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RESEARCH ARTICLE

# Premature Mortality Attributable to Ultraprocessed Food Consumption in 8 Countries

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**Introduction:** Ultraprocessed foods are becoming dominant in the global food supply. Prospective cohort studies have consistently found an association between high consumption of ultraprocessed foods and increased risk of several noncommunicable diseases and all-cause mortality. The study aimed to (1) estimate the risk of all-cause mortality for ultraprocessed foods consumption and (2) estimate the attributable epidemiologic burden of ultraprocessed food consumption in 8 select countries.

**Methods:** First, a dose–response meta-analysis of observational cohort studies was performed to assess the association between ultraprocessed food consumption and all-cause mortality and estimated the pooled RR for all-cause mortality per each 10% increment in the percentage ultraprocessed food. Then, the population attributable fractions for premature all-cause mortality attributable to the ultraprocessed foods in consumption were estimated in 8 select countries with relatively low (Colombia and Brazil), intermediate (Chile and Mexico), and high (Australia, Canada, United Kingdom, and the U.S.) ultraprocessed food consumption. Analysis was conducted in November 2023–July 2024.

**Results:** The meta-analysis showed a linear dose–response association between the ultraprocessed food consumption and all-cause mortality (RR for each 10% increase in percentage ultraprocessed food=1.03; 95% CI=1.02, 1.04). Considering the magnitude of the association between ultraprocessed foods intake and all-cause mortality and the ultraprocessed food dietary share number (percentage ultraprocessed food) in each of the 8 selected countries, estimations varied from 4% (Colombia) to 14% (United Kingdom and U.S.) of premature deaths attributable to ultraprocessed food intake.

**Conclusions:** The findings support that ultraprocessed food intake contributes significantly to the overall burden of disease in many countries, and its reduction should be included in national dietary guideline recommendations and addressed in public policies.
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## INTRODUCTION

Ultraprocessed foods (UPFs), as defined by the Nova classification, are industrial formulations made from food-derived substances and cosmetic food additives with little, if any, whole food. UPFs are frequently energy dense and nutritionally unbalanced and made of ingredients and processes that create highly palatable and convenient low-cost products and have the potential to replace unprocessed or minimally processed foods and culinary preparations.[1]

UPFs are becoming dominant in part of the global food supply[2] and already account for over half of the average daily energy content of the diets in many high-income countries.[3−5] Although UPF consumption remains lower in low- and middle-income countries, there is evidence that the exposure and adherence to a ultraprocessed dietary pattern has increased significantly over the last decades.[6]

An increasing body of scientific evidence, including many observational cohort studies and meta-analyses, have consistently found an association between the adherence to ultraprocessed dietary pattern and increased risk of several noncommunicable diseases, such as obesity, diabetes, cardiovascular diseases, and some types of cancer.[7−9] Of note, a recent umbrella review, including 45 pooled analyses with almost 9.8 million participants, found that adherence to ultraprocessed dietary pattern was associated with 32 poor physical and mental health outcomes.[10]

Previous modeling studies, using different methodologic approaches, including the Global Burden of Disease Study, have estimated the potential impact of specific dietary risk factors on all-cause and cause-specific noncommunicable diseases, including morbidity, mortality, and disability-adjusted life years, by assessing the inadequate consumption of macro and micronutrients and the consumption of specific foods (such as sugar-sweetened beverages, processed meats, fruits, and vegetables).[11−15] However, studies modeling the impact of consuming UPFs are just developing.[16−18]

In this study, the authors (1) conducted a meta-analysis to estimate the dose−response association between UPF consumption and all-cause mortality and (2) estimated the population attributable fractions (PAFs) and the total number of all-cause premature deaths (ages 30−69 years)[19] attributable to UPF consumption pattern in adults from 8 countries with relatively low (Colombia and Brazil), intermediate (Chile and Mexico), and high (Australia, Canada, United Kingdom, and U.S.) consumption of UPF.

## METHODS

First, the authors performed a dose−response meta-analysis of observational cohort studies assessing the association between the UPF dietary share and all-cause mortality. Studies were selected on the basis of recently published systematic reviews on low versus high UPF consumption dietary pattern and all-cause mortality.[7,20,21] The authors included only studies that assessed UPF intake according to Nova classification and excluded studies assessing UPF as individual food items (e.g., sugar-sweetened beverages). In these previously published meta-analyses, 10 prospective studies examined the association between UPF and all-cause mortality.[22−30] The authors contacted the corresponding author of these studies and asked whether they could provide estimates after converting UPF intake to percentage of total energy intake. The authors obtained this information from 7 studies.[22−27]

The authors extracted the maximally adjusted RRs (confounders included in the models are displayed in the Appendix Material, available online) and 95% CIs for all-cause mortality for each category of contribution (%) of UPFs on total energy intake (e.g., quartiles of percentage UPF) and considered the mean or medium value of percentage UPF in each category (dose). For the highest category of UPF intake (e.g., 4th quartile), the authors considered the dose as the lowest value of percentage of UPF in the category. The authors also obtained the number of participants and deaths in each category of percentage UPF. The authors performed a random-effects dose−response model using generalized least squares for trend estimation of summarized dose−response data. Random effects meta-analysis assumed that the true UFP effect on all-cause mortality differs from study to study and provides an estimate of the average effect. Of note, RR estimates for some countries included in the study (Brazil, Chile, Mexico, and Australia) are lacking. Therefore, the authors used the average effect (RR) obtained from the random-effects meta-analysis model from all countries included in the study.

The authors estimated the pooled RR (and its 95% CI) for all-cause mortality per each 10% increment in the percentage UPF as the authors found evidence of linearity. The authors conducted leave-one-out sensitivity analysis to assess the robustness of the main analysis.

The consumption of UPFs, stratified by sex, was obtained from microdata of the most recent national dietary surveys in each country (Table 1): the

Pesquisa de Orçamentos Familiares 2017−2018 (Brazil), the National Health and Nutrition Examination Survey 2017−2018 (U.S.), National Diet and Nutrition Survey 2018−2019 (United Kingdom), Canadian Community Health Survey 2015 (Canada), Encuesta Nacional de Salud y Nutrición 2016 (Mexico), Encuesta Nacional de Situación Nutricional 2015 (Colombia), Encuesta Nacional de Consumo Alimentario 2010 (Chile), and National Nutrition and Physical Activity Survey 2011−2012 (Australia). Foods and beverages were classified according to the Nova food classification system into 4 major groups: unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and UPFs. The UPF dietary share was measured on the basis of the contribution of UPF to total energy intake, which was computed as the ratio of the mean energy from the UPF group over the mean total energy intake of the diet. All data used in this study are publicly available and deidentified; therefore, IRB approval was not required.

The authors estimated the PAFs of all-cause premature mortality (ages 30−69 years) attributable to the consumption of UPF on the basis of the framework of a previously published comparative risk assessment model.[17] The PAFs and attributable deaths referred to the proportion and the number of all-cause premature deaths that could be averted by reducing the consumption of UPFs to the theoretical minimum risk level, assumed as 0% of the total energy intake. PAF was calculated using the following equation:

$$PAF = \frac{\int_l^h RR(x)P(x)dx - \int_l^h RR(x)P*(x)dx}{\int_l^h RR(x)P(x)dx}$$

Where x denotes the values that the adherence to ultraprocessed dietary pattern can take on (0%−100%), RR is the RR function (log linear) for all-cause mortality, P(x) is the percentage of UPF intake in each country, P*(x) is the theoretical minimum risk exposure level (assumed as 0% of UPF intake), dx denotes that the integration was done with respect to x, and l and h are the integration boundaries.

Data on premature deaths that occurred on the same year of the national dietary survey for each country were obtained from the Global Burden of Disease Study.[30] Monte Carlo simulation with 5,000 iterations was used to estimate the uncertainty of the PAFs attributable to the consumption of UPF. Data analyses were performed in Stata, Version 17; Microsoft Excel; and Ersatz.

## RESULTS

The main results extracted from each of the 7 prospective cohort studies included in the meta-analysis are displayed in Table 2. The dose−response meta-analysis for the association between the dietary share of UPF (percentage of UPF on total energy intake) and all-cause mortality, including 239,982 participants and 14,779 deaths, is displayed in Figure 1. The pooled RR for each 10% increase in percentage of UPF on total energy intake was 1.027 (95 % CI=1.017, 1.037; $p<0.0001$). Leave-one-out sensitivity analysis provided results consistent with those of the main analysis.

The average contribution of UPF to total energy intake varied among the countries. Lower UPF consumption was observed in Latin American countries. Whereas UPF consumption represented <20% of energy intake in Colombia and Brazil, it increased to 20%−30% in Chile and Mexico. UPF consumption increased significantly in the other countries, such as Australia (37.5%) and Canada (43.7%), and exceeded 50% of the energy intake in the United Kingdom and in the U.S. (Table 3).

In the 8 selected countries, PAFs ranged widely according to the average consumption of UPFs, going from 3.9% in Colombia, the country with the lowest UPF consumption levels, to almost 14% in the United Kingdom and the

**Table 1.** UPF Consumption as Percentage of Total Energy Intake in National Dietary Surveys by Country and Year

| Country | Survey, year | Age, years | Mean (95%CI) |
|---|---|---|---|
| Brazil | POF, 2017−2018 | 30−69 | 17.4 (17.1, 17.7) |
| U.S. | NHANES, 2017−2018 | 30−69 | 54.5 (52.8, 56.1) |
| United Kingdom | NDNS, 2018−2019 | 30−69 | 53.4 (51.6, 55.3) |
| Canada | CCHS-Nutrition, 2015 | 30−69 | 43.7 (42.7, 44.7) |
| Mexico | ENSANUT, 2016 | 30−69 | 24.9 (22.6, 27.1) |
| Colombia | ENSIN, 2015 | 30−69 | 15.0 (14.2, 15.7) |
| Chile | ENCA, 2010 | 30−69 | 22.8 (21.6, 24.0) |
| Australia | NNPAS, 2011−2012 | 30−69 | 37.5 (36.8, 38.2) |

ENCA, Encuesta Nacional de Consumo Alimentario; ENSANUT, Encuesta Nacional de Salud y Nutrición; ENSIN, Encuesta Nacional de Situación Nutricional; CCHS, Canadian Community Health Survey; NDNS, National Diet and Nutrition Survey; NHANES, National Health and Nutrition Examination Survey; NNPAS, National Nutrition and Physical Activity Survey; POF, Pesquisa de Orçamentos Familiares; UPF, ultraprocessed food.

**Table 2.** Main Results Extracted From Studies Included in the Dose−Response Meta-Analysis on the Association Between the Dietary Share of UPF and All-Cause Mortality

| | | | | Maximally adjusted RR | | |
|---|---|---|---|---|---|---|
| UPF category | Dose (% UPF) | Participants | Deaths | RR | 95% CI | |
| Blanco-Rojo/2019 | | | | | | |
| First quartile | 8.68 | 2,976 | 158 | 1 | 1 | 1 |
| Second quartile | 18.60 | 2,974 | 105 | 0.91 | 0.67 | 1.23 |
| Third quartile | 27.82 | 2,974 | 103 | 1.23 | 0.91 | 1.67 |
| Fourth quartile | 42.83 | 2,974 | 74 | 1.44 | 1.01 | 2.07 |
| Rico-Campa/2019 | | | | | | |
| First quartile | 14.70 | 4,975 | 108 | 1 | 1 | 1 |
| Second quartile | 22.50 | 4,975 | 74 | 1.18 | 0.85 | 1.63 |
| Third quartile | 28.60 | 4,975 | 80 | 1.39 | 1.00 | 1.93 |
| Fourth quartile | 35.90 | 4,974 | 73 | 1.44 | 1.01 | 2.05 |
| Schnabel/2019 | | | | | | |
| First quartile | 10.80 | 11,137 | 147 | 1 | 1 | 1 |
| Second quartile | 24.90 | 11,138 | 141 | 0.84 | 0.64 | 1.11 |
| Third quartile | 31.95 | 11,138 | 148 | 0.79 | 0.59 | 1.06 |
| Fourth quartile | 35.70 | 11,138 | 166 | 1.10 | 0.83 | 1.45 |
| Bonaccio/2021 | | | | | | |
| First quartile | 11.50 | 5,618 | 492 | 1 | 1 | 1 |
| Second quartile | 17.90 | 5,619 | 313 | 1.07 | 0.92 | 1.23 |
| Third quartile | 23.00 | 5,619 | 224 | 1.17 | 1.02 | 1.36 |
| Fourth quartile | 29.90 | 5,619 | 187 | 1.26 | 1.09 | 1.46 |
| Ferreiro/2021 | | | | | | |
| First quartile | 6.90 | 846 | 96 | 1 | 1 | 1 |
| Second quartile | 18.55 | 881 | 90 | 1.15 | 0.87 | 1.53 |
| Third quartile | 28.45 | 871 | 59 | 1.22 | 0.88 | 1.70 |
| Fourth quartile | 33.60 | 826 | 58 | 1.62 | 1.08 | 2.43 |
| Chen/2022 | | | | | | |
| First quartile | 10.40 | 15,075 | 596 | 1 | 1 | 1 |
| Second quartile | 26.05 | 15,073 | 621 | 1.03 | 0.92 | 1.16 |
| Third quartile | 37.15 | 15,075 | 636 | 1.06 | 0.94 | 1.19 |
| Fourth quartile | 43.00 | 15,075 | 737 | 1.22 | 1.08 | 1.38 |
| Orlich/2022 | | | | | | |
| First quintile | 8.50 | 15,442 | 1917 | 1 | 1 | 1 |
| Second quintile | 20.80 | 15,342 | 1961 | 1.03 | 0.96 | 1.10 |
| Third quintile | 28.05 | 15,415 | 1946 | 1.08 | 1.00 | 1.16 |
| Fourth quintile | 36.05 | 15,500 | 1765 | 1.09 | 1.01 | 1.17 |
| Fifth quintile | 68.20 | 15,738 | 1704 | 1.14 | 1.05 | 1.23 |

UPF, ultraprocessed food.

U.S., where UPF consumption was higher among the countries studied. The absolute number of premature deaths per year attributable to UPF (i.e., which is influenced by PAF, number of premature deaths, and population size) ranged from more than 2 thousand in Chile to almost 124 thousand in the U.S. (Table 3).

## DISCUSSION

In this study, the authors investigated the relationship between the consumption of UPFs and all-cause mortality, uncovering a linear dose−response association. The study findings indicate that with each 10% increase in UPF contribution to total energy intake, there is a corresponding 2.7% rise in the risk of all-cause mortality. Moreover, the authors estimated the proportion of premature deaths attributable to UPF consumption in 8 selected countries, ranging from approximately 4% in Colombia to 14% in both the United Kingdom and the U.S., on the basis of the magnitude of the association between UPFs intake and all-cause mortality.

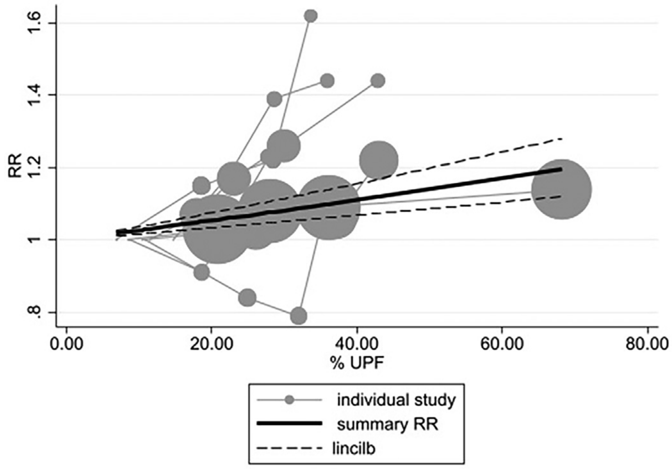


**Figure 1.** Dose−response meta-analysis for the association between the dietary share of UPF (percentage of UPF on total energy intake) and all-cause mortality in 7 prospective cohort studies, including 239,982 participants and 14,779 deaths.
UPF, ultraprocessed food.

First, the findings showing a linear, dose−response association between ultraprocessed intake and all-cause mortality, solely on the basis of analyses using the contribution of UPF on total energy, adds knowledge to the body of the epidemiologic evidence on UPF and health outcomes.[10] Second, by assessing premature all-cause mortality in countries with different levels of consumption of UPFs, the results may additionally contribute to the evidence on the epidemiologic burden of dietary exposures in both middle- and high-income countries using modeling tools that could be useful to support surveillance, public policies, and interventions for promoting healthy diets.

Many previous modeling studies estimated the health and economic burden of critical nutrients and specific foods/drinks.[11−15] In addition, other modeling studies in different countries estimated the potential impacts of reducing the consumption of sugar-sweetened beverages on obesity-related deaths.[12,31−34] However, to the authors' knowledge, the potential impact of the dietary contribution of UPF on premature deaths has only been investigated in Brazil, using the available RRS at the time, which highlighted the importance of dietary patterns on health over a nutrient approach.[18]

A major limitation of assessing individual nutrients and specific foods is that possible synergies between them and their impacts on population health are not incorporated in the analyses. In addition, epidemiologic studies assessing the association between specific foods and nutrients on health outcomes are prone to residual confounding by other constituents of diet.[35] Considering the reasons mentioned earlier, the study leveraged data on the association between the dietary contribution of UPF (or the adherence to the ultraprocessed dietary pattern) and all-cause mortality.[35] This methodologic decision was supported by a set of justifications, commencing with the extensive detrimental health impact of UPF intake described in the literature. In addition, there is growing evidence on the associations between the consumption of UPFs with specific health outcomes such as diabetes, obesity, cancer, and cardiovascular disease.[10] The mechanisms of these health effects are likely associated with excessive consumption, displacement of staple foods and poor nutritional dietary quality, food additives and other xenobiotics, physical structure, and other attributes of UPFs such as the increased risk of obesity and other cardiometabolic outcomes.[36]

It is also likely that addressing specific diseases associated with UPF consumption may underestimate the attributable mortality, because of the complexity and the number of diseases and health outcomes potentially associated with UPFs through the mechanisms previously mentioned. In the particular case of UPF, the Nova food classification has only been included in cohorts in the last decade, and associations of high UPF intake started first with obesity, diabetes, and cardiovascular diseases but now include 32 different health parameters, including mortality; cancer; and mental, respiratory, cardiovascular, gastrointestinal, and metabolic outcomes.[10] Therefore, all-cause mortality works as a summative marker of the total burden of UPF consumption, estimating its average total net effect as a surrogate outcome of the total burden attributable to UPF, considering the premature deaths (ages 30−69 years) in

**Table 3.** Premature Deaths Attributable to UPF Consumption Levels in 8 Countries

| | UPF intake (% of total energy) | | | Population attributable fraction | | | Premature deaths | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total | Attributable to UPF consumption | | |
| Country, year | UPF | 95% CI | | % | 95% CI | | Number | Number | 95% CI | |
| Colombia, 2015 | 15.0 | 14.2 | 15.7 | 3.9 | 2.5 | 5.4 | 72,940 | 2,813 | 1,860 | 3,906 |
| Brazil, 2017–2018 | 17.4 | 17.1 | 17.7 | 4.5 | 3.0 | 6.2 | 556,696 | 25,296 | 16,887 | 34,750 |
| Chile, 2010 | 22.8 | 21.6 | 24.0 | 5.7 | 3.8 | 8.0 | 32,607 | 1,874 | 1,231 | 2,610 |
| Mexico, 2016 | 24.9 | 22.6 | 27.1 | 6.3 | 4.1 | 8.8 | 272,293 | 17,110 | 11,184 | 23,852 |
| Australia, 2011–2012 | 37.5 | 36.8 | 38.2 | 9.4 | 6.3 | 12.8 | 34,994 | 3,277 | 2,204 | 4,472 |
| Canada, 2016 | 43.7 | 42.7 | 44.7 | 10.9 | 7.3 | 14.8 | 70,994 | 7,735 | 5,175 | 10,527 |
| UK, 2018–2019 | 53.4 | 51.6 | 55.3 | 13.8 | 9.0 | 19.0 | 128,743 | 17,781 | 11,621 | 24,499 |
| U.S., 2017–2018 | 54.5 | 52.8 | 56.1 | 13.7 | 9.1 | 18.8 | 906,795 | 124,107 | 82,804 | 170,801 |

UK, United Kingdom; UPF, ultraprocessed food.

each country. The premature deaths have a large societal relevance because they are mostly preventable and represent high direct and indirect costs to families and economies.

Notably, UPFs are heavily marketed and dominate the global food supply.[2] The increase in their consumption globally over the last decades is mostly represented by the low- and middle-income countries gradually replacing their traditional diets predominantly made of fresh foods and culinary preparations.[6] UPFs represent over half of the energy content of the diets in many high-income countries, and consumption is high in almost all population subgroups.[3–5] UPF intake starts early in life, and frequently, children and adolescents proportionally consume more UPF than adults in many countries, likely representing a higher risk of noncommunicable diseases in adulthood.[37,38]

These findings suggest that UPF consumption represents a relevant public health issue globally, and policy responses should reshape food systems to incentive the consumption of fresh and minimally processed foods as well as culinary preparations and disincentive UPFs. Reducing the consumption of UPFs requires multiple interventions and policies, such as creating healthy and supportive environments, through various strategies, including food-based dietary guidelines and fiscal and regulatory policies, such as the regulation of food marketing and sales of foods in school and work environments, the implementation of front-of-package nutritional labeling, subsidies for the production and sales of fresh local foods, and taxation of UPFs.[39–45]

## Limitations

As strengths of this study, studies using comparative risk assessment have been extensively validated and replicated in different countries for dietary risk factors and assessing the potential impacts of food policies.[14,46–49] In addition, the estimation of UPF intake was based on the most recent representative national dietary surveys of each country using comparable methods for food classification.[50] Mortality and demographic data were obtained from robust national official statistical records and international estimates. Finally, the RRs incorporated in the model were obtained from recent observational studies from various countries that assessed the consumption of UPF on the basis of their contribution to the total energy intake. Limitations of this study include the limited number of cohort studies that evaluated the association between the dietary patterns and all-cause mortality on the basis of the contribution to total energy of the diet. Limitations of the model include the incorporation of inputs prone to residual confounding, the use of similar RRs for all age and sex groups, and the failure to capture potential time lag between dietary changes and mortality. Although the authors extracted RR estimates adjusted for potential confounders from each individual study, residual confounding cannot be ruled out. Of note, the small RR of 1.03 corresponds to a 10% increment in the percentage of UPF on total energy intake, meaning that a high amount of UPF intake can significantly affect health. In addition, the magnitude of the association is similar to what has been reported in a recent umbrella review on UPFs and health outcomes.[10] Finally, there are only a few risk factors and preventive interventions with substantial impact on human health to influence all-cause mortality outcomes. For cause-specific mortality (e.g., diabetes and cardiovascular disease), the magnitude of the associations with UPF is higher than for all-cause mortality.[10]

## CONCLUSIONS

These findings highlight that adherence to ultraprocessed dietary pattern represents a relevant public health concern in middle- and high-income countries. The findings support the need for reducing the consumption of UPF through creation of healthy environments using regulatory and fiscal policies. National dietary guidelines of the 21st century must consider the purpose and extent of industrial processing of foods in their recommendations and the body of existing evidence on UPF and human health.[51,52]

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## SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2025.02.018.

## REFERENCES

1. Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. *Public Health Nutr.* 2019;22 (5):936–941. https://doi.org/10.1017/S1368980018003762.
2. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. *Obes Rev.* 2013;14(suppl 2):21–28. https://doi.org/10.1111/obr.12107.
3. Mertens E, Colizzi C, Peñalvo JL. Ultra-processed food consumption in adults across Europe. *Eur J Nutr.* 2022;61(3):1521–1539. https://doi.org/10.1007/s00394-021-02733-7.
4. Moubarac JC, Batal M, Louzada ML, Martinez Steele E, Monteiro CA. Consumption of ultra-processed foods predicts diet quality in Canada. *Appetite.* 2017;108:512–520. https://doi.org/10.1016/j.appet.2016.11.006.
5. Liu J, Steele E, Karageorgou D, Micha R, Monteiro C, Mozaffarian D. Consumption of ultra-processed foods and diet quality among U.S. adults and children. *Curr Dev Nutr.* 2020;4:543. https://doi.org/10.1093/cdn/nzaa046_043.
6. Levy RB, Andrade GC, da Cruz GL, et al. Three Decades of Household Food Availability According to NOVA - Brazil, 1987−2018. *Rev Saúde Publ.* 2022;56:75. https://doi.org/10.11606/s1518-8787.2022056004570
.
7. Pagliai G, Dinu M, Madarena MP, Bonaccio M, Iacoviello L, Sofi F. Consumption of ultra-processed foods and health status: a systematic review and meta-analysis. *Br J Nutr.* 2021;125(3):308–318. https://doi.org/10.1017/S0007114520002688.
8. Suksatan W, Moradi S, Naeini F, et al. Ultra-processed food consumption and adult mortality risk: a systematic review and dose-response meta-analysis of 207,291 participants. *Nutrients.* 2021;14(1):174. https://doi.org/10.3390/nu14010174.
9. Moradi S, Entezari MH, Mohammadi H, et al. Ultra-processed food consumption and adult obesity risk: a systematic review and dose-response meta-analysis. *Crit Rev Food Sci Nutr.* 2023;63(2):249–260. https://doi.org/10.1080/10408398.2021.1946005.
10. Lane MM, Gamage E, Du S, et al. Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. *BMJ.* 2024;384:e077310. https://doi.org/10.1136/bmj-2023-077310.
11. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet.* 2020;396 (10258):1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2.
12. Salgado MV, Penko J, Fernandez A, et al. Projected impact of a reduction in sugar-sweetened beverage consumption on diabetes and cardiovascular disease in Argentina: a modeling study. *PLoS Med.* 2020;17(7):e1003224. https://doi.org/10.1371/journal.pmed.1003224.
13. Dötsch-Klerk M, Bruins MJ, Detzel P, et al. Modelling health and economic impact of nutrition interventions: a systematic review. *Eur J Clin Nutr.* 2023;77(4):413–426. https://doi.org/10.1038/s41430-022-01199-y.
14. Verly Jr E, ÍE Machado, Meireles AL, Nilson EAF. Avoidable diet-related deaths and cost-of-illness with culturally optimized modifications in diet: the case of Brazil. *PLoS One.* 2023;18(7):e0288471. https://doi.org/10.1371/journal.pone.0288471.

15. Pearson-Stuttard J, Kypridemos C, Collins B, et al. Estimating the health and economic effects of the proposed U.S. Food and Drug Administration voluntary sodium reformulation: microsimulation cost-effectiveness analysis. *PLoS Med.* 2018;15(4):e1002551. https://doi.org/10.1371/journal.pmed.1002551.
16. Nilson EAF, Ferrari G, Louzada MLDC, Levy RB, Monteiro CA, Rezende LFM. The estimated burden of ultra-processed foods on cardiovascular disease outcomes in Brazil: a modeling study. *Front Nutr.* 2022;9:1043620. https://doi.org/10.3389/fnut.2022.1043620.
17. Nilson EAF, Ferrari G, Louzada MLC, Levy RB, Monteiro CA, Rezende LFM. Premature deaths attributable to the consumption of ultraprocessed foods in Brazil. *Am J Prev Med.* 2023;64(1):129–136. https://doi.org/10.1016/j.amepre.2022.08.013.
18. Taneri PE, Wehrli F, Roa-Díaz ZM, et al. Systematic review and meta-and pooled analysis association between ultra-processed food intake and all-cause mortality : a systematic review and meta-analysis. *Am J Epidemiol.* 2022;191(7):1323–1335. https://doi.org/10.1093/aje/kwac039.
19. Chen X, Zhang Z, Yang H, et al. Consumption of ultra-processed foods and health outcomes: a systematic review of epidemiological studies. *Nutr J.* 2020;19(1):86. https://doi.org/10.1186/s12937-020-00604-1.
20. Blanco-Rojo R, Sandoval-Insausti H, López-Garcia E, et al. Consumption of ultra-processed foods and mortality: a national prospective cohort in Spain. *Mayo Clin Proc.* 2019;94(11):2178–2188. https://doi.org/10.1016/j.mayocp.2019.03.035.
21. Rico-Campà A, Martínez-González MA, Alvarez-Alvarez I, et al. Association between consumption of ultra-processed foods and all cause mortality: SUN prospective cohort study. *BMJ.* 2019;365:l1949. https://doi.org/10.1136/bmj.l1949.
22. Schnabel L, Kesse-Guyot E, Allès B, et al. Association between ultra-processed food consumption and risk of mortality among middle-aged adults in France. *JAMA Intern Med.* 2019;179(4):490–498. https://doi.org/10.1001/jamainternmed.2018.7289.
23. Bonaccio M, Di Castelnuovo A, Costanzo S, et al. Ultra-processed food consumption is associated with increased risk of all-cause and cardiovascular mortality in the Moli-sani Study. *Am J Clin Nutr.* 2021;113(2):446–455. https://doi.org/10.1093/ajcn/nqaa299.
24. Romero Ferreiro C, Martín-Arriscado Arroba C, Cancelas Navia P, Lora Pablos D, Gómez de la Cámara A. Ultra-processed food intake and all-cause mortality: DRECE cohort study. *Public Health Nutr.* 2022;25(7):1854–1863. https://doi.org/10.1017/S1368980021003256.
25. Chen X, Chu J, Hu W, et al. Associations of ultra-processed food consumption with cardiovascular disease and all-cause mortality: UK Biobank. *Eur J Public Health.* 2022;32(5):779–785. https://doi.org/10.1093/eurpub/ckac104.
26. Orlich MJ, Sabaté J, Mashchak A, et al. Ultra-processed food intake and animal-based food intake and mortality in the Adventist Health Study-2. *Am J Clin Nutr.* 2022;115(6):1589–1601. https://doi.org/10.1093/ajcn/nqac043.
27. Kim H, Hu EA, Rebholz CM. Ultra-processed food intake and mortality in the USA: results from the Third National Health and Nutrition Examination Survey (NHANES III, 1988−1994). *Public Health Nutr.* 2019;22(10):1777–1785. https://doi.org/10.1017/S1368980018003890.
28. Zhong GC, Gu HT, Peng Y, et al. Association of ultra-processed food consumption with cardiovascular mortality in the U.S. population: long-term results from a large prospective multicenter study. *Int J Behav Nutr Phys Act.* 2021;18(1):21. https://doi.org/10.1186/s12966-021-01081-3.
29. Dehghan M, Mente A, Rangarajan S, et al. Ultra-processed foods and mortality: analysis from the Prospective Urban and Rural Epidemiology study. *Am J Clin Nutr.* 2023;117(1):55–63. https://doi.org/10.1016/j.ajcnut.2022.10.014.
30. IHME. Global Burden of Disease 2019. https://vizhub.healthdata.org/gbd-results/.
31. Seferidi P, Laverty AA, Pearson-Stuttard J, et al. Implications of Brexit for the effectiveness of the UK soft drinks industry levy on coronary heart disease in England: a modelling study. *Lancet.* 2017;390(suppl 9).. https://doi.org/10.1016/S0140-6736(17)32944-6.
32. Sánchez-Romero LM, Penko J, Coxson PG, et al. Projected impact of Mexico's sugar-sweetened beverage tax policy on diabetes and cardiovascular disease: a modeling study. *PLoS Med.* 2016;13(11):e1002158. https://doi.org/10.1371/journal.pmed.1002158.
33. Manyema M, Veerman LJ, Tugendhaft A, Labadarios D, Hofman KJ. Modelling the potential impact of a sugar-sweetened beverage tax on stroke mortality, costs and health-adjusted life years in South Africa. *BMC Public Health.* 2016;16:405. https://doi.org/10.1186/s12889-016-3085-y.
34. Nucci LB, Rinaldi AEM, Ramos AF, Itria A, Enes CC. Impact of a reduction in sugar-sweetened beverage consumption on the burden of type 2 diabetes in Brazil: a modeling study. *Diabetes Res Clin Pract.* 2022;192:110087. https://doi.org/10.1016/j.diabres.2022.110087.
35. Juul F, Vaidean G, Parekh N. Ultra-processed foods and cardiovascular diseases: potential mechanisms of action. *Adv Nutr.* 2021;12(5):1673–1680. https://doi.org/10.1093/advances/nmab049.
36. Costa CS, Del-Ponte B, Assunção MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr.* 2018;21(1):148–159. https://doi.org/10.1017/S1368980017001331.
37. Livingston AS, Cudhea F, Wang L, et al. Effect of reducing ultraprocessed food consumption on obesity among U.S. children and adolescents aged 7−18 years: evidence from a simulation model. *BMJ Nutr Prev Health.* 2021;4(2):397–404. https://doi.org/10.1136/bmjnph-2021-000303.
38. Silver LD, Ng SW, Ryan-Ibarra S, et al. Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, U.S.: a before-and-after study. *PLoS Med.* 2017;14(4):e1002283. https://doi.org/10.1371/journal.pmed.1002283.
39. Taillie LS, Bercholz M, Popkin B, Reyes M, Colchero MA, Corvalán C. Changes in food purchases after the Chilean policies on food labelling, marketing, and sales in schools: a before and after study. *Lancet Planet Health.* 2021;5(8):e526–e533. https://doi.org/10.1016/S2542-5196(21)00172-8.
40. Rincon Gallardo Patino S, Carriedo Á, Tolentino-Mayo L, et al. Front-of-pack warning labels are preferred by parents with low education level in four Latin American countries. *WN.* 2019;10(4):11–26. https://doi.org/10.26596/wn.201910411-26.
41. WHO. From burden to "Best Buys": reducing the economic impact of non-communicable diseases in low- and middle-income countries. Geneva, Switzerland: World Economic Forum, WHO; 2011. https://ncdalliance.org/sites/default/files/resource_files/WHO%20From%20Burden%20to%20Best%20Buys.pdf, Accessed March 25, 2025.
42. Smed S, Scarborough P, Rayner M, Jensen JD. The effects of the Danish saturated fat tax on food and nutrient intake and modelled health outcomes: an econometric and comparative risk assessment evaluation. *Eur J Clin Nutr.* 2016;70(6):681–686. https://doi.org/10.1038/ejcn.2016.6.
43. Kaur A, Scarborough P, Rayner M. Regulating health and nutrition claims in the UK using a nutrient profile model: an explorative modelled health impact assessment. *Int J Behav Nutr Phys Act.* 2019;16(1):18. https://doi.org/10.1186/s12966-019-0778-5.
44. Labonté M-E, Emrich TE, Scarborough P, Rayner M, L'Abbé MR. Traffic light labelling could prevent mortality from noncommunicable diseases in Canada: a scenario modelling study. *PLoS One.* 2019;14(12):e0226975. https://doi.org/10.1371/journal.pone.0226975.
45. Webb M, Fahimi S, Singh GM, et al. Cost effectiveness of a government supported policy strategy to decrease sodium intake: global analysis across 183 nations. *BMJ.* 2017;356:i6699. https://doi.org/10.1136/bmj.i6699.
46. Trieu K, Coyle DH, Afshin A, Neal B, Marklund M, Wu JHY. The estimated health impact of sodium reduction through food

reformulation in Australia: a modeling study. *PLoS Med.* 2021;18(10): e1003806. https://doi.org/10.1371/journal.pmed.1003806.

47. Nilson EAF, Khandpur N, da Silva Gomes F. Development and application of the TFA macrosimulation model: a case study of modelling the impact of trans fatty acid (TFA) elimination policies in Brazil. *BMC Public Health.* 2022;22:2010. https://doi.org/10.1186/s12889-022-14361-9.
48. Julia C, Leroy P, Adjibade M, et al. Public health potential of guidelines-based dietary scores for non-communicable diseases mortality prevention: simulation study using the Preventable Risk Integrated ModEl (PRIME) model. *Public Health Nutr.* 2021;24(16):5539–5549. https://doi.org/10.1017/S1368980021002871.
49. Scrinis G, Monteiro C. From ultra-processed foods to ultra-processed dietary patterns. *Nat Food.* 2022;2022:1–3. https://doi.org/10.1038/s43016-022-00599-451.
50. Martinez-Steele E, Khandpur N, Batis C, et al. Best practices for applying the Nova food classification system. *Nat Food.* 2023;4:445–448. https://doi.org/10.1038/s43016-023-00779-w.
51. Ministry of Health of Brazil. Ministério da Saúde. Dietary Guidelines for the Brazilian Population; https://bvsms.saude.gov.br/bvs/publicacoes/dietary_guidelines_brazilian_population.pdf.
52. Koios D, Machado P, Lacy-Nichols J. Representations of ultra-processed oods: a global analysis of how dietary guidelines refer to levels of food processing. *Int J Heal Policy Manag.* 2022;11:2588–2599. https://doi.org/10.34172/ijhpm.2022.6443.