = 308$ and 345, respectively), higher consumption of ultra-processed foods at baseline (age 3–4 years) was associated with higher levels of total cholesterol and triglycerides at age 6 years [54] and greater increases in total and LDL cholesterol at 7–8 years [53].

Ideal Cardiovascular Health and Excess Heart Age

A cross-sectional study among US adults ($n = 11,246$) found that intake of ultra-processed foods was inversely associated with cardiovascular health based on the American Heart Association's ideal cardiovascular health index, which include smoking, physical activity, body mass index (BMI), total cholesterol, blood pressure, and fasting plasma glucose (excluding the healthy diet metric) [55]. Participants consuming the most ultra-processed foods had more than two-fold higher odds of poor cardiovascular health compared to those consuming the least (AOR: 2.57, 95% CI: 1.79, 3.70 for quartile 4 vs. 1) [55]. Another cross-sectional study among Americans aged 30–74 years ($n = 12,640$) found that greater intake of ultra-processed foods was associated with higher excess heart age (difference between estimated heart age by the Framingham heart age algorithm and chronological age) and greater likelihood of having an excess heart age of ≥ 10 years (AOR: 1.66 (95% CI:1.29, 2.14 for quintile 5 vs. 1) [56].

Obesity

One US randomized controlled trial [57••] and six high-quality prospective cohort studies conducted in Spain [58, 59], France [60], the UK [61], Brazil [62], and the multinational European Prospective Investigation into Cancer and Nutrition (EPIC) study [63] investigated the association between ultra-processed food intake and weight gain or excess adiposity in adults. In a randomized controlled trial with a crossover design, inpatients ($n = 20$) gained an average of 0.9 ± 0.3 kg body weight ($p = 0.009$) and 0.4 ± 0.1 kg body fat ($p = 0.0015$) when receiving an ultra-processed diet for 14 consecutive days [57••]. In contrast, participants lost an average of 0.9 ± 0.3 kg body weight ($p = 0.007$) and 0.3 ± 0.1 kg body fat when assigned an unprocessed diet for the same length of time. Diets were matched for calories, macronutrients, energy density, sugar sodium, and fiber, yet ad libitum daily energy intake was on average ~ 500 cal higher during the ultra-processed diet compared to the unprocessed diet ($p = 0.0001$) [57••].

A direct association between ultra-processed food intake and incident overweight/obesity [59, 62, 63], incident obesity [60, 62, 63], weight gain [63], and age-related visceral and overall adiposity accumulation [58] was consistently observed among adult participants in the European Prospective Investigation into Cancer and Nutrition (EPIC) study ($n = 348,748$), the NutriNet-Santé cohort ($n = 110,260$), the Seguimiento de Navarra study (SUN; $n = 8,451$), the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil; $n = 4,527$), and the PREDIMED-Plus cohort ($n = 1,485$). In the prospective UK Biobank cohort ($n = 22,659$, age range 40–69 years at baseline), participants consuming the most ultra-processed food had 79% higher risk of developing obesity (HR: 1.79, 95% CI: 1.06, 3.03) and 30% higher risk of developing abdominal obesity (HR: 1.30, 95% CI: 1.14, 1.48) compared to those consuming the least [61].

Findings from cross-sectional studies are largely in line with the prospective evidence. In two Brazilian cross-sectional studies, adults with the highest compared to the lowest intake of ultra-processed foods (≥ 29–44% calories vs. < 14–16% calories) had 31% greater odds of overweight [64], 41–98% greater odds of obesity [64, 65], and 41% greater odds of abdominal obesity [64]. In a nationally representative sample of US adults ($n = 15,977$), ultra-processed food intakes of ≥ 74.2 vs. ≤ 36.5% calories were associated with 48, 53, and 62% higher odds of overweight, obesity, and abdominal obesity, respectively (AOR: 1.48, 95%CI: 1.25, 1,76; AOR: 1.53, 95%CI: 1.29, 1.81; AOR 1.62, 95% CI: 1.39, 1.89, respectively) [66]. In both US and Brazilian populations, the association between ultra-processed food intake and BMI was more pronounced among women [65, 66]. Among adults in the UK National Diet and Nutrition Survey ($n = 2,174$), consumption

of minimally processed foods was inversely associated with excess adiposity, while no association was observed for ultra-processed foods [23]. However, it should be noted that this study combined processed and ultra-processed foods into a single exposure category.

Six prospective cohort studies conducted in the UK [67], Brazil [51, 68, 69], and Portugal [70] evaluated the association between ultra-processed food intake and indicators of excess weight among youth. In the Avon Longitudinal Study of Parents and Children ($n=9{,}025$), higher baseline intake of ultra-processed food intake was associated with greater increases in BMI, fat mass index, weight, and waist circumference from 7 to 24 years [67]. Likewise, ultra-processed food intake was associated with greater increases in fat mass index from age 6 to 11 among Brazilian children ($n=3{,}454$) [69]. In a smaller Brazilian study ($n=307$), ultra-processed food intake at age 4 years was associated with greater waist circumference, but not with BMI, waist to height ratio, or sum of skinfolds, at age 8 years [51]. Ultra-processed food intake was also associated with BMI z-score at age 10 ($\beta=0{\cdot}028$; 95% CI 0.006, 0.051) among 1,175 Portuguese children [70]. In contrast, ultra-processed food intake was inversely associated with BMI and body fat trajectories ($p<0.001$; risk estimates not published) among Brazilian adolescents over a 3-year follow-up ($n=1{,}035$) [68]. In the Portuguese Generation XXI cohort ($n=1{,}175$), ultra-processed food intake at age 4, but not at age 7, was directly associated with BMI z-score at age 10 years [70]. A small cross-sectional study conducted in Brazil ($n=249$) did not observe an association between ultra-processed food intake and excess weight or waist circumference among adolescents [48].

Cardiovascular Disease

Six high-quality prospective cohort studies conducted in the USA [71–74], France [32], and Italy [75] assessed the association between ultra-processed foods and cardiovascular disease (CVD) incidence ($n=3$) and/or mortality ($n=4$). A direct dose–response association was observed in all studies assessing CVD incidence [32, 71, 74] and in three out of the four studies evaluating CVD mortality [71, 73, 75]. In the prospective Framingham Offspring Study ($n=3{,}003$), each additional daily serving of ultra-processed foods was associated with a 7% (95% CI: 1.03, 1.12) increase in the risk of incident CVD during an average follow-up of 18 years [71]. The results remained robust when controlling for measures of excess weight and diet quality. In the French prospective NutriNet-Santé cohort study ($n=105{,}159$), each 10% increment in the consumption of ultra-processed foods was associated with a 11–13% increased risk of CVD, CHD, and cerebrovascular disease [32]. In a sample of 22, 275 Italian men and women followed for an average of 8.2 years, individuals consuming the most ultra-processed foods had a 58% increased risk of CVD mortality, compared to those consuming the least ((HR: 1.58; 95% CI: 1.23, 2.03) [75]. While no association was observed in relation to CVD mortality in a prospective analysis of the US Third NHANES ($n=11{,}898$), ultra-processed food consumption was associated with a 31% greater risk of all-cause mortality [72].

Literature Critique

In summary, the current evidence supports that higher total intake of ultra-processed foods is associated with increased risk of type 2 diabetes, excess weight, and CVD in adults. A limited number of studies also link ultra-processed food intake to the development of hypertension and dyslipidemia. These findings are consistent with those from meta-analyses of specific ultra-processed foods (processed meat, sugar-sweetened beverages) and nutrients that are abundant in ultra-processed foods (e.g., trans fats, sodium) in relation to cardiometabolic health [16–20].

Ultra-processed foods constitute a novel and emerging area of scientific enquiry. As a result, the current evidence base remains somewhat limited and is continuously evolving. Certain points regarding the design and quality of studies reviewed need to be mentioned. First, the design and sample size varied substantially, ranging from cross-sectional studies with small sample sizes to several large-scale cohort studies and one well-designed randomized controlled trial. Second, most studies lacked dietary assessment methods specifically designed to collect food processing level, contributing to exposure measurement error, and increasing the risk of null findings. Food frequency questionnaires, used widely in large cohort studies, often lack sufficient specificity to distinguish ultra-processed foods and information indicative of processing level may be insufficiently and inconsistently collected by 24-h dietary recalls [76]. Open-ended dietary assessment tools such as 24-h dietary recalls are the most appropriate methods to collect data regarding food processing level and should include probing questions to differentiate between food sources, types of processing, ingredients in mixed dishes, and brand/product names [76]. Alternatively, food frequency questionnaires could be enhanced for better validity of ultra-processed food exposure measurement [76]. Advancements in research methods will improve the precision of research on the topic of ultra-processed foods and health outcomes.

Implications for Public Health and Clinical Practice

Reducing the consumption of ultra-processed foods at the population level requires a consistent, multi-pronged effort (Fig. 2). Complex intra- and interpersonal and systemic

factors are at play, and the general public is often conflicted about what constitutes healthy nutrition. Clinicians and policymakers need to intensify and refine current approaches and strategically prioritize messages to patients and communities to combat the opposing efforts of the food industry. Consumption of ultra-processed foods represents an ideal dietary target as a) current evidence support a deleterious association with cardiometabolic risk; b) ultra-processed foods are highly prevalent, accessible, and affordable in the consumer marketplace; and c) diets low in ultra-processed foods can be compatible with all cultures and cuisines.

Population-Level Interventions

A variety of population-level approaches exist which, if consistently implemented, can be extremely effective to reduce the consumption of ultra-processed foods. Targeted food-literacy interventions are needed to educate individuals and communities about the characteristics and harms of ultra-processed foods, correct nutrition misinformation, and enhance behavioral skills at the point of purchase and required for preparation. Food literacy refers to the degree to which individuals are proficient in food-related skills and knowledge necessary to make appropriate food decisions to meet nutritional needs and improve health [77]. Examples of interventions to improve food-literacy include education-based programs for youth, such as "The Edible Schoolyard Project" [78].

Furthermore, there is an opportunity for the federal Dietary Guidelines for Americans to distinguish foods by processing levels and include explicit directives concerning the overall quality of foods. Future studies should determine if advice to limit ultra-processed foods and chose nutritious minimally processed foods is more effective for facilitating healthy food choices than the current federal recommendation to choose "nutrient-dense forms" of foods without added sugars, sodium, or saturated fat [79].

Given the omnipresence, convenience, palatability, affordability, and aggressive marketing of ultra-processed foods coupled with the relatively higher cost and limited availability of fresh whole foods in some environments (including schools) and for low-income individuals and communities, it is critical that educational efforts and dietary recommendations are supported by comprehensive local initiatives and governmental fiscal and regulatory policies (Fig. 2). Examples include providing price support for healthy whole foods and taxation of sugar-sweetened beverages and other ultra-processed foods, limiting the number of fast-food outlets near schools and hospitals (a strategy referred to as zoning), requiring front-of-package warning labels on products of low nutritional quality, and imposing stricter marketing regulations especially for marketing of ultra-processed foods towards children and youths. Criteria for public procurement of foods may also be set to limit the amount of ultra-processed foods that schools and other institutions acquire, and to increase purchases of locally produced, minimally processed foods. These strategies would have the added benefits of enhancing local agriculture and food systems.

Policies and public health efforts need to be sensitive to the fact that preparation of meals from minimally processed foods requires resources that are often scarce in disadvantaged populations, including education, time, cooking skills, and financial means. In order to not aggravate existing diet and

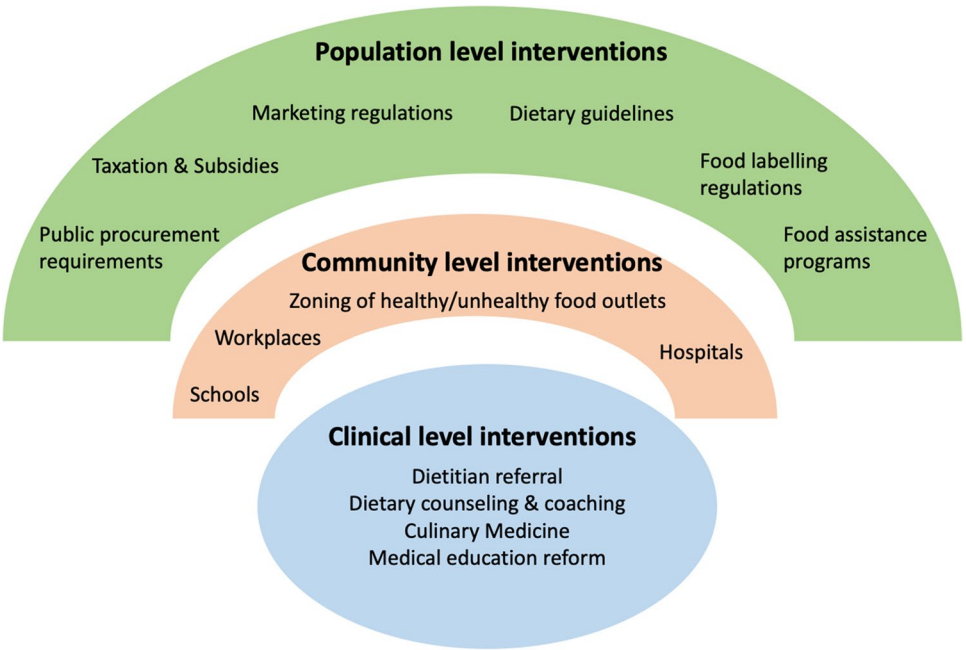

Fig. 2 Proposed population-, community-, and clinical-level interventions to reduce ultra-processed food consumption

health disparities that are worsened by food insecurity, it is critical to increase the availability, accessibility and affordability of nutritious, minimally processed foods, especially within low-resource populations and settings which are often labelled as food deserts. In this context, food assistance programs such as the Supplemental Nutrition Assistance Program (SNAP) could be designed to incentivize the consumption of nutritious, minimally processed foods and restrict the use of benefits for non-nutritious ultra-processed foods such as sugar-sweetened beverages [80]. However, to enable the implementation of policies in the public interest, it will be essential to reduce the influence of vested interests from the food industry in the public policy development process.

Clinical-Level Interventions

While a healthy diet represents a pillar of preventive medicine, its population-wide adoption remains challenging. In primary care and clinical medicine, dietary guidelines have primarily recommended avoiding trans fats and minimizing a few select ultra-processed foods, specifically processed red meats and sweetened beverages [81]. Based on the emerging evidence reviewed here, intensified efforts are needed for a more inclusive nutrition counseling strategy and global narrative concerning ultra-processed foods in patients' diets, highlighting their pervasive metabolic effects, ubiquitous availability, and "hidden" sources of sugar, fat, and salt in a variety of food formulations. The American Heart Association recently took an important step in this direction by including "choose minimally processed foods instead of ultra-processed foods" as one of 10 key evidence-based pieces of dietary guidance in their directive entitled, 2021 Dietary Guidance to Improve Cardiovascular Health [82••].

Healthcare providers need simple, evidence-based and meaningful dietary advice to communicate to their patients. When implemented, even a brief intervention can set a patient on a healthier nutrition trajectory [83]. In addition, referral to a registered dietitian nutritionist (RDN) for more comprehensive assessment, nutrition counseling, and tailored interventions customized to the individual's sociodemographic circumstance is often needed to achieve dietary behavior change. Healthcare providers are also well-positioned to champion local initiatives to promote healthy eating such as heart-healthy nutrition initiatives in hospitals [84]. In the clinic and the community, "culinary medicine" programs and "food is medicine" initiatives offer additional avenues for behavioral impact [85]. Additionally, leaders in medical education can advocate for the inclusion of nutrition science in medical school and health professions curricula. Finally, given their expertise and authority, healthcare providers can find additional venues to communicate and champion healthy nutrition by advocating and supporting legislative, regulatory, fiscal, and marketing strategies at local and national level.

Opportunities for Dietary Guidance

While ultra-processed foods encompass a broad spectrum of food products, directives concerning ultra-processed foods must be clearly articulated in advice given to patients or the public. This reality presents an important opportunity in the context of the emerging literature. Messages capable of specifically impacting awareness, knowledge, and behavioral skills required to purposefully lower intakes of ultra-processed foods must be incorporated in the current dietary advice that healthcare providers use to inform conversations with patients [82••] and guidelines for population-based health promotion [79]. By applying the principles of the NOVA framework, more targeted educational messages can be crafted to guide dietary behavior change (Table 1). Since most consumers cannot altogether avoid these foods for a variety of reasons including food insecurity and a heavily processed food environment, it is important to identify the most meaningful language to convey the distinction between nutrient-rich, minimally processed foods that are recommended for daily consumption and ultra-processed foods that are intended to be limited to infrequent consumption if not avoided altogether. Consumer research to hone these messages seems important to achieve clarity in an empowering message grounded in positive nutrition rather than negative nutrition messages shrouded in judgement.

As the concept and definition of ultra-processed foods are not yet widely known, they have been criticized as ambiguous and prone to misclassification [86]. To avoid confusion, it is essential that dietary guidance to patients and the public clearly define what ultra-processed foods are. Educational public health campaigns may also be helpful to increase awareness and knowledge about ultra-processed foods. Furthermore, dietary guidance based on NOVA should be formulated to complement and enhance, rather than replace, current guidelines based on nutrients and specific foods. As shown by a recent study comparing the nutrient profiling system Food Compass to the NOVA classification, the vast majority of ultra-processed foods received a low food compass score, indicating poor nutritional quality [87]. Only 12.8% of ultra-processed foods received a Food Compass score > 70 (out of 100), indicating good nutritional quality [87]. Therefore, recommendations to limit ultra-processed foods and choose fewer processed foods, when possible, have the potential to enhance current dietary guidelines and to help individuals select more healthful options within each food category.

Conclusions

A growing body of evidence conducted in a variety of study populations supports an association between ultra-processed food intake and increased risk of metabolic syndrome, hypertension, type 2 diabetes, overweight and obesity trajectories, and cardiovascular disease. The high intake of ultra-processed foods in all population groups and its associated risks make

Table 1 Combining the principles of the NOVA framework with the American Heart Association dietary guidelines [82••] and the Dietary Guidelines for Americans 2020–2025 (79) to achieve healthy dietary pattern and healthful food choices

American Heart Association Dietary Guidelines	Dietary Guidelines for Americans 2020–2025	Operationalization of dietary guidelines based on NOVA	
Recommended dietary patterns			
Fruits and vegetables: Eat plenty of fruits and vegetables, choose a wide variety	Fruits, especially whole fruits	Choose more: Fresh fruits and those processed (canned, frozen or dried) without added sugars, dyes, flavorings or preservatives	Choose less: Processed fruits with sugar or honey added, fruit drinks that are not 100% fruit juice and have sugars and/or high-fat dairy ingredients added (like whipped cream)
	Vegetables of all types – dark green; red and orange; beans, peas, and lentils; starchy; and other vegetables	Choose more: Vegetables, including dark green, red and orange, legumes (beans and peas), starchy, and other vegetables that are fresh or processed (canned, frozen or dried) without added sugars, fats/oils, salt, vinegar, dyes, flavorings or preservatives	Choose less: Canned vegetables with added salt, frozen vegetables with added salt, sugars, or fats including cream or cheese sauce, pickled vegetables, fried vegetables including fast food and French fries
Grains: Choose foods made mostly with whole grains rather than refined grains	Grains, at least half of which are whole grain	Choose more: Fiber-rich whole grain breads, cereals, pasta and rice (constituting at least half of daily grain choices) and other grains that are minimally processed without added sugars, fats, salt, dyes, flavorings or preservatives	Choose less: Refined grains, breads, cereals, pasta and rice that contain <2 gm of fiber per serving and added sugars, fats, salt, dyes, flavorings and preservatives; sweetened breakfast cereals, salty snack foods like chips and crackers, granola bars and energy bars, commercially baked breads, sweets and desserts
Protein: Choose healthy sources of protein; mostly protein from plants (legumes and nuts); fish and seafood; low-fat or fat-free dairy products instead of full-fat dairy products; if meat or poultry are desired, choose lean cuts and avoid processed forms	Protein foods, including lean meats, poultry, and eggs; seafood; beans, peas, and lentils; and nuts, seeds, and soy products	Choose more: A variety of protein foods including fresh dried legumes (beans and peas); fresh fish and other seafoods; unprocessed lean meats; fresh poultry; eggs; unsalted nuts and seeds without added oils	Choose less: Processed meat including deli meats, hot dogs and sausages; salted, smoked or cured meat or fish; processed poultry (chicken nuggets, breaded tenders or patties); fish sticks/breaded fish patties; fast food entrees; canned beans and soups with added salt and preservatives; salted nuts and seeds or those roasted with added oils
Dairy, low-fat or fat-free dairy products instead of full-fat dairy products	Dairy, including fat-free or low-fat milk, yogurt, and cheese, and/or lactose-free versions and fortified soy beverages and yogurt as alternatives	Choose more: Minimally processed dairy products such as unsweetened plain milk and yogurt, cheeses without additives, low-fat varieties of dairy foods, where possible	Choose less: Sweetened and/or flavored dairy products; non-dairy milks with additives (emulsifiers, sweeteners, flavors, preservatives); ultra-processed cheese products and imitation cheese products
Oils, use liquid plant rather than tropical oils (coconut, palm, and palm kernel), animal fats (e.g., butter and lard), and partially hydrogenated fats	Oils, including vegetable oils and oils in food, such as seafood and nuts	Choose more: Olive oil and other vegetable oils	Choose less: Foods with high fat content derived from deep frying, as in fast foods; ultra-processed dressings, sauces and spreads with additives and/or salt and sugar, including "light" and low-calorie products
Ultra-processed foods, choose minimally processed foods instead of ultra-processed foods	Not specified	Limit or avoid ultra-processed foods	

Table 1 (continued)

American Heart Association Dietary Guidelines	Dietary Guidelines for Americans 2020–2025	Operationalization of dietary guidelines based on NOVA
Foods & nutrients to limit		
Trans fats should be replaced with non-tropical liquid plant oils	Trans fats, read Nutrition Facts labels and choose foods with no trans fats	Limit or avoid: Fast foods, commercially manufactured baked goods and fried foods to limit the intake of trans fat
Saturated fats should be replaced with non-tropical liquid plant oils	Saturated fat, < 10%kcal per day starting at age 2	Limit or avoid: Products with added animal fats (cream, butter, lard) and hydrogenated fats like coconut oil. Read food labels and beware of hidden fats used as ingredients in ultra-processed foods. Use olive oil or other vegetable oils as your primary source of added fat
Added sugar, minimize intake of beverages and foods with added sugars	Added sugar, < 10%kcal per day starting at age 2. Avoid foods and beverages with added sugars for those younger than age 2	Limit or avoid: Ultra-processed foods including soft drinks and other sugar-sweetened beverages including fruit drinks, sports drinks, smoothies and sweetened coffees and teas; sugary beverages mixed with alcohol; candy; ice cream; cakes, dessert confections and cookies; pastries; and condiments containing added sugars such as ketchup/barbeque sauce
Sodium, choose and prepare foods with little or no salt	Sodium, < 2300 mg/day, and even less for children younger than age 14	Limit or avoid: Ultra-processed foods with visible salt (salted chips, nuts and crackers) and with hidden salt (instant soups, frozen dinners, condiments, commercially baked sweets and desserts, deli and processed or breaded meats, cheeses, frozen vegetables with cheese sauce, bottled salad dressings, salty condiments such as soy sauce, etc.); read food labels to look for added salt ingredients and sodium content per serving. Limit your salt use at the table and in cooking
Alcohol, if you do not drink alcohol, do not start; if you choose to drink alcohol, limit intake	Alcohol, adults of legal drinking age can choose not to drink, or to drink in moderation by limiting intake to 2 drinks or less in a day for men and 1 drink or less in a day for women. Drinking less is better for health than drinking more	Limit or avoid: Drink no more than one alcoholic drink/day for women and no more than two drinks/day for men; limit sugary beverages mixed with alcohol; read labels to avoid added sugars and additives (preservatives, flavors, colors) in beer, wine, flavored hard liquor, spiked seltzers, and hard cider

ultra-processed foods an ideal target for intensive health promotion messaging and interventions. Policy efforts and dietary guidance at both the population and individual levels need to address a more comprehensive definition of ultra-processed foods that goes beyond so-called "empty calorie" or "junk" foods. Healthcare providers are at the forefront of championing nutrition for health promotion and a variety of approaches exist at the patient and clinic-level, as well as through advocacy at the population-level.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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•• Of major importance

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