Policy Research Working Paper 10747

Understanding the Links between Diet Quality, Malnutrition, and Economic Costs

An Evidence Review for LMICs

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WORLD BANK GROUP
Agriculture and Food Global Practice
April 2024

Policy Research Working Paper 10747

Abstract

Understanding the economic costs attributable to unhealthy diets is crucial to inform health and agrifood investments in low- and middle-income countries experiencing nutrition transition. To review the current evidence on the association between diet quality and economic costs in low- and middle-income countries, this paper first conducted a literature search to identify studies that include a dietary exposure, nutrition, or health outcome, and a cost estimate. Given the limited studies in terms of life stage groups represented, a second search was conducted for systematic reviews and meta-analyses of observational studies, with effect size estimates for the risk of nutrition or health outcomes associated with diet quality. Of 21 studies (search 1), most were based on the Global Burden of Disease model and estimated the fraction of diet-related noncommunicable disease outcomes attributable to individual or groups of dietary risk factors. The search found 82 systematic reviews and meta-analyses (search 2) that estimated the burden of malnutrition associated with dietary risk factors. Low dietary diversity was associated with increased risk of undernutrition and anemia in pregnant women and children. Dairy consumption was protective for low birthweight, child obesity, and diabetes and hypertension. Low animal source food intake increased the risk of anemia and zinc deficiency during pregnancy. Unhealthy food consumption, including ultra-processed foods and sugar-sweetened beverages, increased the risk of overweight/obesity, diabetes, and hypertension. Healthy dietary patterns were protective during pregnancy for maternal and birth outcomes, and for diabetes and hypertension in adults. The results highlight gaps in quantifying the contribution of diet quality to multiple forms of malnutrition and noncommunicable diseases.

This paper is a product of the Agriculture and Food Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at kisekmans@nurturedev.com.

Produced by the Research Support Team

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Keywords: diet, undernutrition, overweight, obesity, non-communicable disease

JEL classification: I12 (Health Behavior), I18 (includes public health), Q18 (food policy)

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Acknowledgments
The authors would like to thank our colleagues from the 'Estimating the economic costs of unhealthy diets project' (under the World Bank 'Repurposing Agrifood Public Policies and Support for Healthy Diets' Programmatic Advisory Services and Analytics (PASA)), for their support of related work, including Erkan Ozcelik and Giles Hanley-Cook from FAO, and Hina Khan Sherwani from the World Bank. We thank Lora Iannotti, Mireya Vilar and Theresa McMenomy for their reviews of the paper. We thank Lynnette Neufeld, Bridget Holmes, Ramani WijesinhaBettoni and participants in a joint World Bank-FAO seminar on September 14, 2023, for helpful comments on earlier drafts. We thank Emily Meier for research assistance.

Introduction

This paper aims to review and summarize the current evidence on the association between diet quality, malnutrition (in all its forms), and related economic costs in low- and middle-income countries (LMICs). Economic arguments are useful particularly for influencing government policy changes that can support societies to adopt healthier diets. Economic arguments have been widely used to advocate for action against undernutrition and are now increasingly being used to advocate for policies to stem the increase in overweight, obesity, and risk of non-communicable diseases (NCDs). This follows the shift in concern from undernutrition, initially focused on calorie intake, subsequently on inadequacy of micronutrients, and most recently on overweight and obesity. The term "nutrition transition" has been used to describe big shifts in human diets towards consumption of foods high in fat, salt, sugar, and refined carbohydrates, mostly accompanied by low consumption of fiber, fruits and vegetables.

While a broad array of economic, social and environmental factors affect stunting, the agrifood system is strongly implicated in increases in overweight and obesity and hence NCDs. Very rapid changes in the food system, especially in the food retail environment, have led to higher availability and wider variety of ultra-processed foods (UPF) (Reardon et al. 2021). UPF foods are highly palatable, cheap, ready-to-consume food products that are characteristically energy-dense, fatty, sugary or salty (Monteiro et al. 2013).

Although the nature and pace of the nutrition transition has varied by location and income groups, the lowest income LMICs face severe levels of what is termed the double burden of malnutrition (DBM) as the rapid increases in overweight and obesity are not accompanied by equal reductions in child stunting (Popkin, Corvalan, and Grummer-Strawn 2020). The DBM is defined as the simultaneous manifestation of both undernutrition and overweight and obesity within various contexts, such as within the same country, the same household, or even the same individual (where the individual is both stunted and overweight/obese).

The DBM affects most LMICs and has increased in the poorest LMICs, mainly due to overweight and obesity increases (Popkin, Corvalan, and Grummer-Strawn 2020). Between 1990 and 2022, there has been a transition in many countries from underweight dominance to obesity dominance in the DBM, with growing prevalence of obesity among school-age and adolescent children as well (NCD Risk Factor Collaboration (NCD-RisC) 2024). The work of Barker (2004) on what is termed DOHAD (Developmental Origins and Health and Disease) posits a biological basis for why diets with insufficient appropriate nutrients for pregnant women predispose their children to higher risks of obesity and associated NCDs in adulthood (Wells et al. 2020). Furthermore, with recent global estimates that over half of preschool-aged children and two-thirds of non-pregnant women of reproductive age have at least one of three micronutrient deficiencies (Stevens et al. 2022), most LMICs are dealing in reality with a "triple burden" of malnutrition. Micronutrient deficiencies can occur "at either end of the anthropometric spectrum" as well as in individuals with healthy weights (Mwangome and Prentice 2019). The double and triple burdens of malnutrition render greater complexity for policy interventions (Hawkes et al. 2020).

Earlier economic studies of the cost of malnutrition in LMICs have focused on the effects of undernutrition, while those in high income countries focused on overweight and obesity. The nutrition transition and the DBM have led to a growth in studies of the economic cost of malnutrition in all its forms in LMICs (Schneider et al. 2020). However, associating cost with nutritional status does not directly inform policy, as there are multiple factors which determine nutritional status. Recent work has increased focus on the health and economic consequences of diet since this provides an entry point to examine agrifood policies.

A growing number of economic studies attempt to assess the economic cost of unhealthy diets. Candari and colleagues (2017) reported just six studies from Australia, China, the United Kingdom and the United States that generated evidence on the costs of unhealthy diets, but these varied widely in their definition of unhealthy diets and reported a wide range of cost estimates which were sensitive to the study methodology. The majority of recent studies rely on impacts on health using data from the Global Burden of Disease (GBD) project (Institute for Health Metrics and Evaluation, IHME). These include studies by The Food and Land Use Coalition (2019) and FAO et al. (2023). These estimates face methodological issues discussed elsewhere (Beal et al. 2021; Stanton et al. 2022; Horton et al. 2024).

To begin, we present a conceptual framework that describes the pathways from unhealthy diets to economic costs. Based on this framework, we define the three components of importance to estimating these costs (dietary exposure, nutrition and health outcomes, and economic impacts on individuals and society) and conduct a scoping literature review to examine the range and characteristics of the evidence on this topic. We assess the adequacy of the evidence by life-stage group with a focus on the most vulnerable periods, namely during pregnancy and lactation, early childhood (from birth to 23 months of age), school age and adolescence and older adulthood (beyond 65 years of age). As a result, we identify the knowledge gaps that remain. We then provide key findings that can inform modeling efforts to estimate the nutrition and health economic costs of unhealthy diets, highlighting limitations in the evidence that need to be considered when interpreting the results, with the aim of informing policy.

Conceptual framework and definitions

Figure 1 shows the conceptual framework that is guiding the review, describing the pathways leading from diet quality to various nutrition and health outcomes, that in turn have economic impacts on individuals and their society. There are different pathways for individuals in different stages in their life cycle, since the short- and long-term effects of diet quality may be different at each stage of development (Gernand et al. 2016). We next discuss in turn exposures, outcomes and impacts.

Exposure of interest

First, the starting point and exposure of interest is diet quality which can be defined as 'healthy' or 'unhealthy'. A '**healthy diet**' is defined as one which promotes growth and development and prevents malnutrition in all its forms (FAO and WHO 2019). Dietary patterns tend to be highly contextual and depend on food availability, access, affordability, preferences, cultures and traditions. While there can be many healthful dietary patterns, the principles of what constitutes a healthy diet are universal: i) **adequacy** in amount of energy (calories) and essential nutrients, ii) **diversity** of food groups and within food groups, iii) **balance** of energy from protein, fats and carbohydrates; and iv) **moderation** of unhealthy foods and components (Verger et al. 2023). The State of Food and Agriculture flagship report (SOFA 2023) defines '**unhealthy diets'** as those that do not meet one or more of the principles of healthy diets (adequacy, diversity, balance, and moderation) and are one of the primary drivers of all forms of malnutrition, and related morbidities (FAO et al. 2023).

The WHO dietary recommendations are global reference points for preventing undernutrition, including micronutrient deficiencies, and reducing NCD risks (WHO 2020). WHO recommends exclusive breastfeeding for infants during the first 6 months of their life, followed by continued breastfeeding with appropriate complementary foods for up to 2 years or beyond. The 2023 WHO guidelines for complementary feeding recommend that not breastfed infants 6–23 months can be fed with either animal milk or commercial formula milk up to 11 months while follow-up commercial milk is not recommended. The same guidelines recommend that infants and children 6-23 months should consume a diverse diet including daily consumption of animal source food, fruits and vegetables and frequent consumption of pulses, nuts and seeds, particularly when meat, fish or eggs and vegetables are limited in the diets. The new guidelines also provide specific recommendations on food that should be avoided or consumed in moderation. The new guidelines recommend that infant and young children 6-23 months should not consume foods high in sugar, salt and trans fats and sugar-sweetened beverages and should limit consumption of 100% fruit juice (WHO 2023a).

There are no specific WHO dietary recommendations for other age groups but the universally recognized guidelines for all age groups do emphasize increasing intakes of fruits, vegetables, legumes, nuts and whole grains; limiting energy intake from free sugars and total fats; consuming unsaturated rather than saturated or trans fats; and limiting salt intake. The Global Burden of Disease (GBD) study, which seeks to quantify the contribution of diet-related risks to NCD burden, aligns its definition of a 'healthy diet' with WHO recommendations but includes additional risk factors like any consumption of processed meat and high consumption of red meat (Kumanyika et al. 2020). Characterization of healthy diets based on dietary patterns (rather than individual foods or nutrients) better reflects what people eat. The evidence to date on the health effects of dietary patterns is consistent with the WHO and GBD findings, suggesting a focus on plant-based diets and lower level of food processing (FAO and WHO 2019)**.**

While there is evidence of diets changing globally over time, there are no harmonized metrics monitoring diet quality or how diets are evolving (Verger et al. 2023)**. Diets are assessed in a variety of ways, based on the population of interest and type of data available**. For example, breastfeeding practices are measured for infants and children 0-23 months of age. Measures distinguish those who are exclusively breastfed up to six months and continue to be breastfed while receiving complementary food up to 23 months from those who entirely stop breastfeeding at any time and receive instead breast-milk substitutes such as commercial infant formula and/or animal milk. For LMICs, the micronutrient adequacy of the diet is estimated using updated standardized methods for the assessment of minimum diet diversity (MDD) in children 6-23 months of age (WHO and UNICEF 2021) and minimum diet diversity in non-pregnant women of reproductive age (15-49 years, MDD-W) (FAO 2021). However, diet diversity is also assessed among other age groups (Arimond et al. 2021) and pregnant women (e.g. by the most recent Demographic Health Surveys). Since the consensus on standardized metrics for monitoring healthy diets is just emerging (Verger et al. 2023), current evidence focuses on dietary risk factors associated with negative nutrition and health outcomes, such as inadequate consumption of fruits, vegetables, legumes, whole grains, meat, dairy and fiber, or overconsumption of salt, trans-fatty acids, red meat, processed meat and sugar-sweetened beverages.

Outcomes of interest

Second, the outcomes of interest are all forms of malnutrition and diet-related co-morbidities such as type II diabetes and hypertension defined as including undernutrition (such as child wasting, child stunting, child/adult thinness or child/adult micronutrient deficiencies), overweight and obesity, and diet-related NCDs such as heart disease, stroke, diabetes and certain cancers (WHO 2023b). As overweight and obesity increase in poorer populations of LMICs, the coexistence of undernutrition (e.g. stunting) and overweight or obesity in the same individual, one form of the ‘double burden of malnutrition’, is also increasing (Popkin, Corvalan, and Grummer-Strawn 2020). The Developmental Origins of Health and Disease (DOHAD) theory proposes a biological basis for why diets with inadequate energy and nutrient levels during early pre-conception and pregnancy predispose offspring to higher risks of obesity and associated NCDs in adulthood (Wells et al. 2020). Coexisting micronutrient deficiencies, estimated to affect over half of preschool-aged children and two-thirds of non-pregnant women of reproductive age (Stevens et al. 2022), contribute to a “triple burden” of malnutrition. Furthermore, co-morbidities associated with overweight and obesity, such as type II diabetes (T2DM) and hypertension are common (Agrawal and Agrawal 2016), including among children (Obita and Alkhatib 2022).

Malnutrition status based on anthropometric measures of weight and height are defined by age group. In children under five, we focus on stunting (height-for-age z-score <-2 SD); wasting (weight-for-height z-score <-2 SD); and overweight (weight-for-height z-score >2 SD) (de Onis 2006). In older children and adolescents, measures of thinness (BMI for age z-score <-2 SD) and obesity (BMI for age >+2 SD) are most relevant (Butte, Garza, and de Onis 2007). Similarly, in individuals 20+ years, BMI-based measures of thinness (BMI <18.5); overweight (BMI 25-29) and obesity (BMI 30+) are used to describe nutrition outcomes of concern (Abarca-Gómez et al. 2017). Micronutrient deficiencies commonly are defined using biochemical measures in children and adults, including, for example iron deficiency (inflammation-adjusted serum ferritin concentration), vitamin A deficiency (inflammation-adjusted serum retinol concentration) and anemia (hemoglobin concentration). Diet-related NCDs are defined using clinical measures, including diabetes (raised fasting blood glucose levels) and hypertension (raised blood pressure) as the two most critical metabolic risk factors for a range of diseases (World Cancer Research Fund International and The NCD Alliance 2014). We chose diabetes and hypertension as the diagnosis was linked to the highest metabolic risk factors associated with raised blood glucose and raised blood pressure aligned with the WHO STEPwise approach to NCD risk factor surveillance in LMICs (WHO, n.d.).

Impact of interest

Third, the impact of these health and nutrition outcomes is the economic costs to individuals and society. Economic costs are defined as the direct and indirect impacts of malnutrition on individual and national economic activity, including the costs of preventable mortality, costs of medical care and income lost to ill health, costs of impaired physical growth, and costs and losses linked to impaired cognitive growth (Global Panel 2016).

The measures of economic impact (i.e. cost) include disability adjusted life years (DALYs), the monetary value of losses of goods and services production in a country each year (gross domestic product, GDP), as well as various measures of human capital, such as years of educational attainment and value of future income/wage earnings. Studies on the cost of diet-related NCDs also frequently report the annual per capita health care costs associated with health services (hospitalization, consultations) and treatment of NCDs (medications), as well as indirect health care costs, such as work absenteeism and reduced work productivity.

Literature search approach

We chose to conduct a scoping review as this type of review is useful for presenting a broad overview of the evidence for a specific topic, examining emerging aspects of research on that topic, clarifying key concepts and identifying gaps (Tricco et al. 2016). The scoping review aimed to assess the extent to which research on the contribution of unhealthy diets to nutrition and health outcomes and their associated economic costs in LMICs has been undertaken. This implied mapping the types of evidence available on which subpopulations (life stage groups) are represented, which diet metrics (or specific dietary factors) are used, and which outcome types and economic costs are considered.

As a first step, we conducted a comprehensive literature search to identify primary research articles that included all three components described in our conceptual framework, namely: a diet metric (or a specific dietary factor), a nutrition or health outcome, and economic cost. These criteria yielded a body of literature that was limited in scope, especially in terms of the life stage groups represented.

For this reason, we conducted a second comprehensive literature search that expanded the inclusion criteria to include systematic review papers that assessed the evidence for the contribution of a diet exposure measure to a nutrition or health outcome described in our conceptual framework and reported an estimate of effect size based on a meta-analysis of observational study data. This was expected to help the mapping of evidence from the first literature search in two ways. First, the biggest gap from the first search was the lack of evidence on the contribution of diet to nutrition and health outcomes for the various life stage groups (beyond adulthood). Second, while there are a reasonable number of studies which provide estimates of the cost of undernutrition and overweight/obesity in LMICs (Horton et al. 2024), there are very few studies that incorporate the contribution of the diet to these outcomes. Since conducting a full literature review on the diet and outcome components would yield a very large body of evidence on these relationships without necessarily providing the desired information on the effects, we chose to limit the second search to studies that consolidated this body of evidence in a systematic way, including calculation of effect sizes. See **Table 1** for a PICO summary of the elements that guided Search 2.

Eligibility criteria

Peer-reviewed journal articles were included if they were: published during 2000-2023 (arbitrary cutoff used to focus on evidence produced with a recent timeframe since dietary patterns are changing rapidly in LMICs), written in English, and involved human participants of any age living in a low- or middle-income country (using the World Bank's classification in 2023 fiscal year). Articles were excluded if they were case reports, editorials, letters to editors, comments, conference abstracts, short communications, or qualitative studies.

Articles were included if they assessed a dietary exposure that was food-based (as opposed to specific nutrients), including breastmilk, food groups or categories (e.g. animal source foods, dairy products, sugar-sweetened beverages) or measures of diet quality (e.g. diet adequacy, diet diversity and different ways of defining healthy or unhealthy dietary patterns, which focus more on balance and moderation). We included studies assessing salt intake (not just sodium in foods) as condiment/seasoning. Articles were excluded if the dietary exposure was a specific nutrient (e.g. omega-3 PUFA, cholesterol, protein), therapeutic diet (gluten-free, DASH diet), uncommon individual food item (e.g. sesame seed), micronutrient supplement (including micronutrient powders, small-quantity lipid nutrient supplements), therapeutic food (e.g. RUTF), food supplement or fortified food product. Dietary behaviours (e.g. initiation of breastfeeding, frequency of feeding, fast food restaurant frequency), and food insecurity were not considered to be a dietary exposure.

Articles were included if they assessed the relationship between the diet exposure and one or more nutrition or health outcomes relevant to our theoretical framework, including stunting, wasting, overweight, obesity, anemia, micronutrient deficiencies, raised fasting blood glucose, raised blood pressure, and maternal and neonatal outcomes during pregnancy and the perinatal period (e.g. gestational diabetes, gestational hypertension and the hypertensive disorder known as pre-eclampsia, preterm birth, low birthweight, small-for-gestational-age). Other disease outcomes associated with dietary intake were not included (e.g. depression, asthma, kidney or liver disease). We focused on two of the most critical metabolic risk factors for a range of diseases, namely high blood pressure (referred to hereafter as hypertension) and high blood glucose (referred to hereafter as diabetes) (World Cancer Research Fund International and The NCD Alliance 2014). In much of the literature found, high blood glucose and type 2 diabetes mellitus (T2DM) were used interchangeably. We did not include type 1 diabetes mellitus, an autoimmune condition that is not diet related. In the second literature search, articles were further limited to original systematic review articles that included a meta-analysis of observational study data (e.g. cross-sectional and prospective or retrospective cohort studies). Systematic review articles were excluded if they reported only on intervention trials (RCTs) or did not report an estimate of the effect size or odds ratio for the risk of the outcome associated with the diet exposure. We did not include experimental studies because we were interested in estimates based on normal population dietary intake. Articles were excluded if they reported evidence specific to high-income countries only.

Information sources

To identify relevant articles, we conducted the first search in April 2023 using the Web of Science Core Collection database and Cochrane Database of Systematic Reviews. We conducted the second search in January 2024 using the same two databases. The search strategies were developed by life stage group and health/nutrition outcome, with search terms for each of the three components (diet exposure, outcome and cost) combined to identify relevant studies. The list of search terms for each life stage group and health/nutrition outcome are shown in **Annex 1.** The electronic database search was supplemented by scanning the reference lists of selected articles and other relevant reviews.

A team of six reviewers assessed the eligibility of the search results, with two reviewers for each search list (by life stage group/outcome). In the first step, each reviewer independently screened the list of articles based on the title and abstract. In the second step, one reviewer scanned the full text of the article and noted the presence or absence of each of the components required by the inclusion criteria. Disagreements on study selection were resolved by consensus and discussion with other reviewers.

Approach to data charting and synthesis of results

A standard data charting table was jointly developed by two reviewers and data from eligible studies were charted by the lead reviewer, grouped by life stage. The table columns captured the relevant information on key study characteristics (e.g. author, publication year, study design, sample size), age and geographic location of study participants, type of diet exposure and metric used, type of nutrition/health outcome(s) and measure used, type of economic cost and measure used, and relevant key findings (e.g. strength of association observed, economic cost estimate). Since the purpose of this scoping review was to provide an overview of the existing evidence regardless of methodological quality or risk of bias, the articles included were not critically appraised (Tricco et al. 2018).

Results

Search 1: Evidence on the link between diet quality, health/nutrition outcomes and economic costs (all three components)

Search results and characteristics of selected studies

The study selection process for the first literature search objective is shown in **Figure 2**. The total number of records screened, after removing duplicates was 704; 142 full texts were screened. We identified a total of 20 studies that included data from LMICs and estimated the burden of unhealthy food choice by quantifying the impact of individual dietary factors (dairy products, salt, sugar, sugar-sweetened beverages, ultra-processed foods) or poor-quality diets (measured by healthy eating indices) on diet-related NCD outcomes (cardio-vascular diseases, diabetes, chronic disease) (see **Table 2**). A comparison of key findings in terms of mortality, DALYs and health care costs are summarized in **Table 3**.

Most of the studies were based on the GBD data and methodology. Several studies estimated the cost (mortality and DALYs) of cardiovascular disease or the NCD burden attributable to the dietary risk factors, using the GBD dataset for 204 countries (B. Zhang et al. 2023; Dong et al. 2022; Qiao et al. 2022) or in specific country contexts (Brazil, Mexico) (Dávila-Cervantes 2020; Machado et al. 2022). Globally, in 2019, 6.9 million CVD deaths and 153.2 million CVD DALYs were attributable to dietary risk factors, with high sodium, low whole grains, low legumes, low fruits and high red meat being the top risks (B. Zhang et al. 2023; Dong et al. 2022). This increased to 7.9 million deaths and 187.7 million DALYs globally when including other NCDs such as cancers and T2DM (Qiao et al. 2022). Using the same dataset at country level for Brazil, Machado and colleagues (2022) show a lower age-standardized death rate (65.3 per 100,000 in Brazil vs. 101 globally in 2019) for NCDs attributable to dietary risks.

Four studies (three in Brazil, one in Costa Rica) estimated the costs associated with excess salt/sodium consumption, one using the GBD dataset (Guedes et al. 2022) and the others assessed health care costs associated with hypertension (Nilson, da Silva, and Jaime 2020; Nilson et al. 2020; Vega-Solano et al. 2023). In 2017, the burden of hypertension and CVDs associated with excessive salt intake in Brazil accounted for USD 192.1 million in health care costs (hospitalization, outpatient care and medication for hypertension) and USD 752.7 million in productivity losses due to premature deaths (Nilson et al. 2020). In Costa Rica, excessive salt intake was estimated to cost USD 15.1 million in health care costs and USD 6.8 million in annual productivity costs (GDP losses) (Vega-Solano et al. 2023).

An additional eight studies were found that estimated costs (usually mortality and DALYs) associated with specific dietary risk factors such as diets high in red meat (Liu et al. 2022) or processed meat (Rocha et al. 2023), high in sugar-sweetened beverage intake (Bardach et al. 2023; Li et al. 2021), or low in fiber (Zhuo et al. 2022).

Two studies modeled the savings in health care costs associated with improvements in population dietary intake. Basto-Abreu and colleagues (2020) estimated that a 36.8 kcal/day reduction in energy intake from beverages and snacks would result in a 5 percentage point decrease over five years in adult obesity prevalence and save USD 1.84 billion in direct and indirect health care costs in Mexico. In the Islamic Republic of Iran, the estimated reduction in CVD and T2DM incidence due to optimal dairy food consumption would result in $0.43 per capita savings in health care costs over one year and $190.25 in 20 years (Javanbakht et al. 2018).

Three studies included children in their study population. In a study of SSB consumption in four countries (Argentina, Brazil, Trinidad & Tobago, El Salvador), Alcaraz et al. estimated that SSB consumption in one year was associated with 12% of overweight and obesity cases in children and adolescents, as well as 2.8% of those in adults. The total cost associated with SSB consumption was 18,000 deaths, 0.5 million DALYs and USD 2 billion in direct medical costs. Bardach and colleagues (2023) produced similar estimates for children, adolescents and adults in Argentina alone.

Walters and colleagues (2019) estimated the global human and economic costs of not breastfeeding according to recommendations, including 974,956 cases of childhood obesity each year, 595,379 childhood deaths per year (6-59 months) from diarrhea and pneumonia, and 98,243 women's deaths from cancer (breast and ovarian) and T2DM. The total annual global losses associated with inadequate breastfeeding are estimated to be between US$257 billion and US$341 billion (0.37%-0.70% of global gross national income), including US$1.1 billion in health care costs, US$53.7 billion in economic losses due to premature mortality, and US$285.4 billion in cognitive losses.

Search 2: Evidence on the link between diet quality and health/nutrition outcomes

Search results and characteristics of selected studies

The study selection process for the second literature search objective is shown in **Figure 3**. The total number of records screened, after removing duplicates was 2,335 and 222 full texts were screened. We identified a total of 82 systematic reviews with meta-analyses (SRM) that included data from LMICs and estimated the burden of nutrition and/or health outcomes associated with specific dietary risk factors. The following sections provide an overview of the evidence available for the diet's contribution to nutrition and health outcomes, organized by life-stage group.

Pregnant and lactating women

A total of 19 SRM articles were found that included women of reproductive age in LMICs and assessed the association of diet with maternal and/or neonatal nutrition and health outcomes. **See Table 4.**

Maternal nutrition outcomes

Five (5) SRM assessed risk factors for maternal nutrition outcomes, including anemia (Seid et al. 2023; Geta, Gebremedhin, and Omigbodun 2022; J. Zhang et al. 2022), thinness (Getaneh et al. 2021), and zinc deficiency (Berhe, Gebrearegay, and Gebremariam 2019). Four of the five were based either exclusively or dominantly on studies in Ethiopia, with extensive overlap of studies included. All five SRM included dietary diversity as a risk factor and proxy for diet quality during pregnancy. Low diet diversity was associated with higher risk of maternal anemia, with the effect size estimates ranging from 2.15 to 2.61. However, there was heterogeneity in the number of food groups and dietary diversity score (DDS) cutoffs used to define low or inadequate diet diversity across the studies included in the SRM.

Consumption of specific food groups (e.g. meat, dark green leafy vegetables) relevant to anemia as an outcome was assessed in two studies. Risk of anemia was over two times higher among pregnant women eating meat ≤1 time per week (OR 2.02; 95% CI 1.55, 2.50) and those eating vegetables ≤3 times per week (OR 2.97; 95% CI 1.59, 4.34) (J. Zhang et al. 2022). In a review of four studies from Ethiopia, zinc deficiency was also associated with a low intake of ASF (OR 2.57; 95% CI 1.80, 3.66) and low dietary diversity (OR 2.12; 95% CI 1.28, 3.53) (Berhe et al. 2022).

Maternal health outcomes

Twelve (12) SRM summarized the evidence for the contribution of diet during or before pregnancy to maternal health outcomes, including gestational diabetes, hypertension, pre-eclampsia and gestational weight gain. Three of these assessed the association of maternal adherence to a 'healthy' or 'unhealthy' dietary pattern (Abdollahi et al. 2021; Chia et al. 2019; Kibret et al. 2019; Haghighatdoost et al. 2023; X. Gao et al. 2023; Hassani Zadeh, Boffetta, and Hosseinzadeh 2020) with various maternal health outcomes during pregnancy. Paula et al. (2022) estimated the risks during pregnancy of UPF-rich diet consumption.

Gestational diabetes mellitus (GDM) – A total of 25 effect estimates for GDM were recorded. Dietary risk factors for GDM included low diet diversity in two Ethiopian studies (effect size 1.51; 95% CI 1.25, 1.83) (Beyene et al. 2023) and unhealthy food intake, including fried food (Cui et al. 2023), fast food (Cui et al. 2023; Quan et al. 2021), red and processed meat (Cui et al. 2023; Quan et al. 2021), and a diet rich in UPF (Paula et al. 2022). Women consuming a 'western' dietary pattern were at higher risk of GDM (RR 1.27; 95% CI 1.03, 1.56) in one meta-analysis of 13 cohort studies (Hassani Zadeh, Boffetta, and Hosseinzadeh 2020) with a similar effect size that was marginally non-significant in 2 other meta-analyses due to the lower confidence limit (Haghighatdoost et al. 2023; Quan et al. 2021).

Higher maternal adherence to a healthy diet (defined in various ways) was protective for GDM in 10 of 11 effect estimates (including between 6 and 26 studies), with the effect size ranging from 0.39 (95% CI 0.31, 0.48) for a high quality diet that adhered to national dietary guidelines to 0.86 (95% CI 0.76, 0.96) for a healthy dietary pattern rich in fruits, vegetables and whole grains (Haghighatdoost et al. 2023). Higher quality diet, as measured by higher adherence to Mediterranean, DASH, AHEI or plant-based diets, also was associated with lower risk of gestational diabetes (range of OR 0.51-0.66).

Hypertensive disorders of pregnancy - Higher maternal adherence to a healthy diet was associated with lower risk of gestational hypertension (OR 0.86) (Abdollahi et al. 2021) and pre-eclampsia (OR 0.78) (Kibret et al. 2019). Risk of pre-eclampsia was also lower among pregnant women consuming adequate vegetables and fruit, based on 4 and 5 studies in LMICs, respectively (Kinshella et al. 2021). Conversely, unhealthy dietary pattern adherence increased the odds of gestational hypertensive disorders (OR 1.23) (Abdollahi et al. 2021) and maternal diets rich in UPF also were associated with increased risk of pre-eclampsia (OR 1.28) (Paula et al. 2022).

Birth outcomes

Seven (7) SRM summarized the evidence for the contribution of diet during pregnancy to neonatal birth outcomes such as preterm birth, birth weight/length, small/large-for-gestational-age, and low birthweight (LBW). The odds of preterm birth were lower among pregnant women with healthy dietary pattern adherence, with estimates from meta-analyses of 6-10 studies ranging from 0.44 to 0.79 (Abdollahi et al. 2021; Chia et al. 2019; Kibret et al. 2019).

Evidence was also available on the association of maternal diet characteristics to the infant's birth weight and length. Low dietary diversity during pregnancy was associated with an increased risk of having a LBW baby (OR 2.04) based on 9 studies in Africa (Seid et al. 2023). An *unhealthy* dietary pattern (high intake of refined grains, processed meat, and foods high in saturated fat or sugar) was associated with lower birth weight (mean difference -40 g; 95% CI -61, -20) in 3 studies but the pooled effect size for birth weight among mothers with high adherence to *healthy* dietary patterns during pregnancy in 13 studies (n=25,499) was close to zero (Chia et al. 2019). Yet higher maternal adherence to a healthy diet was associated with higher birth weight (mean difference +0.19 g; 95% CI 0.05, 0.32) in a meta-analysis of 15 studies (n=75,041) by Abdollahi et al. (2021) as well as lower risk of LBW (OR 0.72; 0.53, 0.97), based on 7 prospective cohort studies. Milk consumption during pregnancy was associated with higher birth weight (mean diff =51.0 g; 95% CI 24.7, 77.3) and birth length (mean diff 0.33 cm; 95% CI 0.03, 0.64), as well as lower risk of small-for-gestational-age (OR 0.69; 95% CI 0.56, 0.84) and LBW (OR 0.63; 95% CI 0.48, 0.84) (Pérez-Roncero et al. 2020).

Children < 5 years of age

Evidence on the risk of malnutrition associated with nutrient-inadequate and unhealthy diets for children less than five years of age includes nine (9) SRM articles with effect size estimates (see **Table 5**). Diet diversity is a recommended measure of nutrient adequacy for this age group in LMICs. We found only three SRMs, all based on studies from Ethiopia, that looked at the association of low diet diversity in children < 5 years with stunting (Abdulahi et al. 2017) and anemia (Azmeraw et al. 2023; Belachew and Tewabe 2020). The evidence for dietary risk factors for overweight and obesity in children <5 years was also very limited, with one SRM on breastfeeding and three SRMs that included overweight and/or obesity among children 1-21 years as an outcome. There is strong evidence across 159 studies that breastfeeding is protective against overweight or obesity among children 1-9 years (pooled OR 0.73, 95% CI 0.71, 0.76), with subgroup analysis showing an even higher effect size for LMICs (OR 0.70; 95% CI 0.64, 0.78) (Horta et al. 2023). Breastfed children are also at lower risk for diabetes in later life, with a higher protective effect among adolescents 10-19 years (OR 0.49; 95% CI 0.38, 0.63) compared to adults 20+ years (OR 0.77; 95% CI 0.66, 0.90) (Horta and de Lima 2019).

Based on cross-sectional studies, total dairy product (including milk, yogurt and cheese) consumption in children 2-21 years is associated with a reduced risk of obesity (OR 0.66; 95% CI 0.48, 0.91) but not overweight (Babio et al. 2022). In a meta-analysis of 14 studies (11 cross-sectional and 3 cohort), regular consumption of *whole* milk (compared to reduced fat milk) was associated with a lower risk of overweight and obesity among children 1-18 years (OR 0.61; 95% CI 0.52, 0.72) (Vanderhout et al. 2020).

High SSB intake is also associated with increased BMI in children 2-18 years, with a mean difference of 0.75 kg/m2 (95% CI 0.35, 1.15), higher waist circumference (WMD 2.35 cm; 95% CI, 1.34, 3.37; $p = 0.016$) and higher body fat percentage (WMD: 2.81; 95% CI 2.21–3.41; $p < 0.001$) (Abbasalizad Farhangi et al. 2022).

Children 5+ years of age

Our search identified 16 SRM on the risk of malnutrition associated with dietary intake in older children, with four overlapping with children <5 years and one overlapping with adults (see **Table 6**). As with children <5 years, there is evidence that low diet diversity among children 5-18 years across six LMICs is associated with increased risk of stunting (OR 1.43; 95% CI 1.08, 1.89), and wasting (OR 2.18; 95% CI 1.41, 3.36), but not thinness (Zeinalabedini et al. 2023). Low diet diversity is also associated with increased risk of low BMI-for-age (<-2 SD) in adolescents in Ethiopia (OR 1.95; 95% CI 1.31, 2.92) (Berhe et al. 2019). Low diet diversity increases the odds of anemia among adolescent girls in Ethiopia, with effect size estimates ranging from 1.35-2.81 (Berhe et al. 2022; Habtegiorgis et al. 2022; Endale et al. 2022). Based on two studies from Ethiopia, low diet diversity is also associated with increased risk of overweight and obesity (OR 2.26; 95% CI 1.28, 3.99) (Gezaw et al. 2023a).

Several SRM have summarized the evidence on the contribution of unhealthy diets, including SSB intake, to the growing burden of overweight and obesity in children 5-19 years. Higher adherence to an unhealthy dietary pattern (mainly represented by red and processed meat, confectionery and bakery items, full-fat dairy products, refined grains, desserts and candies) was associated with higher BMI (mean diff 0.57 kg/m² (95% CI 0.51, 0.63) and waist circumference (mean diff 0.57 cm (95% CI 0.47, 0·67) in children and adolescents 7-19 years (Cunha et al. 2018). SSB consumption, in particular, has been shown to increase the odds of overweight and obesity, with an effect size of 1.2 in two very large meta-analyses (Jakobsen, Brader, and Bruun 2023; Poorolajal et al. 2020). As stated above for children <5 years, high SSB intake is associated with higher BMI, body fat percentage and waist circumference (Abbasalizad Farhangi et al. 2022). Other unhealthy foods associated with overweight/obesity in children and adolescents include fast food (OR 1.17; 95% CI 1.07, 1.28) and refined grains (OR 1.28; 95% CI 1.05, 1.56) (Jakobsen, Brader, and Bruun 2023).

Healthy dietary patterns (mostly composed of legumes, vegetables, fruit, fish, low-fat dairy products, nuts, olive oil and others) have been shown to be protective for overweight and obesity in children 7-19 years, associated with lower mean BMI (-0.41 kg/m2; 95% CI -0.46, -0.36) and waist circumference (-0.43 cm; 95% CI -0.52, -0.33) (Cunha et al. 2018). Milk and dairy product consumption are also associated with reduced risk of overweight and obesity in children of all ages, with effect sizes ranging from 0.54 to 0.87 (Babio et al. 2022; Vanderhout et al. 2020; W. Wang, Wu, and Zhang 2016).

Adults

Our search identified 44 SRM articles that assessed the risk of overweight and obesity, T2DM or hypertension associated with dietary intake in adults (see **Table 7**).

Nutrition outcomes

Only one SRM was found that looked at a micronutrient-related outcome in adults. Haider et al. (2018) found that adult vegetarians had significantly lower serum ferritin concentration compared to non-vegetarians.

Dietary risk factors for overweight and obesity outcomes were assessed in 25 meta-analyses across 15 SRM articles, with the diet exposure varying from dietary diversity to healthy/unhealthy dietary patterns, as well as consumption of specific food groups, including UPF, SSB, fried foods, red and processed meat, dairy products, fruit and vegetables. A healthy dietary pattern was associated with reduced risk of overweight and obesity (OR 0.64) (Mu et al. 2017). There was no evidence of an association with dietary diversity (Qorbani et al. 2022; Salehi-Abargouei et al. 2016). Vegetarian and vegan diets were associated with lower BMI compared to omnivore diets (Dinu et al. 2017). Higher consumption of fruits and vegetables was associated with lower risk of overweight and obesity as well as lower waist circumference and body weight (Schwingshackl et al. 2015). Total dairy consumption also was protective in multiple studies (Feng et al. 2022; Schwingshackl et al. 2016; W. Wang, Wu, and Zhang 2016).

Evidence for dietary risk factors for higher overweight and obesity included fried food consumption (OR 1.16) as well as high consumption of SSB (RR 1.12) (Qin et al. 2020). High UPF intake was consistently associated with increased risk of overweight and obesity across four SRM, as a combined outcome (OR 1.39) (Pagliai et al. 2021) or for overweight (range OR 1.02-1.36) and obesity (range OR 1.26-1.55) (Askari et al. 2020; Lane et al. 2021; Moradi et al. 2023). While red meat consumption was not associated with obesity in a meta-analysis that included mostly HICs and only the Islamic Republic of Iran, red and processed meat intake was associated with increased risk of obesity (OR 1.37) and higher mean waist circumference and BMI (Rouhani et al. 2014). High adherence to an unhealthy 'western' dietary pattern was a strong risk factor for overweight/obesity in one meta-analysis of 18 studies in HICs and LMICs (OR 1.65; 95% CI 1.45, 1.87) (Mu et al. 2017) but not in a meta-analysis of 8 studies from China (OR 1.34, 95% CI 0.98, 1.84) (Jiang et al. 2022).

Health outcomes – diabetes and hypertension

The SRM for adults included 24 meta-analyses with T2DM and 11 with hypertension as the outcome. In the only study that summarized the evidence for dietary diversity, there was no evidence of an association with cardio-metabolic risk factors, including T2DM and hypertension (Qorbani et al. 2022). High adherence to healthy dietary patterns is protective for both T2DM and hypertension, with relative risk estimates in the range of 0.79-0.86 for T2DM (Alhazmi et al. 2014; Esposito et al. 2014; McEvoy et al. 2014; Morze et al. 2020; Maghsoudi, Ghiasvand, and Salehi-Abargouei 2016). Adherence to a vegetarian diet also was associated with lower blood glucose levels (Dinu et al. 2017) and risk of T2DM (Lee and Park 2017). The odds of hypertension were lower (OR 0.87; 95% CI 0.78, 0.98) among adults with higher adherence to a Mediterranean diet(Cowell et al. 2021). Total dairy consumption was also associated with reduced risk of T2DM and hypertension, although there were very small numbers of LMIC studies included in these estimates (Chen et al. 2022; Feng et al. 2022; Mishali et al. 2019; Khoramdad et al. 2017; D. Gao et al. 2013).

In contrast, high consumption of unhealthy foods and beverages, including UPF and SSB was associated with increased risk of T2DM and hypertension. Relative risks for diabetes incidence associated with SSB intake ranged from 1.27 to 1.38 (Neelakantan et al. 2021; B. Li et al. 2023). Adherence to unhealthy dietary patten also increased the risk of T2DM (Alhazmi et al. 2014; Maghsoudi, Ghiasvand, and Salehi-Abargouei 2016; McEvoy et al. 2014). UPF consumption significantly increased the risk of hypertension (OR 1.23; 1.11, 1.37) (M. Wang et al. 2022).

Evidence gaps by life stage group, dietary exposures and outcomes

In **Table 8** we show a mapping of the associations observed in the included SRM by life stage group, dietary exposures and outcomes.

Diet quality during pregnancy – the evidence available on the risks associated with various dietary factors during pregnancy covers a wide range of maternal nutrition and health outcomes, as well as birth outcomes (e.g. LBW). Diet diversity is a common metric used to assess nutrient adequacy during pregnancy, particularly in LMICs, but is less useful for estimating the risk of pregnancy complications such as gestational diabetes and hypertension. Dietary risk factors for NCD-related outcomes were commonly assessed using specific food groups as well as healthy and unhealthy dietary patterns. Intake of ASF was used to assess risk of micronutrient deficiency and anemia during pregnancy. There were no studies found for LMICs that used a common diet metric to look at both nutrient inadequacies and NCD-related complications during pregnancy.

Diet diversity was also a common and consistent measure of diet quality for children, with studies from LMICs focused largely on the association of diet diversity with undernutrition outcomes, including stunting, wasting and anemia. No SRM was found that looked at diet diversity or consumption of meat, fish or eggs in relation to young child overweight and obesity. While several SRM assessed the risk of overweight and obesity with SSB intake in children <5 years, no other SRM with studies from LMICs was found for this age group that looked at nutrition or health outcomes associated with energy-dense and nutrient-poor foods, including UPF. In older children 5-19 years, various dietary exposures, including specific food groups (e.g. dairy, meat, SSB) and food patterns (e.g. diet diversity, unhealthy dietary pattern, fast food) were assessed in relation to risk of overweight and obesity.

Diets for adults – the mapping of evidence from meta-analyses of dietary risk factors for nutrition and health outcomes in adults in LMICs shows a wide range of food groups and dietary patterns, with emphasis on their contribution to obesity and diet-related NCD outcomes. In general, dietary diversity has shown no evidence of an association with overweight and obesity, diabetes or hypertension. However, there have been multiple SRM looking at healthy and unhealthy dietary patterns, as well as specific food groups such as UPF, SSB, red and processed meat, dairy, and fruits and vegetables in relation to these outcomes.

Discussion

Published evidence on the nutrition and health economic costs associated with dietary risk factors in LMICs is limited. Most of the studies found were based on one specific modeling approach, the GBD, that focuses its estimates on adults and a group of dietary risk factors that are associated with NCD outcomes. While useful for describing the high costs of diet-related NCDs to human life and the health care system, this body of literature has limited relevance for countries facing the DBM, where the burden of undernutrition is still a public health concern, especially in young children. The one study that captured both ends of the spectrum was the Cost of Not Breastfeeding model which described the global costs of child deaths due to infection, child obesity and women's cancer and T2DM (Walters, Phan, and Mathisen 2019). The estimations nevertheless omit the unpaid health care costs of not breastfeeding, such as lost paid work hours or reduced leisure associated with caring for a sick child, opportunity costs which are largely borne by mothers and contribute to gender inequalities (Smith 2019). Non-GBD studies commonly estimated the direct and indirect health care costs for the burden of disease associated with dietary risk factors, evidence that is valuable for increasing awareness of decision makers in LMICs of the burden of disease attributable to diets (Alcaraz et al. 2021).

Similarly, our review of the literature available on the risk of malnutrition associated with diets has revealed the challenges in summarizing a very broad body of research that is not yet well-standardized in terms of common metrics for diet quality. Diet metrics were either limited to the dietary diversity score or they were concentrated on specific dietary factors with known risks for nutrition and health outcomes. Definitions of 'healthy' or 'unhealthy' dietary patterns varied widely across studies and were often data-driven (derived from analytic approaches such as factor analysis) and context-dependent. The lack of consensus on the use of standardized metrics and the heterogenous dietary measures and outcomes used in quantitative studies are an important impediment for a more precise understanding of the dietary effects on different forms of malnutrition.

Restricting our review to articles with systematic reviews that estimated effect size through meta-analysis was a pragmatic way to consolidate the large body of evidence on associations between diet quality and nutrition/health outcomes; however, this approach resulted in some limitations. Most meta-analyses included a limited number of studies conducted in LMICs and these were more often middle-income countries such as Brazil, China and the Islamic Republic of Iran. The small number of meta-analyses that were focused on low-income countries mostly explored associations between diets and undernutrition, with less attention given to the full range of malnutrition outcomes. While the nutrition transition is often more advanced in middle-income countries, the pace of change and the impact in low-income countries cannot be overlooked (Popkin, Corvalan, and Grummer-Strawn 2020). Food consumption patterns vary widely across geographic regions, with big differences between regions in terms of insufficient intakes of healthy foods and excess intakes of unhealthy foods (Miller et al. 2022). Spatial variation in dietary patterns (Zhao et al. 2022) and dietary diversity (Alemu et al. 2022) also occur within the same country. Therefore, it is important for all countries to have evidence based on their local context.

Our scoping review also revealed the polarization in evidence in LMICs. One group of studies focused on the foods that matter for achieving nutrient adequate diets in environments where there are still widespread nutrient inadequacies and undernutrition, especially among nutritionally vulnerable individuals like young children and pregnant women. Another group of studies explored the foods that matter for preventing the rapid rise of overweight/obesity and NCDs with a focus on adult population. For the latter group, although all the SRM reviewed included at least one LMIC, the evidence was heavily weighted toward research conducted in high-income countries. The results of our review show the gaps in evidence for foods and dietary measures that can monitor multiple subconstructs of healthy diets in low-income country contexts, including nutrient adequacy, diversity, balance and moderation (Verger et al. 2023). This is an area of ongoing work to develop, validate and use more widely healthy diet metrics that concurrently capture these two sides of the DBM and are feasible to operationalize in LMICs taking a full life cycle approach.

By relying on meta-analyses for effect size estimates, our review also did not capture emerging approaches to assessment of unhealthy diets and associated outcomes that may be well-suited to monitor the rapid nutrition transition faced by several countries. For example, two relatively new metrics, the Global Dietary Recommendations Score (Herforth et al. 2020) and Global Diet Quality Score (Bromage et al. 2021), have been validated in several countries and are increasing in use in LMICs (Angulo et al. 2021; H. Wang et al. 2022; P. H. Nguyen et al. 2023). Both approaches utilize two sub-scores to monitor dietary factors protective against NCDs and those associated with increased risk of NCDs.

The results of our study provide an overview of the effect sizes for some of the dietary 'culprits' in both high-income and LMIC contexts. While consumption of UPF was not historically a major concern, the average dietary share of UPFs has already reached over 50% of total energy intake in some high-income countries and consumption of these foods has been rising quickly in LMICs over the past 30 years (Scrinis and Monteiro 2022). The summary of effect size ranges from SRM that include data from LMICs provide a starting point for better understanding what links exist and how these could be used to inform modeling assumptions on the nutrition and health costs associated with unhealthy diets in LMICs.

No meta-analysis for UPF as a risk factor for overweight/obesity in children <5 years was found in our search, however. UPF consumption among young children has been an active area of investigation and there are several systematic reviews of observational studies. For example, Pries and colleagues (2019) conducted a systematic review of snack food and SSB intake and nutritional status of children 0-23 months in LMICs, noting mixed results, with only one of three studies reporting a positive association with overweight. Two other systematic reviews also explored the risk of obesity (De Amicis et al. 2022) and body fat (Costa et al. 2018) associated with UPF consumption in children. In a group of 26 studies (15 with cohort design) that assessed groups of UPF (e.g. snacks, fast food, junk food) or specific UPF (e.g. SSB, sweets, ready-to-eat cereals), most reported positive associations between UPF consumption with body fat (Costa et al. 2018). However, De Amicis and colleagues (2022) found in their systematic review that consumption of UPF was positively associated with obesity/adiposity only in four longitudinal studies in children with four or more years of follow-up but not in cross-sectional studies. They suggest that a consistent intake of UPF over time may be needed to have an impact on the nutrition status of children.

Our study also found that, as expected, there are few studies for children in LMICs that assess the contribution of diet to risk factors for NCDs. This is partly due to the limited research on older children and adolescents, when the most critical metabolic risk factors for a range of diseases are most likely to occur compared with younger children. Another reason for the limited research in this area might be due to the emerging nature of the nutrition transition, which is currently under explored also for the adult population in LMICs. It is also likely that there is less recognition of how excess consumption of unhealthy foods such as UPF contributes to nutrient deficiencies in LMICs, since there is a tendency to associate UPF consumption with overweight/obesity and NCDs (Scrinis 2020). In young children, unhealthy snack food and beverages can account for a significant proportion of total energy intake and the micronutrient dilution that results from high consumption of energy-dense but nutrient-poor foods may contribute to micronutrient deficiencies and poor growth outcomes (Pries, Filteau, and Ferguson 2019).

More research is needed to describe how dietary patterns interact with undernutrition (stunting, wasting and micronutrient deficiencies) and overweight/obesity and NCDs at individual, household and country level and in which direction they influence the economic effects. For example, recent evidence from a national survey in South Africa highlights the complexity of malnutrition and diet quality within households, where 18% of children were stunted and 70% of these children lived with an overweight or obese adult (Harper et al. 2022). While children <5 years and adolescents living in households with medium dietary diversity were more likely to be stunted than children in households with high dietary diversity, increased household dietary diversity was associated with increased risk of adult overweight and obesity. The contribution of diet to the growing double and triple burden of malnutrition in LMIC populations is not well-tested in the research available to date, with most SRM looking primarily at the role of diet in contributing to either undernutrition or overweight, obesity and diet-related NCDs.

The widespread use of diet diversity metrics in young children and women of reproductive age along with emerging metrics of diet quality has potential to better capture the link between diet and overweight/obesity and NCDs. Complementary studies are needed to expand the scope of these efforts to include older children, adolescents, men and older adults. This remains challenging given the limited availability, quality and representativeness of dietary data for such groups in LMICs (Demmler et al. 2024).

While no SRM was found that summarized the effect size for the association of ASF intake with nutritional outcomes, there are several observational studies that have used multi-country datasets to explore this (Zaharia et al. 2021; Headey, Hirvonen, and Hoddinott 2018; Krasevec et al. 2017). Four SRM have estimated the risk of child overweight/obesity associated with consumption of dairy products (Babio et al. 2022; Lu et al. 2016; Vanderhout et al. 2020; W. Wang, Wu, and Zhang 2016).

Where SRM looked at the associations between diet diversity and nutrition and health outcomes, it appears that low diet diversity impacts GDM and poor neonatal birth outcomes in a similar way as unhealthy diets. Similarly, low diet diversity was associated with overweight and obesity among older children in one meta-analysis of only two studies (Gezaw et al. 2023b). We could not find a SRM that looked at the relationship between diet diversity and overweight among children <5 years of age. One cross sectional study in India has looked at this, reporting that a dietary diversity score of 7-9 food items for children 0-59 months of age was associated with increased risk of overweight and obesity (OR 1.22; 95% CI 1.12, 1.34) (Saha et al. 2022).

Limitations of this review

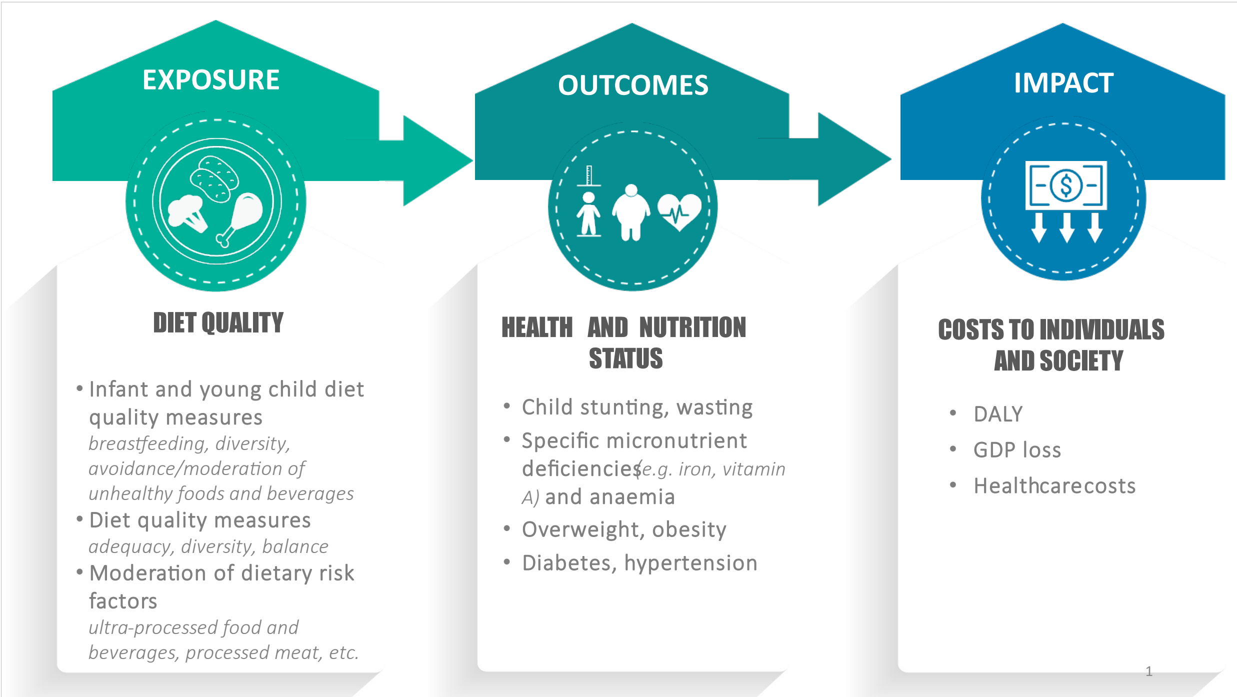
The inclusion criteria were designed to identify research studies that were of high relevance to the theoretical framework we had developed to estimate the nutrition and health economic costs of unhealthy diets. This resulted in excluding several groups of literature, including fortified foods and micronutrient supplementation. Many studies examined individual dietary risks and these have limited usefulness since it is not possible to add them up to obtain overall estimates of the costs of unhealthy diets, since the risk factors may be correlated and/or interact. We also limited our review to studies in English, which likely excluded the emerging body of evidence from studies conducted in LMICs and published in other languages. For diet-related NCD outcomes, the search focused on overweight and obesity, diabetes and hypertension as the most commonly assessed in LMICs but excluded the overarching category of CVD and cancers.

Because this was a scoping review, we did not assess the quality of the studies included, which increases the risk of bias in the results reported, although most of the SRM had stringent quality review criteria for studies they included. The characteristics of the included studies and level of detail describing how diet exposures and outcomes were defined were also based on the quality of information provided in the SRM articles. There was high study variability in terms of methods and how independent and dependent variables were defined and also the extent to which confounding factors such as unhealthy lifestyle behaviours were considered in the multivariable models. For some diet exposures, the same studies were included in multiple SRM; however, we assessed the availability of this evidence qualitatively and did not calculate any summary estimate. The effect size was not often estimated for HICs vs. LMICs in subgroup analysis, preventing us from comparing this difference.

Conclusion

Our results highlight the need to develop theoretical frameworks and conduct research to better quantify the contribution of diet to the coexisting burden of multiple forms of malnutrition and NCDs. This will require increased investment in nationally representative dietary surveys at the individual level in LMICs that support monitoring of the nutrition and health effects of the nutrition transition in these contexts and inform program and policy decision making.

Figure 1: Conceptual framework guiding the review



(Source: the authors)

Figure 2: Flowchart of study selection process for all three framework components (diet, outcomes, cost)

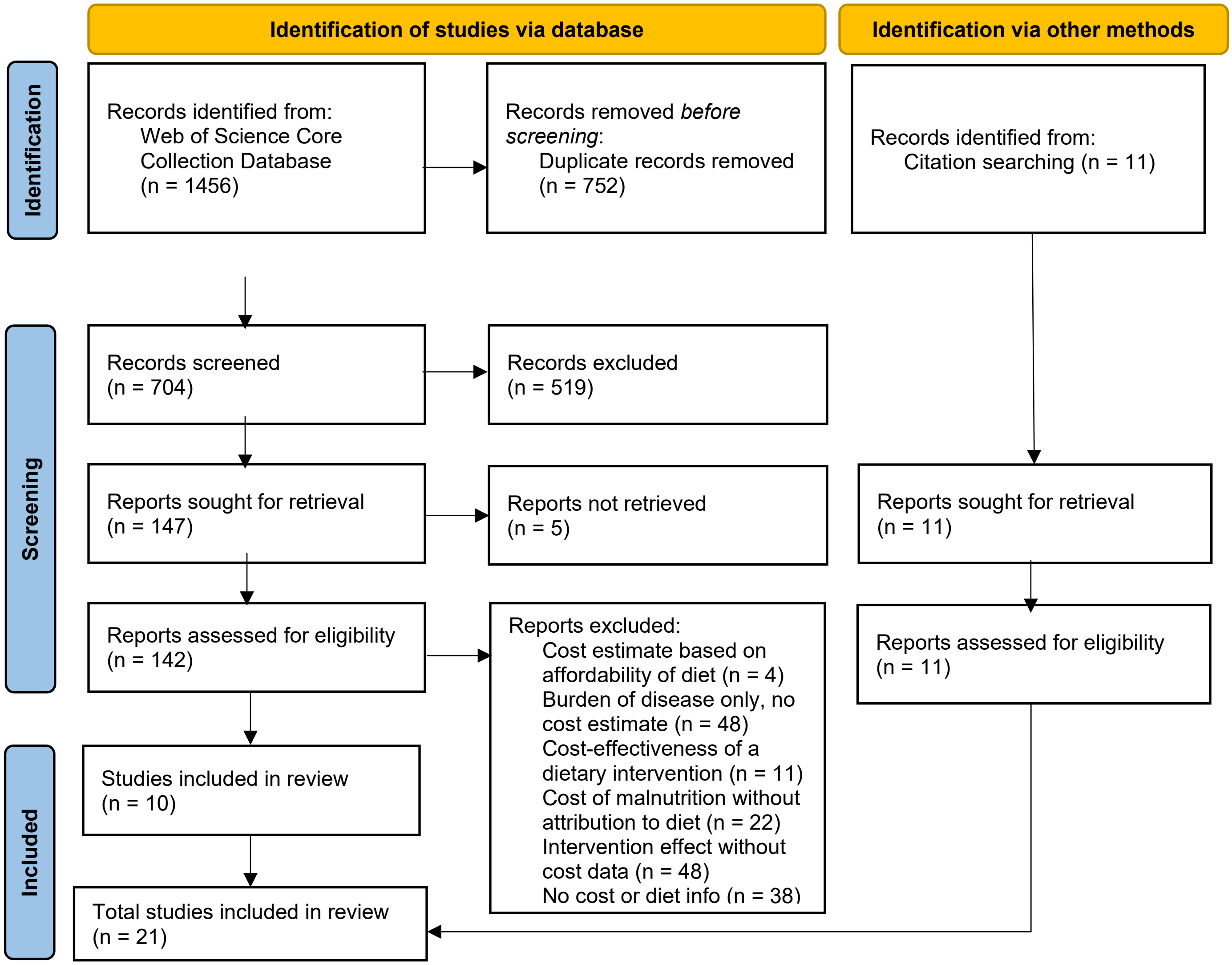


Figure 3: Flowchart of study selection process for burden of malnutrition associated with diets

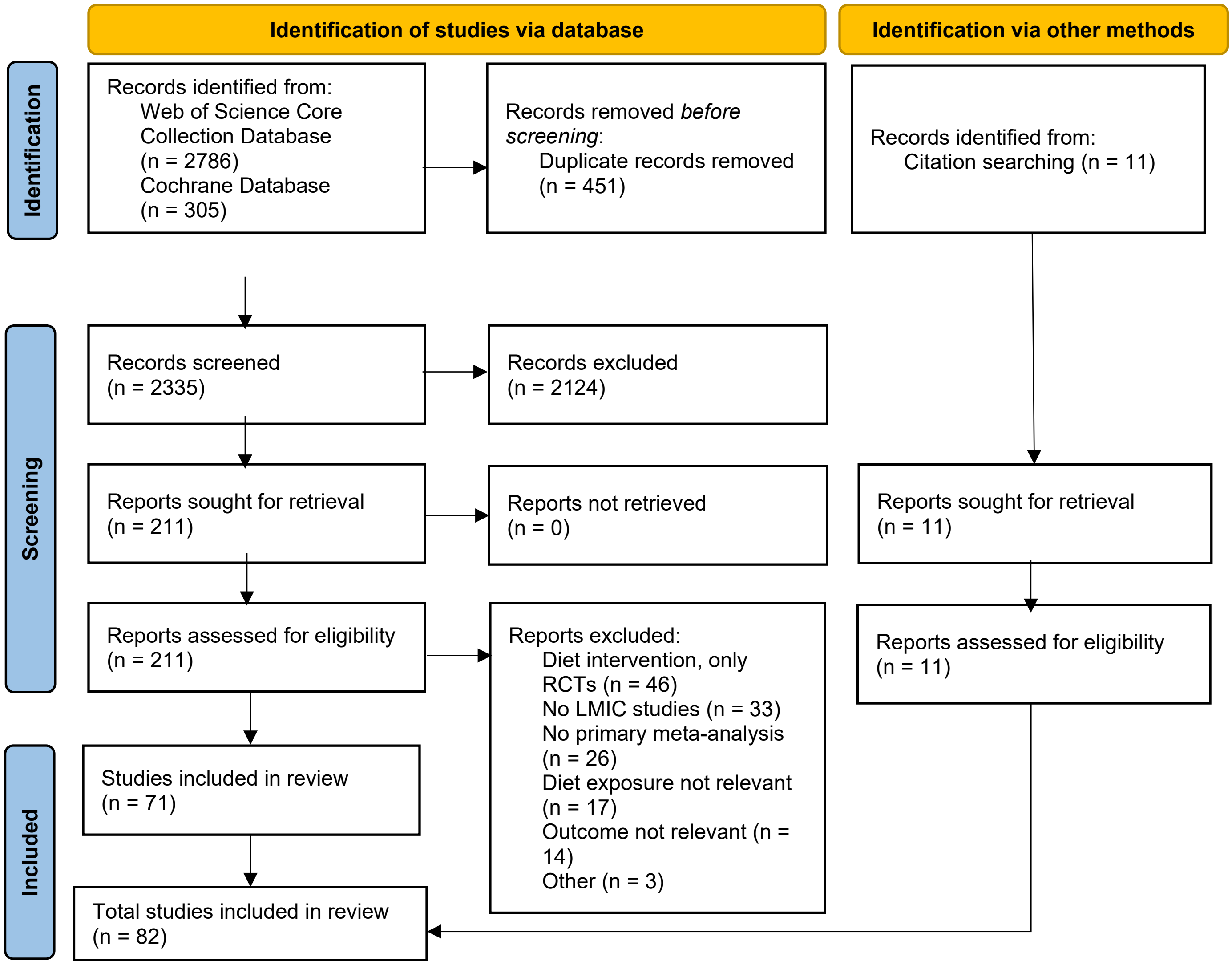


Table 1: Summary of Search 2 literature search elements

P	**Population**	**General population** grouped by age and physiological status: • Infants and young children aged zero to 59 months • Children and adolescents five years or older • Women of reproductive age, including pregnant and lactating women • Adults*
I	**Intervention/ Exposure**	**Any measure of 'diet' or 'food' intake:** • Intake of food items or food groups/categories (breastmilk†, animal source foods, dairy products, ultra-processed food, unhealthy food, sugar-sweetened beverages, salt‡) • Measures of diet quality and patterns (diet diversity, healthy/unhealthy diet pattern)
C	**Comparison**	Any or no comparison
O	**Outcome**	**Anthropometric measures of nutritional status**: incidence and/or prevalence of low birthweight, small-for-gestational age, child stunting (height-for-age), child wasting (weight-for-height, MUAC), thinness (BMI, MUAC), overweight and obesity (weight-for-height, BMI), body fat percentage, waist circumference **Biochemical measures of nutritional status**: incidence and/or prevalence of specific micronutrient deficiencies (e.g. serum retinol or serum ferritin), anemia (hemoglobin) **Biological measures of NCD risk factors and outcomes**: gestational diabetes, gestational hypertensive disorder, pre-eclampsia, raised blood glucose/type 2 diabetes mellitus, raised blood pressure/hypertension

Note:
*Older adults were not separated given the literature gap in LMICs.
†Breastmilk was one of the food groups considered as part of the diet for infants and young children but was not included as a specific search term.
‡Although salt is considered a condiment/seasoning, it was included as part of the diet due to its diet-related NCD policy relevance and direct contribution to NCD outcomes of interest to our search (i.e. hypertension)

Table 2: Summary of study characteristics that describe costs associated with unhealthy diets (listed in groups by type of dietary component assessed)

Author (Year)	Country and dataset	Life stage group	Diet Assessed	Nutrition/health Outcomes Assessed	Cost Assessed
GBD 2019 Risk Factors Collaborators (2020)	Global (204 countries), GBD 1990-2019	General population	13 dietary risk factors* (combined and individually)	*[not reported in the article but deaths and DALYs based on diet-related risk-disease pairings for outcomes like CVD, T2DM]*	Mortality, DALYs
Afshin et al. (2019)	Global (195 countries), GBD 1990-2017	General population	15 dietary risk factors‡	*[not reported in the article but deaths and DALYs based on diet-related risk-disease pairings for outcomes like CVD, T2DM]*	Mortality, DALYs
Studies estimating cost associated with all dietary risk factors					
Zhang et al. (2023)	Global (204 countries), GBD 1990-2019	General population	13 dietary risk factors*	**CVD**	Mortality, DALYs
Dong et al. (2022)	Global (204 countries), GBD 1990-2019	General population	13 dietary risk factors relevant to CVD outcomes*	all forms of **CVD**	Mortality, DALYs
Machado et al. (2022)	Brazil, GBD 1990-2019	General population	15 dietary risks‡	NCDs - **CVD**, **diabetes** and neoplasms	Mortality, DALYs
Qiao et al. (2022)	Global (204 countries), GBD 1990-2019	General population	13 dietary risk factors*	23 **NCDs** attributable to dietary risks in GBD	Mortality, DALYs
Davila-Cervantes (2020)	Mexico, GBD 1990-2017	General population	**dietary risks** were CVD risk factor	**CVD** as outcome • nutrition-related risk factor: **high BMI** • health-related CVD risk factors: high systolic **blood pressure**, high LDL cholesterol, high fasting **plasma glucose**	Mortality, DALYs
Duncan et al. (2017)	Brazil, GBD 1990-2015	General population	**Dietary risk factors** (low in whole grains, nuts and seeds, and fruits; high in red and processed meat, sweetened beverages)	**Diabetes, hyperglycemia** (high fasting plasma glucose)	Mortality, DALYs
Studies estimating cost associated with salt/sodium consumption					
Vega-Solano et al. (2023)	Costa Rica	Adults	**Salt** consumption	**High blood pressure**	Annual cost of hospitalization, consultations and medications

Author (Year)	Country and dataset	Life stage group	Diet Assessed	Nutrition/health Outcomes Assessed	Cost Assessed
Guedes et al. (2022)	Brazil, GBD 2019	General population	**sodium** consumption (excessive = >3g/day)	**hypertension** (intermediate risk factor), **CVD**, chronic kidney disease	Mortality, DALYs
Nilson, da Silva, and Jaime (2020)	Brazil		**Salt** consumption	**CVD**, mediated by effect of salt consumption on systolic **blood pressure**	Direct costs (hospitalization for CVD causes)
Nilson et al. (2020)	Brazil	Adults 30+ years	**Sodium** consumption	**High blood pressure**	Mortality and costs-of-illness (inpatient & outpatient care and medications)
Studies estimating cost associated with other individual dietary risk factors					
Liu et al. (2022)	Global (204 countries), GBD 1990-2019	General population	**diet high in red meat** (beef, pork, lamb and goat, and all processed meats - not poultry, fish or eggs)	**ischemic heart disease**, **diabetes**, and colorectal cancer (3 leading diseases attributable to diet high in red meat)	**Mortality, DALYs**
Rocha et al. (2023)	Brazil	Adults 25+ y	**diet rich in processed meats** (daily consumption of cured, smoked, salted meats)	ischemic heart disease, **diabetes**, colorectal cancer	**Mortality, DALYs + costs of hospitalizations and outpatient procedures**
Zhuo et al. (2022)	Global (204 countries), GBD 1990-2019	General population	Diet low in **fiber**	**NCDs**	Mortality, DALYs
Alcaraz et al. (2023)	Argentina, Brazil, El Salvador, and Trinidad and Tobago	Children/ adolescents, adults	**SSB** consumption	Effects on health **via BMI** and independent effects on **diabetes** and **CVD**	Mortality, DALYs, direct medical costs
Pradhananga et al. (2022)	Nepal + comparator countries†, GBD 2010-2019	General population	suboptimal breastfeeding, diet high in SSB, diet high in trans-fatty acids	Moderate/severe acute wasting **high BMI** (BMI>20-25 in adults 20+y, IOTF cutoffs for obesity in children <20)	Mortality, DALYs
Li et al. (2021)	China, GBD 2017	General population	diet high in SSB	Ischemic heart disease (IHD), **T2DM**	Mortality, DALYs
Basto-Abreu et al. (2020)	Mexico	Adults 20-59 y	Beverages and snacks intake (kcal/day)	Weight change (kg), **obesity**	Direct health care and indirect costs (premature deaths, work absenteeism, others)
Javanbakht et al. (2018)	Islamic Republic of Iran, micro-simulation modeling study	Adults	Dairy foods consumption	CVD, **T2DM**	annual per capita health care costs

Author (Year)	Country and dataset	Life stage group	Diet Assessed	Nutrition/health Outcomes Assessed	Cost Assessed
Walters et al. (2019)	Global (130 countries)	Infants and children <2 y	Not breastfeeding according to recommendations	Child morbidity (diarrhea, pneumonia) Maternal T2DM, breast & ovarian cancer	Child and maternal mortality, direct health care costs, household formula costs, future economic cost of mortality and cognitive losses

* **diets low in** fiber, fruits, legumes, nuts and seeds, polyunsaturated fatty acids, seafood omega-3 fatty acids, vegetables and whole grains, and **diets high in** processed meat, red meat, sodium, sugar-sweetened beverages and trans fatty acids

† India, Bangladesh, Bhutan, Pakistan, Sri Lanka, Maldives, and Afghanistan

‡ **includes diets low in** calcium and milk (in addition to the other 13 dietary risk factors included in GBD 2019)

Table 3: Summary of costs associated with dietary risk factors for nutrition and health outcomes in Search 1 studies

Dietary risk factor (Author, Year)	Geographic context, year	Nutrition/health outcomes	Mortality cost	DALYs cost	Health care and other economic costs
*Dietary risks (Zhang et al. 2023)	Global, 1990-2019	CVD	2019: 41% of CVD mortality attributable to dietary risk factors **6.86 million deaths** (ASDR 87.38) High sodium 21.51 Low whole grains 20.48 Low legumes 14.30	2019: 39% of CVD DALYs attributable to dietary risk factors **153.19 million DALYs** (ASR 1870.06 per 100,000) High sodium 490.68 Low whole grains 433.82 Low legumes 297.51	n/a
*Dietary risks – 13 relevant to CVD (Dong et al. 2022)	Global, 1990-2019	CVD	**6.9 million (37%) CVD deaths** attributed to dietary risks	**153.2 million (39%) CVD DALYs attributed to dietary risks** (ASR 1870.1 per 100,000) Low whole grains 20.1% High sodium 18.1% Low fruits 14.9% Low nuts and seeds 12.2% Low vegetables 9.8% Low seafood OmFA 9.3%	n/a
*Dietary risks – 13 related to CVD (Qiao et al. 2022)	Global, 1990-2019	*NCDs attributable to dietary risks (CVD, cancers and **T8DM**)*	2019: **7.9 million deaths** (ASDR 101.0)	2019: **187.7 million DALYs** Top five dietary risks High sodium Low whole grains Low legumes Low fruits High red meat	n/a
*Dietary risks - 15 (Davila-Cervantes 2020)	Mexico, 1990-2017	CVD	n/a	Risk factors contributing to CVD age-standardized DALY rate per 100,000: High systolic BP 1423.8 **Dietary risks 1397.9** High BMI 883.4	n/a
*Dietary risks for diabetes - 15 (Duncan et al. 2017)	Brazil, 1990-2015 Whole population	**Diabetes** and hyperglycemia	62,466 diabetes deaths	Total 2.11 million (ASR 1102.8 per 100,000) High BMI 610.7 (60.1%) Low whole grains 217.3 (21.4%) High SSB 11.9 (1.2%) Low nuts and seeds 138.1 (13.6%) High red meat 42.0 (4.1%)	n/a

Dietary risk factor (Author, Year)	Geographic context, year	Nutrition/health outcomes	Mortality cost	DALYs cost	Health care and other economic costs
				High processed meat 125.3 (12.3%)	
*Dietary risks - 15 (Machado et al. 2022)	Brazil, 1990-2019 Adults 25+ y	*CVD, **T8DM** and neoplasms are main NCDs attributable to unhealthy diet*	ASDR 65.3 deaths per 100,000 due to NCDs attributable to dietary risks Top 3: High red meat 17.1, low whole grains 14.4, high sodium 13.4	2019: **ASR 1,617.7** per 100,000 Top 3: High red meat 487.0 Low whole grains 348.7 High sodium 293.1	n/a
Salt consumption (Vega-Solano et al. 2023)	Costa Rica, 2018 Population 15+ y	*High blood pressure and CVD outcomes (CHD, hypertensive diseases, stroke)*	n/a	n/a	**USD 15.1 million** total cost of CVD hospitalizations, consultations and medications **USD 6.8 million** annual productivity costs of losses of GDP
*Salt consumption (Guedes et al. 2022)	Brazil, 2019	*CVD, chronic kidney disease, stomach cancer*	30,814 deaths	699,119 DALYs	n/a
Salt consumption (Nilson, Metlzer et al. 2020)	Brazil, 2017	*Hypertension and associated CVD*	46,651 deaths from CVDs (15% of CVD deaths)	575,172 YLL as result of CVD deaths attributable to excessive sodium consumption	**USD 192.1 million** in health care costs (hospitalization, outpatient care & medication for hypertension) **USD 752.7 million** productivity losses due to premature deaths
Salt/sodium consumption (Nilson, da Silva et al. 2020)	Brazil, 2013	*Increased systolic blood pressure and associated CVD*	n/a	n/a	**USD 102 million** CVD hospitalization costs attributable to excessive salt intake in 2013 (9.4% of total hospitalization costs)
*Low fibre (Zhuo et al. 2022)	Global, 1990-2019	All causes, colon and rectum cancer, **T2DM**, IHD, stroke	**ASDR 7.74**	**ASR 186.89**	n/a
*High red meat diet (Liu et al. 2022)	Global, 1990-2019 Adults 25+ y	*IHD (39%), **T8DM** (9%), colorectal cancer (6%) (3 leading diseases attributable to diet high in red meat)*	895,675 deaths (**ASDR 11.3** per 100,000)	23.9 million DALYs (**ASR 289.8** per 100,000)	n/a
*High processed meat diet (Rocha et al. 2023)	Brazil, 1990-2019 Adults 25+ y	*NCDs attributable to high processed meat diet*	2019: **ASDR 2.36** per 100,000 **T2DM 1.22** IHD 0.92	2019: **ASR 79.35** per 100,000 **T2DM 50.75** IHD 23.35	**USD 9.4 million** in health care costs (hospitalization and outpatient procedures)

Dietary risk factor (Author, Year)	Geographic context, year	Nutrition/health outcomes	Mortality cost	DALYs cost	Health care and other economic costs
			Colorectal cancer 0.21	Colorectal cancer 5.26	
SSB consumption in 1 year (Alcaraz et al. 2023)	Argentina, Brazil, Trinidad & Tobago, El Salvador	1.5 million **overweight & obesity** cases in children and adolescents (12%) 2.8 million in adults (2.8%) 2.2 million **T2DM** cases in adults (19%)	**18,000 deaths** (3.2% of total disease-related deaths)	**500,000 DALYs**	**USD 2 billion** direct medical costs
SSB consumption (Bardach et al. 2023)	Argentina, 2020	520,000 **overweight & obese** cases in adults 774,000 in children and adolescents 23% of **T2DM** cases attributed to SSB	**4,425 deaths**	110,000 YLL due to premature death and disability (no DALYs reported)	**$47 million** in adults and **$15 million** in children and adolescents
*SSB consumption, high (Li et al. 2021)	China, 1990-2017	**T2DM**	**924 deaths** due to T2DM	**152,780 DALYs** (8.2 per 100,000) for T2DM	n/a
Not breastfeeding (Walters et al. 2019)	Global	Child morbidity: diarrhea, pneumonia, **obesity** (974,956 cases of childhood obesity each year) Women: **T2DM**, cancer	595,379 childhood deaths per year (6-59 mon) from diarrhea and pneumonia 98,243 women's deaths from breast & ovarian cancers, T2DM		**USD 341.3 billion** total costs (0.7% of global GNI) **USD 1.1 billion** annual global health system treatment costs **USD 53.7 billion** in economic losses due to premature child and women's mortality; **USD 285.4 billion** in cognitive losses
‡Beverage and snack intake (Basto-Abreu et al. 2020)	Mexico, 2019	4.98 percentage point decrease in **obesity** prevalence in adults <60 y over 5 years, as a result of a 36.8 kcal/day reduction in energy intake of beverages and snacks	n/a	n/a	**USD 1.84 billion** savings in direct and indirect health care costs

Dietary risk factor (Author, Year)	Geographic context, year	Nutrition/health outcomes	Mortality cost	DALYs cost	Health care and other economic costs
‡Dairy foods intake (Javanbakht et al. 2018)	Islamic Republic of Iran, 2016	Reduction in CVD and T2DM incidence due to optimal dairy food consumption	n/a	n/a	Per capita savings in health care costs: $0.43 in 1 year $190.25 in 20 years Total cost $33.8 million in 1 year

* study based on GBD model data

† dietary risks comprise the sum of adverse effects of diets in which 15 food types were either underconsumed (fruits, vegetables, legumes, whole grains, nuts and seeds, milk, fiber, calcium, omega-3 fatty acids from seafood, and polyunsaturated fatty acids) or overconsumed (red meat, processed meat, sugar-sweetened beverages, trans-fatty acids, and sodium)

‡ study modeling the cost savings associated with improved diet quality

Abbreviations: ASDR age-standardized death rate; ASR age-standardized rate; BMI body mass index; BP blood pressure; CHD coronary heart disease; CVD cardiovascular disease; DALY disability adjusted life year; IHD ischemic heart disease; n/a not available (not reported); NCD non-communicable diseases; SSB sugar-sweetened beverages; T2DM type 2 diabetes mellitus; USD US Dollar; YLL years of life lost due to premature mortality

Table 4: Summary of systematic review and meta-analyses studies on burden of malnutrition/disease associated with diet during pregnancy

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Maternal nutrition outcomes, including anemia or other nutrient deficiencies					
Seid et al. (2023)	SRM of 22 observational studies in Africa (11 cross-sectional, 6 cohort, 5 case-control)	9,696 pregnant women	**Dietary diversity** during pregnancy *(note: studies used different cutoffs for 'inadequate DD', including <5/10 (n=9) and ≤4/9 (n=2))*	Maternal anemia, low birthweight	Low diet diversity associated with maternal anemia (**OR 2.15;** 95% CI 1.66, 2.65; 13 studies) Low diet diversity associated with LBW (**OR 2.04;** 1.45, 2.63; 9 studies)
Geta, Gebremedhin, and Omigbodun (2022)	SRM of 60 studies (53 cross-sectional, 5 case-control, 2 cohort) from Ethiopia	Pregnant women, Ethiopia	**Dietary diversity** (low, medium, high) assessed in 10 studies	Anemia (Hb <11 g/dL)	Low diet diversity associated with higher risk of anemia (**RR 2.61**; 1.85, 3.68)
J. Zhang et al. (2022)	SRM of 51 studies (42 cross-sectional, 6 case-control, 3 cohort), all in LMICs (36 in Ethiopia)	Pregnant women 15-49 y (n=73,919)	Model tested for 8 dietary habit exposures, including frequency of eating vegetables (n=10) or meat (n=11), DDS (n=7)	Anemia (Hb <11 g/DL)	Risk factors for anemia included frequency of eating meat ≤1 time per week (**OR 2.02**; 1.55, 2.50), eating vegetables ≤ 3 times per week (**OR 2.97**; 95% CI 1.59, 4.34), diet diversity score ≤3 (**OR 2.38**; 1.55, 3.21)
Getaneh et al. (2021)	SRM of 24 studies (22 cross-sectional, 1 cohort, 1 case-control) in Ethiopia	Pregnant women 15–49 y (n=12,893)	**Dietary diversity** (DDS <5 food groups) assessed in 5 studies	Undernutrition, assessed as MUAC <21 (n=6), <22 (n=9) or <23 cm (n=6); BMI <18.5 kg/m^2 (n=3)	Pooled prevalence of undernutrition was 29.2% (MUAC) and 27.9% (BMI). Low diet diversity associated with risk of undernutrition during pregnancy (**effect size 2.89**; 95% CI 1.28, 6.53)
Berhe, Gebrearegay, and Gebremariam (2019)	SRM of 7 studies, Ethiopia	N=2371 pregnant women	ASF intake, diet diversity	Zinc deficiency (plasma or serum Zn concentration)	Pooled prevalence of zinc deficiency 59.9% (95% CI 51.9, 67.7) Dietary risk factors associated with Zn deficiency (n=4 studies): low intake of ASF (**OR 2.57**; 1.80, 3.66), low diet diversity (**OR 2.12**; 1.28, 3.53)
Health outcomes, including gestational diabetes, hypertension, pre-eclampsia and birth outcomes					
Beyene et al. (2023)	SRM of 10 studies (8 cross-sectional, 1 cohort, 1 case-control)	N=6525	**Diet diversity** (2 studies) *(no info on how assessed or cutoffs used)*	GDM	Risk factors for GDM included inadequate diet diversity (**effect size 1.51**; 1.25, 1.83) and high BMI ≥25 (2.24; 2.07, 2.42)
Cui et al. (2023)	SRM of 65 studies (63 cohort and 2 case-control),	Pregnant women 18+ y (n=831,798)	**Dietary intake**, pre-pregnancy (foods or	GDM, neonatal outcomes, preterm birth, SGA	GDM positively associated with pre-pregnancy intake of fried food (pooled **RR 1.59**; 1.08, 2.34), fast food (**RR 1.93**; 1.27,

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
	includes Brazil, China, the Islamic Republic of Iran Meta-analysis (n=38)		food groups, dietary patterns)		2.94), red and processed meat (**RR 1.61**; 1.06, 2.45). High dietary fiber negatively associated with GDM (p<0.05). No association for SSB, potato and fish intake.
Haghighatdoost et al. (2023)	SRM of 31 observational studies (18 prospective cohort, 7 cross-sectional, 6 case-control), includes Brazil, China, the Islamic Republic of Iran; meta-analysis (n=27)	Pregnant women 16+ y (healthy diet patterns 26 studies n=80 849); unhealthy diet patterns 15 studies n= 32 965)	**Dietary patterns** during pregnancy (n=25) or pre-pregnancy (n=5); assessed using FFQ (n=23), dietary recall or record (n=8)	GDM Assessed using glucose test (n-24) or self-report (n=7)	Pregnant women with a healthier dietary pattern (a diet rich in fruits, vegetables, and whole grains) had lower risk for GDM **(RR = 0.86**; 0.76–0.96). Marginally significant association between unhealthy dietary patterns and GDM risk (1.28; 0.99–1.67).
X. Gao et al. (2023)	SRM of 19 studies (15 cohort, 4 case-control), 5 in China, 3 in the Islamic Republic of Iran (11 studies included in meta-analysis)	Pregnant and pre-pregnant (6 studies) women (n=108,084)	**Diet quality** (Mediterranean diet, DASH, Alternate Healthy Eating Index, other quality indices or scores)	GDM	Higher quality diet reduced risk of GDM (Higher Mediterranean diet (**OR 0.51**; 0.30,0.86), DASH (**0.66**;0.44-0.97), AHEI (**0.61**; 0.44-0.83), overall plant-based diet index (**0.57**; 0.41-0.78), and adherence to national dietary guidelines (**0.39**; 0.31-0.48).
Paula et al. (2022)	SRM of 61 studies (47 cohort, 9 cross-sectional, 5 case-control) from various countries	Pregnant women (n=698,803)	**UPF-rich diet consumption** (Western diet pattern n=17; sweetened beverages n=12; specific UPF food groups n=12; et al.)	GWG (n=5), GDM (n=15), hypertension (n=3), pre-eclampsia (n=4) LBW (n=11); LGA (n=8); preterm birth (n=4)	Higher consumption of UPF-rich diet increased the odds of GDM (**OR 1.48**; 1.17, 1.87) and pre-eclampsia (**OR 1.28**; 1.15, 1.42) but not hypertension, excessive GWG, LBW, LGA or PTB.
Abdollahi et al. (2021)	SRM of 66 cohort studies included in meta-analysis, various HICs and LMICs	Adult mothers (18+ y)	**Dietary patterns:** healthy, unhealthy, mixed	GDM (n=17), hypertension (n=15), GWG (n=10), preterm birth (n=12), LBW (n=7)	Higher maternal adherence to healthy diet associated with lower risk of gestational hypertension (**OR 0.86**; 0.81, 0.91), LBW (OR 0.72; 0.53, 0.97), preterm birth (**OR 0.44**; 0.31, 0.62), and higher birth weight (Hedges' g: 0.91; 0.05, 0.32); adherence to unhealthy or mixed diet associated with higher risk of gestational hypertension (**OR 1.23**; 1.14, 1.34)

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Kinshella et al. (2021)	SRM of 13 studies (10 case-control, 2 cohort, 1 RCT), all LMICs (5 studies included in meta-analysis)	Pregnant women	Consumption of **vegetables** (n=4 studies), **fruit** (n=5)	Hypertensive disorders, pre-eclampsia	Lower risk of pre-eclampsia associated with adequate (compared with no or low) consumption of vegetables (OR **0.38**; 0.18, 0.80) and adequate (compared with no or low) consumption of fruit (OR **0.42**; 0.24, 0.71).
Quan et al. (2021)	SRM of 21 cohort studies	Pregnant women (n=191 589)	Western **dietary patterns**	GDM	Consumption of animal meat **(pooled RR 1.35**; 1.16, 1.57) and fast food (**1.75**; 1.41, 2.19) positively associated with risk of developing GDM, but not potatoes (RR 1.12; 0.93, 1.35).
Pérez-Roncero et al. (2020)	SRM of 14 studies (meta-analysis of 10 studies), included India	Pregnant women (n=111,184)	**Milk** and related product consumption	Perinatal outcomes: birth weight and length, SGA, LGA, LBW	Consuming higher amount of milk associated with higher birth weight (**mean diff =51.0 g**, 95% CI 24.7, 77.3; n=10 studies), and infant length (**mean diff 0.33 cm**, 0.03, 0.64; n=5 studies); as well as reduced risk of SGA **(OR 0.69**, 95% CI 0.56, 0.84) and LBW **(OR 0.63**; 0.48, 0.84), and increased risk of LGA **(OR 1.11**; 1.02, 1.21)
Hassani Zadeh, Boffetta, and Hosseinzadeh (2020)	SRM of 18 cohort studies, 1 in Latin America, 2 in Asia (n=13 studies in the meta-analysis)	Pregnant women 18-40 y	**Dietary pattern** (western, prudent, vegetable, Mediterranean), pre-pregnancy (n=6) or during pregnancy (n=7) Assessed using FFQ, 24HR or food record	GDM Assessed by medical test record (n=3) or self-reports	Decreased risk of GDM associated with "prudent" (**RR 0.78**, 0.63–0.96), "vegetable" **(0.86**, 0.76–0.98), and "Mediterranean" (**0.71**, 0.56–0.91), dietary patterns with high levels of whole grain, fruits, vegetables, and low fat dairy intake. The 'Western' dietary pattern associated with increased risk of GDM (**1.27**, 1.03–1.56).
Chia et al. (2019)	SRM of 36 studies (33 cohort, 1 case-control, 1 cross-sectional included in meta-analysis, 1 RCT), various HICs and LMICs	Healthy pregnant women with no pre-existing health conditions reported	**Dietary patterns:** 'healthy' and 'unhealthy'‡ [assessed by FFQ (n=29), 24HR (n=6), 3-d food diary (n=5)]	Preterm birth, birthweight, LBW, SGA, LGA, macrosomia	Healthy dietary pattern (top vs. bottom tertile, n=6 studies) associated with lower risk of preterm birth (**OR 0.79**; 95% CI 0.68, 0.91); weak trend to lower risk of small-for-gestational age (n=10 studies, **OR 0.86**; 0.73, 1.01); Unhealthy dietary patterns (n=3 studies) associated with lower birth weight (mean difference: **-40 g**; -61, -21) and trend to higher risk of preterm birth (OR 1.17; 0.99, 1.39)
Kibret et al. (2019)	SRM of 21 studies (18 cohort, 3 cross-	Pregnant women (n=302,450)	**Healthy diet** (intake of vegetables, fruits,	Hypertensive disorders of pregnancy (n=6),	Healthy dietary pattern adherence associated with lower risk of pre-eclampsia

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
	sectional), various HICs and LMICs		legumes, whole grains) [diet assessed by FFQ (n=15), 24HR (n=5), 4-d food record (n=1)]	GDM (n=6), PTB (n=9), LBW (n=2)	(**OR 0.78**; 0.70, 0.86), GDM (**OR 0.79**; 0.56, 0.99), preterm birth (**OR 0.75**; 0.57, 0.93)
Tan, Zhao, and Wang (2019)	SRM of 19 observational studies	Pregnant women	Vegetarian Diet	LBW, birth weight, GDM, maternal anemia	Association between vegetarian diet in pregnancy and LBW was marginally significant (1.27 (0.98, 1.65), P = 0.07). No conclusive results regarding the risks of maternal anemia and GDM
Liao et al. (2023)	SRM of 12 cohort studies, including China (5), the Islamic Republic of Iran (2)	Pregnant women 18+ y	Fruit, vegetable consumption, highest vs lowest intake quartile	GDM	Fruit consumption (n=8 studies) **RR 0.92** (0.86, 0.99) Vegetable consumption (4 studies) RR 0.95 (0.87, 1.03)

Abbreviations: ASF animal source foods; BP blood pressure; F&V fruit and vegetable; GDM gestational diabetes mellitus; GHT gestational hypertension; GWG gestational weight gain; HT hypertension; LBW low birth weight; LGA large for gestational age; OR odds ratio; OWOB overweight and obesity; PTB preterm birth; RR relative risk; SGA small for gestational age; SSB sugar-sweetened beverages; T2DM type 2 diabetes mellitus; UPF ultra processed food; Zn def'y zinc deficiency

Table 5: Summary of systematic reviews with meta-analyses on the risk of malnutrition/disease associated with diet in children <5 years

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key Findings
Undernutrition outcomes					
Azmeraw et al. (2023)	SRM of 10 studies in Ethiopia	Children 6-23 mon (n=14,733)	**Dietary diversity**	**Anemia**	Low diet diversity associated with risk of anemia (**OR 2.73**, 95% CI 2.06, 3.39)
Belachew and Tewabe (2020)	SRM of 16 cross-sectional studies, Ethiopia	Children <5 y (n=11,924)	**Dietary diversity** (n=5 studies)	**Anemia** (Hb<11 g/dL)	Low diet diversity (<4 food groups per day) associated with anemia (**OR 1.71**; 1.10, 2.68)
Abdulahi et al. (2017)	SRM of 18 cross-sectional studies, Ethiopia	Children 0-5 y (n=39,585)	**Dietary diversity**	**Stunting, underweight, wasting**	Diet diversity was significant protective factor for stunting (n=2 studies) **OR=0.78** (95% CI 0.20, 1.35)
Overweight and obesity outcomes					
Horta et al. (2023)	SRM of 159 studies	Most studies carried out on individuals 1-9 y	**Breastfeeding**	**Overweight or obesity**	Breastfeeding protective for OWOB: pooled **OR 0.73** (0.71, 0.76)
M. Nguyen et al. (2023) †	SRM of 48 articles (40 cohorts)	Children, median age 10 y, range 6 mo to 17 y (n=91,713)	**SSB intake**	**BMI**	Each serving/day increase in SSB intake was associated with a **0.07 kg/m^2** (95% CI 0.04, 0.10) higher BMI in children
Abbasalizad Farhangi et al. (2022) †	SRM of 33 studies (23 cross-sectional, 1 case-control, 4 cohort, 6 longitudinal), included Argentina (3), Mexico, China (7), the Islamic Republic of Iran, Lebanon	Children 2-18 y (n=121,282)	**SSB intake**	**BMI** (n=19), **body fat percentage** (n=5), **waist circumference** (n=15)	High SSB intake associated with **0.75 kg/m^2** increase in BMI in children and adolescents (WMD 0.75; 95% CI 0.35, 1.15), higher WC (WMD 2.35 cm; 1.34, 3.37) and BFP (WMD 2.81; 2.21–3.41).
Babio et al. (2022) †	Cross-sectional and prospective cohort studies (most in HICs but included China, Mexico & Lebanon)	Children 2-21 y (n=28,740 for total dairy and obesity)	**Dairy product consumption**	**Overweight, obesity**	*Cross-sectional studies:* Total dairy consumption inversely associated with risk of obesity (**OR 0.66**, 95% CI 0.48, 0.91) but not overweight (OR 1.04, 95% CI 0.73, 1.49); no evidence for association with milk or yogurt *Prospective studies*: total milk consumption associated with overweight (**OR 1.13**; 95% CI 1.01, 1.26)

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key Findings
Vanderhout et al. (2020) †	SRM of 28 studies (20 cross-sectional, 8 cohort), 7 countries (6 HICs, 1 in Brazil) meta-analysis n=14 (11 cross-sectional, 3 cohort)	Children 1-18 y (n=20,897 in meta-analysis)	**Milk consumption,** whole (3.25% fat) vs reduced fat (0.1-2%) [assessed using FFQ, 24HR, multiday food record, other] Regular consumption defined as typically, daily, or ≥4 times per week	**Overweight and obesity** [assessed by BMI z-score (n=19), body fat percentage (n=4), other (n=5)]	Regularly consuming whole (3.25% fat) vs reduced-fat milk associated with lower risk of OWOB (**OR 0.61**; 95% CI 0.52, 0.72)
Other health outcomes					
Horta and de Lima (2019)	SRM of 14 studies (3 case-control, 4 cross-sectional, 7 cohort), 2 in LMICs	Breastfed subjects (mean age at assessment ranged from 13-71 y)	Breastfeeding	**T2DM** in later life	Risk of T2DM in later life is lower among subjects who had been breastfed vs. non-breastfed (pooled OR **0.67**; 95% CI 0.56, 0.80); subgroup analysis found higher protective effect among adolescents 10-19 y (OR 0.49; 0.38, 0.63) compared to adults 20+ y (OR 0.77; 0.66, 0.90)

Abbreviations: 24HR 24-hour recall; ASF animal source foods; BFP body fat percentage; BMI body mass index; BP blood pressure; CI confidence interval; FFQ food frequency questionnaire; F&V fruit and vegetable; HIC high-income country; LMIC low and middle-income country; OR odds ratio; OWOB overweight and obesity; RR relative risk; SSB sugar-sweetened beverages; SRM systematic review and meta-analysis; T2DM type 2 diabetes mellitus; UPF ultra processed food; WC waist circumference; WMD weighted mean difference

† Study also included in Table 6 for children 5+ y due to age range of participants.

Table 6: Summary of systematic review and meta-analyses studies on burden of malnutrition/disease in children 5-19 y associated with their diet

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key Findings
Undernutrition outcomes					
Zeinalabedini et al. (2023)	SRM of 20 studies, all LMICs	Children 5-18 y (6 studies were girls only)	**Diet diversity** (17 based on 24HR, 1 7-d recall, 1 30-d FFQ, 1 unknown)	Stunting, thinness, wasting	Low diet diversity increased odds of stunting (**OR 1.43**, 95% CI 1.08, 1.89) and wasting (**OR 2.18**; 95% CI 1.41, 3.36) but not thinness (OR 1.10, 95% CI 0.81, 1.49)
Berhe et al. (2019)	SRM of 22 cross-sectional studies, Ethiopia	Adolescents (n=17,854)	**Dietary Diversity** Score, low (DDS<4)	Underweight (BMI-Z <-2 SD) (n=5 studies)	Low diet diversity associated with underweight (**OR 1.95**; 95% CI 1.31, 2.92)
Berhe et al. (2022)	SRM of 15 cross-sectional studies, Ethiopia (includes 2 national surveys in 2016 – EDHS & MNS)	Adolescent girls 10-19 y (n=9,669)	**Dietary diversity** Score, low (DDS <4 of 9 food groups)	Anemia (using WHO Hb cutoffs)	Low diet diversity (n=2 studies) was associated with anemia (**OR=2.81**; 1.33, 5.90)
Habtegiorgis et al. (2022); Endale et al. (2022) (both articles based on the same 10 studies)	SRM of 10 cross-sectional studies, Ethiopia	Adolescent girls	**Dietary diversity** Score, low (DDS <4 of 9 food groups)	Anemia (using WHO 2011 Hb cutoffs by age and pregnancy status)	Low diet diversity (n=5 studies) associated with anemia (**OR 1.35**; 95% CI 1.00, 2.34) or (**OR 1.56**; 95% CI 1.05, 2.32)
Jensen (2023)	SRM of 11 cross-sectional studies (most in HICs, 3 in India, 2 in China) 8 studies included in meta-analysis	Children and adolescents 5-18 y (n=1545 in meta-analysis)	Adherence to **plant based diet** (vegan, vegetarian, macrobiotic, etc)	Vitamin B12 level	Vegan or macrobiotic diets associated with lower vitamin B-12 levels compared to omnivore diet (**-97 pmol/L**; 95%CI -187, -7)
Overweight and obesity outcomes					
Gezaw et al. (2023b)	SRM of 33 studies (32 cross-sectional, 1 case control), Ethiopia	Adolescents 10-19 y (n=25,172)	**Diet Diversity** Score	**Overweight** (BMI >+1 SD), **obesity** (BMI >+2 SD), **thinness** (WAZ <-2 SD)	Low DDS associated with OW/OB (OR 2.26; 95% CI 1.28, 3.99) based on pooled results from 2 studies, but not thinness (8 studies)
Cunha et al. (2018)	SRM of 19 studies (17 cross-sectional, 2 cohort), most in HICs, 1 in Tunisia 7 studies in meta-analysis (7 with BMI	Boys and girls 7-19 y	**Unhealthy dietary pattern** [assessed using FFQ (n=11), factor analysis (n=14)]	**BMI** (n 18), **waist circumference** (WC) (n 9), systolic **blood pressure** (n 7), diastolic blood pressure (n 6), **blood glucose** (n 5) and lipid profile (n 5)	Dietary patterns with highest vs low intake of unhealthy foods resulted in a higher mean BMI (0.57 kg/m^2; 95 % CI 0.51, 0.63) and WC (0.57 cm; 0.47, 0·67) Low intake of healthy foods associated with lower mean BMI

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key Findings
	data, 5 with WC data)				(−0.41 kg/m^2; −0.46,−0.36) and WC (−0.43 cm; −0.52,−0.33)
Nguyen et al. (2023) †	48 articles (40 cohorts)	Children, median age 10 y, range 6 mo to 17 y (n=91,713)	**SSB** intake	**BMI**	Each serving/day increase in SSB intake was associated with higher BMI (0.07 kg/m^2; 95% CI 0.04, 0.10) in children
Abbasalizad Farhangi et al. (2022) †	SRM of 33 studies (23 cross-sectional, 1 case-control, 4 cohort, 6 longitudinal), included Argentina (3), Mexico, China (7), the Islamic Republic of Iran, Lebanon	Children 2-18 y (n=121,282)	**SSB** intake	**BMI** (n=19), **body fact percentage** (n=5), **waist circumference** (n=15)	High SSBs intake was associated with 0.75 kg/m^2 increase in BMI in children and adolescents (WMD: 0.75; CI 0.35–1.15), higher WC (WMD: 2.35 cm; 95% CI, 1.34, 3.37; p = 0.016) and BFP (WMD: 2.81; CI 2.21–3.41; p < 0.001).
Jakobsen, Brader, and Bruun (2023)	SRM of 60 studies (51 cross-sectional, 9 longitudinal), includes mix of HICs and LMICs	Children and adolescents 5-18 y (n=242,061)	Consumption of 14 different **individual food or beverage categories** *(excluded dietary patterns)*	**Overweight and/or obesity** (based on age- and sex-specific BMI cut-offs)	Higher intake of SSB (**OR 1.20**; p <0.05, n=26), fast food (**OR 1.17**; p <0.05, n=24), meat (**OR 1.02**, p < 0.05, n=7), and refined grains (**OR 1.28**, p<0.05, n=3) associated with overweight/obesity; Conversely, higher whole grain (**OR 0.86**, p = 0.04, n:5) and sweet bakery (**OR 0.59**, p < 0.05, n:3) intake associated with lower risk.
Poorolajal et al. (2020)	SRM of 199 studies	Children and adolescents 5-19 y (n=1,636,049)	Diet-related risk factors	**Overweight/obesity**	Factors associated with child OW/OB: sufficient consumption of fruits/vegetables 0.92 (0.84, 1.01) breastfeeding <4 months 1.24 (1.16, 1.33); eating sweets ≥3 times/week 0.78 (0.71, 0.85); eating snack ≥4 times/week 0.84 (0.71, 1.00); drinking SSB ≥4 times/week 1.24 (1.07, 1.43); eating fast-food ≥3 times/week 1.03 (0.89, 1.18); eating fried-food ≥3 times/week 1.09 (0.90, 1.33)

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key Findings
Babio et al. (2022) †	SRM of cross-sectional and prospective cohort studies (most in HICs but included China, Mexico & Lebanon)	Children 2-21 y (n=28,740 for total dairy and obesity)	**Dairy product** consumption	**Overweight, obesity**	*Cross-sectional studies:* Total dairy consumption inversely associated with risk of obesity (**OR 0.66**, 95% CI 0.48, 0.91) but not overweight (OR 1.04, 95% CI 0.73, 1.49); no evidence of association with milk or yogurt consumption. *Prospective studies*: total milk consumption associated with overweight (**OR 1.13**; 95% CI 1.01, 1.26)
Vanderhout et al. (2020) †	SRM of 28 studies (20 cross-sectional, 8 cohort), 7 countries (6 HICs, 1 in Brazil) 14 studies in meta-analysis (11 cross-sectional, 3 cohort)	Children 1-18 y (n=20,897 in meta-analysis)	Whole (3.25% fat) vs reduced fat (0.1-2%) **milk** consumption [assessed using FFQ, 24HR, multiday food record, other] Regular consumption defined as typically, daily, or ≥4 times per week	**Overweight and obesity** [assessed by BMI z-score (n=19), body fat percentage (n=4), other (n=5)]	Regularly consuming whole (3.25% fat) vs reduced-fat milk associated with lower risk of overweight and obesity (**OR 0.61**; 95% CI 0.52, 0.72)
W. Wang, Wu, and Zhang (2016) ‡	SRM of 17 studies for total dairy products (14 cross-sectional, 2 case-control, 1 cohort) and 16 for milk (12 cross-sectional, 4 cohort), 10 in Asia, 2 in South America	Children 6-19 y (13 studies)	**Milk and dairy** products consumption [assessed using FFQ (n=12) and/or 24HR (n=7) or questionnaire (n=9)]	**Obesity** defined using waist circumference or BMI (with cutoffs of ≥25, 28 or 30 kg/m^2)	Lower risk of obesity in children associated with consumption of dairy products (pooled **OR 0.54**; 0.38, 0.77) and milk (pooled **OR 0.87**; 95% CI 0.80, 0.95)
Other health outcomes					
Leyvraz et al. (2018)	SRM of 85 studies (14 experimental, 60 cross-sectional, 6 cohort and 5 case-control studies)	Children and adolescents 0-18 y (n=58,531) (meta-analysis included 3406)	**Salt** consumption, g/day	Systolic and diastolic BP	For every additional gram of sodium intake per day, systolic blood pressure increased by 0.8 mmHg (95% CI: 0.4, 1.3) and diastolic blood pressure by 0.7 mmHg (95% CI: 0.0, 1.4).

Abbreviations: 24HR 24-hour recall; ASF animal source foods; BFP body fat percentage; BMI body mass index; BP blood pressure; CI confidence interval; FFQ food frequency questionnaire; F&V fruit and vegetable; HIC high-income country; LMIC low and middle-income country; OR odds ratio; OWOB overweight and obesity; RR relative risk; SSB sugar-sweetened beverages; SRM systematic review and meta-analysis; T2DM type 2 diabetes mellitus; UPF ultra processed food; WC waist circumference; WMD weighted mean difference

† Study also included in Table 5 for children <5 y due to age range of participants.

‡ Study also included in Table 7 for adults due to age range of participants.

Table 7: Summary of systematic review and meta-analyses studies on burden of malnutrition/disease in adults associated with their diet

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Nutrition.outcomes					
Haider et al. (2018)	SRM of 27 studies (27 cross-sectional, 3 RCTs) includes 1 in Thailand, India, the Islamic Republic of Iran	Adults >18y	**Vegetarian diet**	Iron status	Vegetarians had significantly lower serum ferritin levels compared to non-vegetarian controls (**−29.71 μg/L**; 95% CI -39.69, -19.73). The impact was more pronounced in men, than in premenopausal women and all women
Overweight.and.obesity					
Qorbani et al. (2022)	SRM of 23 studies (22 cross sectional, 1 cohort), 13 in LMICs: the Islamic Republic of Iran 7, Burkina Faso 1, Ethiopia 1, Ghana 1, Sri Lanka 1, Togo 1	Adults 18-67y (n= 113-78235)	**Dietary Diversity** (note: studies used different DDS measurement range scores from 5-24 groups)	Obesity and overweight, diabetes, BMI, blood pressure, lipid profile	Association of DDS with obesity, abdominal obesity, overweight, body mass index, diabetes, blood pressure, and lipid profile (TC, LDL, HDL) was not statistically significant.
Salehi-Abargouei et al. (2016)	SRM of 16 studies (all cross-sectional) 6 in Asia, 5 in Africa, 3 in North America, 2 in South America	Adults (n ranged from 172 to 10,424)	**Dietary Diversity**	Overweight, obesity, BMI	Found no significant association on either overweight/obesity (OR 0.72; 95% CI 0.45-1.16), or mean differences in BMI (MD 0.22; - 0.70, 1.14) when comparing highest and lowest diverse diets
Moradi et al. (2023)	SRM of 12 studies (9 cross-sectional, 3 cohort)	Adults (n=140 577)	**UPF**	overweight, obesity, abdominal obesity	UPF associated with increased risk of obesity (**OR 1.55**; 95% CI 1.36, 1.77), overweight (**OR 1.36**; 1.14, 1.63), abdominal obesity (**OR 1.41**; 1.18, 1.68)
Lane et al. (2021)	SRM of 43 studies ((21 cross-sectional, 19 prospective, 2 case-control, 1 both prospective & cross-sectional analysis) 17 in Brazil, 1 in Lebanon	Adults, adolescents, children (n=891,723)	**UPF**	Overweight, obesity, abdominal obesity	UPF associated with an increased risk of overweight (**OR 1.36**; 95% CI 1.23-1.51), obesity (**OR 1.51**; 1.34-1.70), abdominal obesity (**OR 1.49**; 1.34-1.66)
Pagliai et al. (2021)	SRM of 23 studies (10 cross-sectional, 13 prospective cohort), 3 in Brazil, 1 in Lebanon, rest in HICs	General population	**UPF**	overweight/obesity (5 studies), high waist circumference (4 studies), hypertension	*Cross-sectional studies*: Highest UPF consumption was associated with increased risk of OWOB (OR 1.39, 95% CI 1.29, 1.50), high WC or abdominal obesity (OR 1.39, 95 % CI 1.16, 1.67).

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Askari et al. (2020)	SRM of 14 studies (13 cross sectional, 1 cohort), 7 in Brazil, 1 in Guatemala, rest in HICs	Male and female participants 10-64 y (n=189,966)	**UPF** (defined by NOVA classification system in 13 of 14 studies)	Overweight (10 studies), obesity (6 studies)	UPF intake associated with overweight (effect size 1.02; 95% CI 1.01, 1.03) and obesity (effect size 1.26; 1.13, 1.41)
Qin et al. (2022)	Meta-analysis of 32 studies (12 cross-sectional; 19 cohort; 1 case control), includes Chile, China, India, the Islamic Republic of Iran and Philippines; rest in HICs	Adults	**Fried Food Consumption**	overweight, obesity (11 studies), T2DM (10 studies), hypertension (11 studies)	Fried-food consumption is associated with increased risk of OWOB (**RR 1.16**; 1.07, 1.25) and hypertension (**RR 1.20**; 1.05, 1.38) but not T2DM (RR 1.07; 0.90, 1.27).
Jiang et al. (2022)	SRM of 23 studies (18 cross sectional, 1 cohort), China	Adults	**Dietary patterns** (Traditional Chinese diet (10 studies) vs. modern/western diet (8 studies))	Obesity, overweight	Traditional Chinese dietary pattern was associated with a lower risk of overweight/obesity than Western diet
Mu et al. (2017)	Review of 21 studies (17 cross-sectional, 4 cohort), 2 in Mexico, 1 in Colombia, 1 in Cameroon	Adults	**Dietary patterns** (prudent/healthy (n=17) vs. Western/unhealthy (n=18) defined differently for each study: healthy had high loadings of fruit, vegetables, poultry, fish, low-fat dairy, whole grains. Unhealthy had red and/or processed meats, refined grains, potatoes, sweets and high fat dairy	Obesity, overweight	Highest categories of prudent/healthy dietary pattern associated with reduced overweight/obesity risk (**OR 0.64**; 95% CI 0.52, 0.78). Increased overweight/obesity risk in the highest vs lowest categories of a western/unhealthy dietary pattern (**OR 1.65**; 95% CI 1.45, 1.87)
Dinu et al. (2017)	SRM of 108 studies (86 cross-sectional, 10 cohort prospective)	Healthy adults, 18-81 y	**Vegetarian and vegan diets** vs omnivore diet	BMI (71 vegetarian studies; 19 vegan studies) Blood glucose (27 vegetarian studies; 4 vegan studies)	*Cross-sectional studies*: Vegetarian diet (**WMD -1.49** kg/m^2; 95% CI -1.72, -1.25) and vegan diet (WMD -1.72; -2.21, -1.22) associated with lower BMI; Lower blood glucose observed with vegetarian (WMD -5.08 mg/dL; -5.98, -4.19) and vegan (WMD -6.38; -12.35, -0.41) diet
Daneshzad et al. (2021)	SRM of 21 studies (17 cross-sectional, 3 cohort, 1 case-control), 6 in Europe,	General population (6 y and above)	**Red meat consumption**	Overweight (3 studies) Obesity (7 studies)	Red meat consumption not associated with overweight (effect size: 1.19; 0.97, 1.46) or obesity (effect size: 1.16; 0.93,

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
	10 in Asia, 2 in Africa, 3 in America	(n=193 203)		Overweight/obesity (9 studies)	1.44). OWOB (effect size: **1.29**, 95% CI: 1.09, 1.53)
Rouhani et al. (2014)	SRM of 21 studies, 1 in the Islamic Republic of Iran, rest in HICs	Adults, n=1,135,661	**Red and processed meat consumption**	Obesity	consumption of higher quantities of red and processed meats was a risk factor for obesity (**OR 1.37**; 95% CI 1.14, 1.64)
Feng et al. (2022)	SRM of 42 articles of 52 cohort studies in 4 Asian countries	Adults	**Dairy consumption**	Obesity, overweight, hypertension, T2DM	For overweight/obesity, risk reduction was 25% (total dairy), 7% (high-fat dairy), 12% (milk), and 13% (yogurt) per specified increase. Hypertension had a nonlinear association with total dairy, while low-fat dairy and milk showed a 6% reduction. T2DM had nonlinear associations; total dairy and yogurt showed 3% and 7% lower risk per 200-g/d and 50-g/d increase.
Schwingshackl et al. (2016)	SRM of 22 longitudinal studies, 1 in the Islamic Republic of Iran, 1 in China, rest in HICs	Adults	**Dairy consumption**	Body weight, waist circumference, risk of overweight, risk of obesity	Found an inverse association between body weight and yogurt (**beta -40.99 g/year**, 95% CI:-48.09, -33.88), and a positive association for cheese (**beta -10.97 g/year**, 95% CI: 2.86, 19.07) Highest dairy intake reduced risk of abdominal obesity (**OR 0.85**; 95% CI 0.76, 0.95) and overweight (**OR 0.87**; 95% CI 0.76, 1.00)
W. Wang, Wu, and Zhang (2016) †	SRM of 17 studies for total dairy products (14 cross-sectional, 2 case-control, 1 cohort) and 16 for milk (12 cross-sectional, 4 cohort), 10 in Asia, 2 in South America	Adults 18+ y (19 studies)	**Milk and dairy** products consumption [assessed using FFQ (n=12) and/or 24HR (n=7) or questionnaire (n=9)]	**Obesity** defined using waist circumference or BMI (with cutoffs of ≥25, 28 or 30 kg/m^2)	Lower risk of obesity in adults associated with consumption of dairy products (pooled **OR 0.75;** 95% CI 0.69, 0.81) and milk (pooled **OR 0.77;** 95% CI 0.68, 0.87)
Schwingshackl et al. (2015)	SRM of 17 cohort studies, 1 in the Islamic Republic of Iran, rest in HICs	n=563 277	**Fruit and vegetable consumption**	Body weight (8 studies), waist circumference (3 studies), BMI (2 studies), overweight/obesity (7 studies)	Higher fruit intake was linked to weight decrease (beta -13.68 g/year; 95% CI -22.97, -4.40) and reduced WC (beta -0.04 cm/year; -0.05, -0.02). Lower risk of adiposity associated with highest intake of combined fruit & vegetable (OR 0.91, 95% CI 0.84, 0.99), fruit (OR

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
					0.83, 95% CI 0.71, 0.99), and vegetable (OR 0.83, 95% CI 0.70, 0.99)
Type.8.Diabetes.Mellitus.(T8DM).outcomes					
B. Li et al. (2023)	Meta-analysis 72 articles of prospective cohort studies, 11 in Asia, 11 in Europe. 46 in the United States	Adults	**SSB,** ASB, and fruit juice consumption	T2DM, hypertension	T2DM risk was associated with SSB (RR 1.27; 95% CI 1.17, 1.38), ASBs, (RR 1.32; 1.11, 1.56) and fruit juices (RR 0.98; 0.93, 1.03). Intakes of SSBs and ASBs were significantly associated with risk of hypertension.
Neelakantan et al. (2021)	SR of 17 studies (9 prospective, 7 cross-sectional, 1 clinical), Hong Kong SAR, China; Republic of Korea; Thailand; Singapore; Japan	Adults, Asian population (n=114 208)	**SSB** consumption	T2DM	High SSB consumption was associated with greater T2DM risk (**RR 1.38**; 95%CI 1.09-1.73)
Mishali et al. (2019)	SRM of 16 prospective cohort studies, 2 in China, rest in HICs	Men and women > 18 years (n=545 677)	**Dairy consumption**	T2DM (16 studies)	T2D is inversely associated with dairy intake. Subgroup analysis for sex showed that the association between dairy intake and T2D is significant in women but not in men.
Khoramdad et al. (2017)	SRM of 14 prospective cohort studies, 1 from China, rest from HICs	n=458 082	**Dairy consumption**	T2DM	Total dairy consumption associated with decreased risk of T2DM (**RR 0.88**, 95% CI 0.80, 0.96), even lower risk with consuming low-fat dairy (**RR 0.81**; 0.68, 0.96)
D. Gao et al. (2013)	SRM of 16 cohort studies (15 prospective cohort, 1 case-cohort), 1 from China, rest from HICs	n=526 998	**Dairy consumption**, high vs low total dairy intake (13 studies, n=457,893)	T2DM	Found a nonlinear association of total dairy intake and T2DM risk (**RR 0.89**; 95% CI 0.81, 0.98)
Aune et al. (2013)	SRM of 16 cohort studies, 1 from China, rest from HICs	Adults n=258 078	**Whole grain** (10 studies, n=385,868) and **refined grain** (6 studies, n=258,078) **consumption**, high vs low intake	T2DM (10 studies)	Non linear association was observed between whole grains and T2DM (**RR 0.74**; 95% CI 0.71, 0.78) but not refined grains (RR 0.94; 0.82, 1.09). Size of the association between whole grains and T2DM was stronger when the analyses were not adjusted for BMI compared with adjustment for BMI (RR 0.53 vs. 0.69)

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Becerra-Tomás et al. (2021)	SRM of 8 studies (5 prospective, 3 cross-sectional), 1 in China, rest in HICs	(cross-sectional n=72,559; cohort 7559 cases	Nut intake	T2DM	Nonsignificant association between total nut consumption and T2DM
Quan et al. (2022)	SRM of 9 cohort studies (7 articles), 1 from the Islamic Republic of Iran, rest from HICs	Adults 25-75 years (n=383 211)	Potato intake	T2DM	Association found between potato intake and risk of T2DM (**RR 1.13**, 95% CI 1.02, 1.26)
Yang et al. (2020)	Meta analysis of 28 cohort studies, 11 from the United States, 10 from Europe, 7 from Asia	Total meat consumption (n=386,496) Red meat (n=663,144)	**Meat and fish intake**, highest vs lowest intake categories	T2DM	A linear dose-response relationship between total meat (**RR 1.33**; 95% CI 1.16, 1.52), red meat (**RR 1.22**; 95% CI 1.16, 1.28) and processed meat (**RR 1.25**; 95% CI 1.13-1.37) intakes and T2DM risk. In addition, a non-linear relationship of intake of processed meat with risk of T2DM was detected.
Zhou, Tian, and Jia (2012)	Meta-analysis of 13 cohort studies, 1 from China, rest from HICs	Adults (n=367 757)	**Fish consumption** (9 studies, n=367,757), high vs low intake	T2DM	Fish intake is weakly associated with T2DM (**RR 1.15**; 95% CI 1.05, 1.27), based on 7 cohorts without heterogeneity
Micha et al. (2010)	SRM of 20 studies (17 prospective cohort, 3 case-control), 1 from China, rest from HICs	Healthy adults (n= 1218 380)	**Red meat** (5 studies) and **processed meat** (7 studies) consumption	T2DM	No association between red meat intake and T2DM (RR 1.16; 95% CI 0.92, 1.46). Processed meat intake associated with higher risk of T2DM (**RR 1.19**; 1.11, 1.27)
Morze et al. (2020)	SRM of 113 reports (47 for this update), 1 in the Islamic Republic of Iran, 1 in Israel, 5 in China	n=3,277,684	**Diet quality** assessed by the HEI, AHEI, DASH score	T2DM (16 studies)	Diets of the highest quality were inversely associated with risk of T2DM (**RR 0.81**, 95% CI 0.78, 0.85)
Uloko et al. (2018)	SRM of 23 studies (12 cross sectional, 7 cross sectional perspective, 4 prospective), Nigeria	n=14,650	**Unhealthy dietary habits** (not stated how this was defined)	T2DM	Unhealthy dietary habits are a risk factor for T2DM (OR 8.0; 95% CI 5.4, 10.5)
Maghsoudi et al. (2016)	SRM of 10 cohort studies, 1 from China, rest from HICs	n= 404 528	**Healthy and unhealthy dietary habits**	T2DM	Adherence to healthy dietary patterns associated with lower risk of T2DM (**RR 0.86**; 95 % CI 0.82, 0.90); unhealthy dietary patterns adversely affected T2DM risk (**RR 1.30**; 95 % CI 1.18, 1.43)

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Alhazami et al (2013)	SRM of 15 cohort studies, 2 from China, rest from HICs	Adults 20-90 years	**Healthy and unhealthy dietary patterns**, highest vs. lowest adherence (assessed by FFQ n=14; dietary history n=1)	T2DM	Reduced risk of T2DM for healthy dietary patterns (**RR 0.79**, 95% CI 0.74, 0.86); increased risk for unhealthy dietary patterns (**RR 1.44**, 1.33, 1.57)
Esposito et al. (2014)	Meta-analysis of 18 prospective cohort studies (20 cohorts), 4 regions (the United States 2, Europe 5, Australia 1, Asia 5)	Adults 20-90 years n=21 372	**Healthy dietary patterns** (Mediterranean, DASH, AHEI)	T2DM	Participants with the greatest adherence to healthy diets were less likely to develop T2DM (**RR 0.80**; 95% CI 0.74, 0.86)
McEvoy et al. (2014)	SRM of 33 studies (19 cross-sectional, 12 prospective cohort, 2 nested case control) included Mexico, the Islamic Republic of Iran, India, and China	Adults n=309 430	**Dietary patterns** (healthy/ prudent vs. unhealthy/ western)	T2DM	Those in the highest category of healthy/prudent diet lower risk for T2DM (**OR 0.85**; 95% CI 0.80, 0.91). Highest vs lowest category of unhealthy/western diet had increased risk (**OR 1.41**; 1.32, 1.52)
Lee and Park (2017)	SRM of 14 studies (12 cross sectional, 2 cohort), included India; Barbados; Pakistan; China; Taiwan, China	*Not stated*	**Vegetarian diet**	T2DM	Vegetarian diet is inversely associated with T2DM risk (**OR 0.73**; 95% CI 0.61, 0.87)
Sarsangi et al. (2022)	SRM of 16 prospective studies, 1 from the Islamic Republic of Iran, rest from HICs	n= 759 806	**Mediterranean diet**	T2DM	Greater adherence to Mediterranean diet associated with reduced risk of T2DM (**RR 0.83**; 95% CI 0.77, 0.90),
Yu et al. (2022)	SRM of 19 studies (8 cohort, 11 RCTs), includes China, South Asia, the Middle East, and HICs	Adults 18-87y (n=1034)	**White vs Brown rice intake**	T2DM	Found a positive association between white rice intake and risk of T2DM (**RR, 1.16**; 95% CI 1.02, 1.32). Findings also suggest that brown rice is inversely associated with risk of T2DM (RR 0.89; 95% CI 0.81, 0.97 (based on limited data)
Carter et al. (2010)	SRM of 6 prospective cohort studies, 1 from China, rest from the United States	Adults 30-74 years (n=223 512)	**Fruit and vegetable intake**	T2DM	Greater intake of green leafy vegetables associated with reduced risk of T2DM (hazard ratio **0.86**, 95% CI 0.77, 0.97); no significant benefits of increasing consumption of vegetables, fruit, or fruit and vegetables combined.

Author (Year)	Study Type & Location	Participants	Diet Assessed	Nutrition, health outcomes assessed	Key findings
Hypertension.outcomes					
Chen et al. (2022)	SRM of 55 prospective cohort studies, 1 from the Islamic Republic of Iran, 1 of 21 LMIC countries	included cohorts between 337 and 409,885 adult participants	Dairy consumption , highest compared with lowest level of intake	risk of hypertension	Total dairy consumption was associated with a moderately lower risk of hypertension (RR 0.91, 95% CI: 0.86, 0.95); RR for 1-serving/d increase: 0.96, 95% CI: 0.94, 0.97)
M. Wang et al. (2022)	SRM of 9 studies (5 cross-sectional, 4 cohort), includes 2 from Brazil, 1 from Mexico, 1 from Lebanon	Adults ≥18 (n=111,594)	UPF consumption	hypertension	higher UPFs consumption significantly increased the risk of hypertension (OR 1.23; 95% CI 1.11, 1.37)
Cowell et al. (2021)	SRM of 35 studies (19 RCTs, 14 cross-sectional, 2 prospective)	Adults ≥18 n=59,001	Mediterranean diet, higher vs lower adherence	hypertension	Odds of hypertension were 13% lower with higher versus lower MedDiet adherence (OR 0.87, 0.78, 0.98)
Riaz et al. (2021)	SRM of 37 studies (3- cross-sectional, 7 case-control), all in Pakistan	Adults, children, adolescents 5-80y n=99,391	unrestricted salt in their diet (n=3)	hypertension	Individuals having unrestricted salt in their diet were less likely to have hypertension (OR 0.24; 95% CI 0.12, 0.47)
Filippini et al. (2022)	SRM of 11 cohort studies, includes 1 from China, rest HICs	Adults 18-75 y	Sodium intake (3 studies used dietary recall, 8 estimated based on urinary excretion)	hypertension	Excess risk of hypertension found from an exposure of ≥3 g/day: 4 g/day (RR 1.04; 95% CI 0.96, 1.13) and 6 g/day (RR 1.21; 1.06, 1.37)
Schwingshackl et al. (2017)	SRM of 28 studies, includes 1 from the Islamic Republic of Iran	Adults >20y	Various food groups (12: whole grains, refined grains, vegetables, fruits, nuts, legumes, eggs, dairy, fish, red meat, processed meat, and SSB)	Hypertension	An inverse association with risk of hypertension was observed for 30 g whole grains/d (RR 0.92; 95% CI 0.87, 0.98), 100 g fruits/d (RR 0.97; 0.96, 0.99), 28 g nuts/d (RR 0.70; 0.45, 1.08), and 200 g dairy/d (RR 0.95; 0.94, 0.97), and a positive association for 100 g red meat/d (RR 1.14; 1.02, 1.28), 50 g processed meat/d (RR 1.12; 1.00, 1.26), and 250 mL SSB/d (RR 1.07; 1.04, 1.10)

Abbreviations: 24HR 24-hour recall; ASF animal source foods; BFP body fat percentage; BMI body mass index; BP blood pressure; CI confidence interval; FFQ food frequency questionnaire; F&V fruit and vegetable; HIC high-income country; LMIC low and middle-income country; OR odds ratio; OWOB overweight and obesity; RR relative risk; SSB sugar-sweetened beverages; SRM systematic review and meta-analysis; T2DM type 2 diabetes mellitus; UPF ultra processed food; WC waist circumference; WMD weighted mean difference

† Study also included in Table 6 for children 5+ y due to age range of participants.

Table 8: Mapping the evidence available for the relationship between food and diet measures and nutrition and health outcomes by life stage group (based only on SRM included)

DIET MEASURE	PREGNANCY		CHILDREN < 5 Y		CHILDREN 5-19 Y		ADULTS		
	Maternal Complications	Birth Outcome	Under-nutrition	Overweight, obesity	Thinness Anemia	Overweight, obesity	Thinness Anemia	Overweight, obesity	NCDs: Hypertension, Diabetes
Low diet diversity	↑ Thinness ↑ Anemia ↑ Zn def'y ↑ GDM	↑ LBW	↑ Stunting ↑ Anemia	*No SRM found*	↑ Stunting ↑ Wasting ↑ Anemia	↑ OWOB	*No SRM found*	*Inconsistent association (n=60+ studies)*	*Inconsistent association (n=41+ studies)*
Intake of ASF (meat, fish, eggs)	**Low ASF intake** ↑ Anemia ↑ Zn deficiency **Red, processed meat** ↑ GDM	**Dairy** ↓ LBW, SGA	*No SRM found*	**Dairy** ↓ Obesity	*No SRM found*	**Dairy** ↓ Obesity **Meat** ↑ obesity	Vegetarian diet ↑ low sFerritin	**Dairy** ↓ Obesity **Red, processed meat** ↑ OWOB	**Dairy** ↓ T2DM, HT **Red, processed meat** ↑ T2DM, HT
Diet low in…	**DGL Vegetables** ↑ Anemia								
Diet high in…	**Healthy diet** ↓ GDM, GHT, pre-eclampsia **Fruit** ↓ GDM, pre-eclampsia **Vegetables** ↓ pre-eclampsia **Unhealthy diet, fast food, fried food, UPF** ↑ GDM	**Healthy diet** ↓ LBW, SGA ↓ PTB **Unhealthy diet** ↑ LBW		**SSB** ↑ % body fat		**Unhealthy diet, SSB, fast food** ↑ OWOB **Salt** ↑ BP		**Healthy diet, F&V, fiber** ↓ body weight **Unhealthy diet, SSB, UPF, fried food** ↑ OWOB	**Healthy diet, whole grains, fiber, F&V** ↓ T2DM, HT **Unhealthy diet, SSB, UPF, fried food** ↑ T2DM, HT **Salt** ↑ HT
GBD 13 dietary risk factors								↑ high BMI	↑ T2DM, HT, CVD

Abbreviations: ASF animal source foods; BP blood pressure; F&V fruit and vegetable; GDM gestational diabetes mellitus; GHT gestational hypertension; HT hypertension; LBW low birth weight; OWOB overweight and obesity; PTB preterm birth; SSB sugar-sweetened beverages; T2DM type 2 diabetes mellitus; UPF ultra processed food; Zn def'y zinc deficiency

References

Abarca-Gómez, Leandra, Ziad A Abdeen, Zargar Abdul Hamid, Niveen M Abu-Rmeileh, Benjamin Acosta-Cazares, Cecilia Acuin, Robert J Adams, et al. 2017. "Worldwide Trends in Body-Mass Index, Underweight, Overweight, and Obesity from 1975 to 2016: A Pooled Analysis of 2416 Population-Based Measurement Studies in 128·9 Million Children, Adolescents, and Adults." *The Lancet* 390 (10113): 2627–42. https://doi.org/10.1016/S0140-6736(17)32129-3.

Abbasalizad Farhangi, Mahdieh, Arash Mohammadi Tofigh, Leila Jahangiri, Zeinab Nikniaz, and Leila Nikniaz. 2022. "Sugar-sweetened Beverages Intake and the Risk of Obesity in Children: An Updated Systematic Review and Dose–Response Meta-analysis." *Pediatric Obesity* 17 (8). https://doi.org/10.1111/ijpo.12914.

Abdollahi, Shima, Sepideh Soltani, Russell J. De Souza, Scott C. Forbes, Omid Toupchian, and Amin Salehi-Abargouei. 2021. "Associations between Maternal Dietary Patterns and Perinatal Outcomes: A Systematic Review and Meta-Analysis of Cohort Studies." *Advances in Nutrition* 12 (4): 1332–52. https://doi.org/10.1093/ADVANCES/NMAA156.

Abdulahi, Ahmed, Sakineh Shab-Bidar, Shahabeddin Rezaei, and Kurosh Djafarian. 2017. "Nutritional Status of under Five Children in Ethiopia: A Systematic Review and Meta-Analysis." *Ethiopian Journal of Health Sciences* 27 (2): 175. https://doi.org/10.4314/ejhs.v27i2.10.

Afshin, Ashkan, Patrick John Sur, Kairsten A. Fay, Leslie Cornaby, Giannina Ferrara, Joseph S Salama, Erin C Mullany, et al. 2019. "Health Effects of Dietary Risks in 195 Countries, 1990–2017: A Systematic Analysis for the Global Burden of Disease Study 2017." *The Lancet* 393 (10184): 1958–72. https://doi.org/10.1016/S0140-6736(19)30041-8.

Agrawal, Sutapa, and Praween Kumar Agrawal. 2016. "Association Between Body Mass Index and Prevalence of Multimorbidity in Low-and Middle-Income Countries: A Cross-Sectional Study." *International Journal of Medicine and Public Health* 6 (2): 73–83. https://doi.org/10.5530/IJMEDPH.2016.2.5.

Alcaraz, Andrea, Ariel Esteban Bardach, Natalia Espinola, Lucas Perelli, Federico Rodriguez Cairoli, Althea La Foucade, Cid Manso de Mello Vianna, et al. 2023. "Health and Economic Burden of Disease of Sugar-Sweetened Beverage Consumption in Four Latin American and Caribbean Countries: A Modelling Study." *BMJ Open* 13 (2): e062809. https://doi.org/10.1136/bmjopen-2022-062809.

Alcaraz, Andrea, Andrés Pichon-Riviere, Alfredo Palacios, Ariel Bardach, Dario Javier Balan, Lucas Perelli, Federico Augustovski, and Agustín Ciapponi. 2021. "Sugar Sweetened Beverages Attributable Disease Burden and the Potential Impact of Policy Interventions: A Systematic Review of Epidemiological and Decision Models." *BMC Public Health* 21 (1): 1460. https://doi.org/10.1186/s12889-021-11046-7.

Alemu, Tewodros Getaneh, Masresha Asmare Techane, Chalachew Adugna Wubneh, Nega Tezera Assimamaw, Getaneh Mulualem Belay, Tadesse Tarik Tamir, Addis Bilal Muhye, et al. 2022. "Spatial Variation and Determinates of Dietary Diversity among Children Aged 6–23 Months in Ethiopia: Spatial and Multilevel Analysis Using Ethiopian Demography Health Survey (EDHS) 2019." *Archives of Public Health* 80 (1): 1–13. https://doi.org/10.1186/S13690-022-00905-3/TABLES/6.

Alhazmi, A., E. Stojanovski, M. McEvoy, and M. L. Garg. 2014. "The Association between Dietary Patterns and Type 2 Diabetes: A Systematic Review and Meta-analysis of Cohort Studies." *Journal of Human Nutrition and Dietetics* 27 (3): 251–60. https://doi.org/10.1111/jhn.12139.

Amicis, Ramona De, Sara Paola Mambrini, Marta Pellizzari, Andrea Foppiani, Simona Bertoli, Alberto Battezzati, and Alessandro Leone. 2022. "Ultra-Processed Foods and Obesity and Adiposity Parameters among Children and Adolescents: A Systematic Review." *European Journal of Nutrition* 61 (5): 2297–2311. https://doi.org/10.1007/s00394-022-02873-4.

Angulo, Erick, Dalia Stern, Analí Castellanos-Gutiérrez, Adriana Monge, Martín Lajous, Sabri Bromage, Teresa T Fung, et al. 2021. "Changes in the Global Diet Quality Score, Weight, and Waist Circumference in Mexican Women." *The Journal of Nutrition* 151 (October): 152S-161S. https://doi.org/10.1093/jn/nxab171.

Arimond, Mary, Doris Wiesmann, Sonia Rodríguez Ramírez, Teresa Shamah Levy, Sheng Ma, Zhiyong Zou, Anna Herforth, and Ty Beal. 2021. "Food Group Diversity and Nutrient Adequacy: Dietary Diversity as a Proxy for Micronutrient Adequacy for Different Age and Sex Groups in Mexico and China." Geneva. https://doi.org/10.36072/dp.9.

Askari, Mohammadreza, Javad Heshmati, Hossein Shahinfar, Nishant Tripathi, and Elnaz Daneshzad. 2020. "Ultra-Processed Food and the Risk of Overweight and Obesity: A Systematic Review and Meta-Analysis of Observational Studies." *International Journal of Obesity* 44 (10): 2080–91. https://doi.org/10.1038/s41366-020-00650-z.

Aune, Dagfinn, Teresa Norat, Pål Romundstad, and Lars J. Vatten. 2013. "Whole Grain and Refined Grain Consumption and the Risk of Type 2 Diabetes: A Systematic Review and Dose–Response Meta-Analysis of Cohort Studies." *European Journal of Epidemiology* 28 (11): 845–58. https://doi.org/10.1007/s10654-013-9852-5.

Azmeraw, Molla, Amare Kassaw, Samuel Derbie Habtegiorgis, Agimasie Tigabu, Abraham Tsedalu Amare, Kindie Mekuria, Dessie Temesgen, et al. 2023. "Prevalence of Anemia and Its Associated Factors among Children Aged 6–23 Months, in Ethiopia: A Systematic Review and Meta Analysis." *BMC Public Health* 23 (1): 2398. https://doi.org/10.1186/s12889-023-17330-y.

Babio, Nancy, Nerea Becerra-Tomás, Stephanie K. Nishi, Leyre López-González, Indira Paz-Graniel, Jesús García-Gavilán, Helmut Schröder, Nerea Martín-Calvo, and Jordi Salas-Salvadó. 2022. "Total Dairy Consumption in Relation to Overweight and Obesity in Children and Adolescents: A Systematic Review and Meta-Analysis." *Obesity Reviews* 23 (S1). https://doi.org/10.1111/OBR.13400.

Bardach, Ariel Esteban, Natalia Espínola, Federico Rodríguez Cairoli, Lucas Perelli, Darío Balan, Alfredo Palacios, Federico Augustovski, Andrés Pichón-Riviere, and Andrea Olga Alcaraz. 2023. "The Burden of Disease and Economic Impact of Sugar-Sweetened Beverages' Consumption in Argentina: A Modeling Study." *PLOS ONE* 18 (2): e0279978. https://doi.org/10.1371/JOURNAL.PONE.0279978.

Barker, D.J.P. 2004. "The Developmental Origins of Adult Disease." *Journal of the American College of Nutrition* 23 (sup6): 588S-595S. https://doi.org/10.1080/07315724.2004.10719428.

Basto-Abreu, Ana, Rossana Torres-Alvarez, Francisco Reyes-Sánchez, Romina González-Morales, Francisco Canto-Osorio, M. Arantxa Colchero, Simón Barquera, Juan A. Rivera, and Tonatiuh Barrientos-Gutierrez. 2020. "Predicting Obesity Reduction after Implementing Warning Labels in Mexico: A Modeling Study." *PLOS Medicine* 17 (7): e1003221. https://doi.org/10.1371/journal.pmed.1003221.

Beal, Ty, Anna Herforth, Shelly Sundberg, Sonja Y Hess, and Lynnette M Neufeld. 2021. "Differences in Modelled Estimates of Global Dietary Intake." *The Lancet* 397 (10286): 1708–9. https://doi.org/10.1016/S0140-6736(21)00714-5.

Becerra-Tomás, Nerea, Indira Paz-Graniel, Pablo Hernández-Alonso, David JA Jenkins, Cyril WC Kendall, John L Sievenpiper, and Jordi Salas-Salvadó. 2021. "Nut Consumption and Type 2 Diabetes Risk: A Systematic Review and Meta-Analysis of Observational Studies." *The American Journal of Clinical Nutrition* 113 (4): 960–71. https://doi.org/10.1093/ajcn/nqaa358.

Belachew, Amare, and Tilahun Tewabe. 2020. “Under-Five Anemia and Its Associated Factors with Dietary Diversity, Food Security, Stunted, and Deworming in Ethiopia: Systematic Review and Meta-Analysis.” *Systematic Reviews* 9 (1): 1–9. https://doi.org/10.1186/S13643-020-01289-7/FIGURES/5.

Berhe, Kidanemaryam, Freweini Gebrearegay, Hadush Gebreegziabher, Lemlem Weldegerima, Amaha Kahsay, Haven Hadush, Brhane Gebremariam, et al. 2022. “Magnitude and Associated Factors of Anemia among Adolescent Girls in Ethiopia: A Systematic Review and Meta-Analysis.” *Archives of Public Health* 80 (1): 1–15. https://doi.org/10.1186/S13690-022-00942-Y/FIGURES/14.

Berhe, Kidanemaryam, Freweini Gebrearegay, and Hadush Gebremariam. 2019. “Prevalence and Associated Factors of Zinc Deficiency among Pregnant Women and Children in Ethiopia: A Systematic Review and Meta-Analysis.” *BMC Public Health* 19 (1): 1–11. https://doi.org/10.1186/S12889-019-7979-3/FIGURES/6.

Berhe, Kidanemaryam, Abadi Kidanemariam, Gebrehiwot Gebremariam, and Alem Gebremariam. 2019. “Prevalence and Associated Factors of Adolescent Undernutrition in Ethiopia: A Systematic Review and Meta-Analysis.” *BMC Nutrition* 5 (1): 1–13. https://doi.org/10.1186/S40795-019-0309-4/FIGURES/8.

Beyene, Fentahun Yenealem, Bekalu Getnet Kassa, Gedefaye Nibret Mihretie, and Alemu Degu Ayele. 2023. “Gestational Diabetes Mellitus and Its Associated Factors in Ethiopia: A Systematic Review and Meta-Analysis.” *European Journal of Medical Research* 28 (1): 1–14. https://doi.org/10.1186/S40001-023-01088-5/FIGURES/11.

Bromage, Sabri, Carolina Batis, Shilpa N. Bhupathiraju, Wafaie W. Fawzi, Teresa T. Fung, Yanping Li, Megan Deitchler, et al. 2021. “Development and Validation of a Novel Food-Based Global Diet Quality Score (GDQS).” *The Journal of Nutrition* 151 (Suppl 2): 75S. https://doi.org/10.1093/JN/NXAB244.

Butte, Nancy F., Cutberto Garza, and Mercedes de Onis. 2007. “Evaluation of the Feasibility of International Growth Standards for School-Aged Children and Adolescents.” *The Journal of Nutrition* 137 (1): 153–57. https://doi.org/10.1093/jn/137.1.153.

Candari, Christine Joy, Jonathan Cylus, and Ellen Nolte. 2017. “Assessing the Economic Costs of Unhealthy Diets and Low Physical Activity.” Copenhagen, Denmark. https://www.euro.who.int/__data/assets/pdf_file/0004/342166/Unhealthy-Diets-ePDF-v1.pdf.

Carter, P., L. J. Gray, J. Troughton, K. Khunti, and M. J. Davies. 2010. “Fruit and Vegetable Intake and Incidence of Type 2 Diabetes Mellitus: Systematic Review and Meta-Analysis.” *BMJ* 341 (aug18 4): c4229–c4229. https://doi.org/10.1136/bmj.c4229.

Chen, Zhangling, Mavra Ahmed, Vanessa Ha, Katherine Jefferson, Vasanti Malik, Paula A B Ribeiro, Priccila Zuchinali, and Jean-Philippe Drouin-Chartier. 2022. “Dairy Product Consumption and Cardiovascular Health: A Systematic Review and Meta-Analysis of Prospective Cohort Studies.” *Advances in Nutrition* 13 (2): 439–54. https://doi.org/10.1093/advances/nmab118.

Chia, Ai Ru, Ling Wei Chen, Jun Shi Lai, Chun Hong Wong, Nithya Neelakantan, Rob Martinus Van Dam, and Mary Foong Fong Chong. 2019. “Maternal Dietary Patterns and Birth Outcomes: A Systematic Review and Meta-Analysis.” *Advances in Nutrition* 10 (4): 685–95. https://doi.org/10.1093/ADVANCES/NMY123.

Costa, Caroline Santos, Bianca Del-Ponte, Maria Cecília Formoso Assunção, and Iná Silva Santos. 2018. “Consumption of Ultra-Processed Foods and Body Fat during Childhood and Adolescence: A Systematic Review.” *Public Health Nutrition* 21 (1): 148–59. https://doi.org/10.1017/S1368980017001331.

Cowell, Owen R., Nathan Mistry, Kevin Deighton, Jamie Matu, Alex Griffiths, Anne Marie Minihane, John C. Mathers, Oliver M. Shannon, and Mario Siervo. 2021. “Effects of a Mediterranean Diet on Blood Pressure: A

Systematic Review and Meta-Analysis of Randomized Controlled Trials and Observational Studies." *Journal of Hypertension* 39 (4): 729–39. https://doi.org/10.1097/HJH.0000000000002667.

Cui, Yunfeng, Minqi Liao, Aihua Xu, Gengdong Chen, Jun Liu, Xiaoxuan Yu, Shuna Li, et al. 2023. "Association of Maternal Pre-Pregnancy Dietary Intake with Adverse Maternal and Neonatal Outcomes: A Systematic Review and Meta-Analysis of Prospective Studies." *Critical Reviews in Food Science and Nutrition* 63 (19): 3430–51. https://doi.org/10.1080/10408398.2021.1989658.

Cunha, Carla de Magalhães, Priscila R. F. Costa, Lucivalda P. M. de Oliveira, Valterlinda A. de O. Queiroz, Jacqueline C. D. Pitangueira, and Ana Marlúcia Oliveira. 2018. "Dietary Patterns and Cardiometabolic Risk Factors among Adolescents: Systematic Review and Meta-Analysis." *British Journal of Nutrition* 119 (8): 859–79. https://doi.org/10.1017/S0007114518000533.

Daneshzad, Elnaz, Mohammadreza Askari, Maedeh Moradi, Sima Ghorabi, Tohid Rouzitalab, Javad Heshmati, and Leila Azadbakht. 2021. "Red Meat, Overweight and Obesity: A Systematic Review and Meta-Analysis of Observational Studies." *Clinical Nutrition ESPEN* 45 (October): 66–74. https://doi.org/10.1016/j.clnesp.2021.07.028.

Dávila-Cervantes, Claudio Alberto. 2020. "Cardiovascular Disease in Mexico 1990–2017: Secondary Data Analysis from the Global Burden of Disease Study." *International Journal of Public Health* 65 (5): 661–71. https://doi.org/10.1007/s00038-020-01377-4.

Demmler, Kathrin M, Ty Beal, Mona Z Ghadirian, and Lynnette M Neufeld. 2024. "Characteristics of Global Data on Adolescent's Dietary Intake: A Systematic Scoping Review." *Current Developments in Nutrition* 8 (1): 102054. https://doi.org/10.1016/j.cdnut.2023.102054.

Dinu, Monica, Rosanna Abbate, Gian Franco Gensini, Alessandro Casini, and Francesco Sofi. 2017. "Vegetarian, Vegan Diets and Multiple Health Outcomes: A Systematic Review with Meta-Analysis of Observational Studies." *Critical Reviews in Food Science and Nutrition* 57 (17): 3640–49. https://doi.org/10.1080/10408398.2016.1138447.

Dong, Caijuan, Xiang Bu, Jing Liu, Linyan Wei, Aiqun Ma, and Tingzhong Wang. 2022. "Cardiovascular Disease Burden Attributable to Dietary Risk Factors from 1990 to 2019: A Systematic Analysis of the Global Burden of Disease Study." *Nutrition, Metabolism and Cardiovascular Diseases* 32 (4): 897–907. https://doi.org/10.1016/j.numecd.2021.11.012.

Duncan, Bruce Bartholow, Maria Inês Schmidt, Ewerton Cousin, Maziar Moradi-Lakeh, Valéria Maria de Azeredo Passos, Elisabeth Barboza França, Fátima Marinho, and Ali H. Mokdad. 2017. "The Burden of Diabetes and Hyperglycemia in Brazil-Past and Present: Findings from the Global Burden of Disease Study 2015." *Diabetology & Metabolic Syndrome* 9 (1): 18. https://doi.org/10.1186/s13098-017-0216-2.

Endale, Fitsum, Demelash Woldeyohannes, Fanuel Belayneh, Aiggan Tamene, Aklilu Habte, Addisalem Gizachew, Dawit Sulamo, et al. 2022. "Menstrual Abnormality, Maternal Illiteracy, and Household Factors as Main Predictors of Anemia among Adolescent Girls in Ethiopia: Systematic Review and Meta-Analysis." *Women's Health* 18 (November). https://doi.org/10.1177/17455057221129398/ASSET/IMAGES/LARGE/10.1177_17455057221129398-FIG11.JPEG.

Esposito, Katherine, Paolo Chiodini, Maria Ida Maiorino, Giuseppe Bellastella, Demosthenes Panagiotakos, and Dario Giugliano. 2014. "Which Diet for Prevention of Type 2 Diabetes? A Meta-Analysis of Prospective Studies." *Endocrine* 47 (1): 107–16. https://doi.org/10.1007/s12020-014-0264-4.

FAO. 2021. "Minimum Dietary Diversity for Women: An Updated Guide to Measurement - from Collection to Action." Rome.

FAO and WHO. 2019. “Sustainable Healthy Diets.” Rome. https://doi.org/10.4060/CA6640EN.

FAO, IFAD, UNICEF, WFP, and WHO. 2023. “The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets across the Rural–Urban Continuum.” Rome, Italy.

Feng, Yifei, Yang Zhao, Jiong Liu, Zelin Huang, Xingjin Yang, Pei Qin, Chuanqi Chen, et al. 2022. “Consumption of Dairy Products and the Risk of Overweight or Obesity, Hypertension, and Type 2 Diabetes Mellitus: A Dose–Response Meta-Analysis and Systematic Review of Cohort Studies.” *Advances in Nutrition* 13 (6): 2165–79. https://doi.org/10.1093/advances/nmac096.

Filippini, Tommaso, Marcella Malavolti, Paul K. Whelton, and Marco Vinceti. 2022. “Sodium Intake and Risk of Hypertension: A Systematic Review and Dose–Response Meta-Analysis of Observational Cohort Studies.” *Current Hypertension Reports* 24 (5): 133–44. https://doi.org/10.1007/s11906-022-01182-9.

Gao, Dengfeng, Ning Ning, Congxia Wang, Yuhuan Wang, Qing Li, Zhe Meng, Yang Liu, and Qiang Li. 2013. “Dairy Products Consumption and Risk of Type 2 Diabetes: Systematic Review and Dose-Response Meta-Analysis.” *PLoS ONE* 8 (9): e73965. https://doi.org/10.1371/journal.pone.0073965.

Gao, Xiaoxia, Qingxiang Zheng, Xiumin Jiang, Xiaoqian Chen, Yanping Liao, and Yuqing Pan. 2023. “The Effect of Diet Quality on the Risk of Developing Gestational Diabetes Mellitus: A Systematic Review and Meta-Analysis.” *Frontiers in Public Health* 10 (January). https://doi.org/10.3389/FPUBH.2022.1062304/FULL.

GBD 2019 Risk Factors Collaborators. 2020. “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 (London, England)* 396 (10258): 1223–49. https://doi.org/10.1016/S0140-6736(20)30752-2.

Geta, Teshome Gensa, Samson Gebremedhin, and Akinyinka O. Omigbodun. 2022. “Prevalence and Predictors of Anemia among Pregnant Women in Ethiopia: Systematic Review and Meta-Analysis.” *PLOS ONE* 17 (7): e0267005. https://doi.org/10.1371/journal.pone.0267005.

Getaneh, Temesgen, Ayenew Negesse, Getenet Dessie, Melaku Desta, Moges Agazhe Assemie, and Agimasie Tigabu. 2021. “Predictors of Malnutrition among Pregnant Women in Ethiopia: A Systematic Review and Meta-Analysis.” *Human Nutrition & Metabolism* 26 (December): 200131. https://doi.org/10.1016/J.HNM.2021.200131.

Gezaw, Aragaw, Wolde Melese, Bekalu Getachew, and Tefera Belachew. 2023a. “Double Burden of Malnutrition and Associated Factors among Adolescent in Ethiopia: A Systematic Review and Meta-Analysis.” *PLOS ONE* 18 (4): e0282240. https://doi.org/10.1371/journal.pone.0282240.

———. 2023b. “Double Burden of Malnutrition and Associated Factors among Adolescent in Ethiopia: A Systematic Review and Meta-Analysis.” *PLOS ONE* 18 (4): e0282240. https://doi.org/10.1371/journal.pone.0282240.

Global Panel. 2016. “The Cost of Malnutrition: Why Policy Action Is Urgent.” London, UK.

Guedes, Larissa Fernanda Fonseca, Mariana Santos Felisbino-Mendes, Aline Siqueira Fogal Vegi, Adriana Lúcia Meireles, Mariana Carvalho de Menezes, Deborah Carvalho Malta, and Ísis Eloah Machado. 2022. “Health Impacts Caused by Excessive Sodium Consumption in Brazil: Results of the GBD 2019 Study.” *Revista Da Sociedade Brasileira de Medicina Tropical* 55 (suppl 1). https://doi.org/10.1590/0037-8682-0266-2021.

Habtegiorgis, Samuel Derbie, Pammla Petrucka, Animut Takele Telayneh, Daniel Shitu Getahun, Lemma Getacher, Simegn Alemu, and Molla Yigzaw Birhanu. 2022. “Prevalence and Associated Factors of Anemia among Adolescent Girls in Ethiopia: A Systematic Review and Meta-Analysis.” *PLOS ONE* 17 (3): e0264063. https://doi.org/10.1371/JOURNAL.PONE.0264063.

Haghighatdoost, Fahimeh, Roya Riahi, Shahla Safari, and Zahra Heidari. 2023. “Dose–Response Association between Dietary Patterns and Gestational Diabetes Mellitus Risk: A Systematic Review and Meta-analysis of Observational Studies.” *Food Science & Nutrition* 11 (1): 57. https://doi.org/10.1002/FSN3.3042.

Haider, Lisa M., Lukas Schwingshackl, Georg Hoffmann, and Cem Ekmekcioglu. 2018. “The Effect of Vegetarian Diets on Iron Status in Adults: A Systematic Review and Meta-Analysis.” *Critical Reviews in Food Science and Nutrition* 58 (8): 1359–74. https://doi.org/10.1080/10408398.2016.1259210.

Harper, Abigail, Jane Goudge, Esnat Chirwa, Alan Rothberg, Winnie Sambu, and Sumaya Mall. 2022. “Dietary Diversity, Food Insecurity and the Double Burden of Malnutrition among Children, Adolescents and Adults in South Africa: Findings from a National Survey.” *Frontiers in Public Health* 10 (September). https://doi.org/10.3389/fpubh.2022.948090.

Hassani Zadeh, Shirin, Paolo Boffetta, and Mahdieh Hosseinzadeh. 2020. “Dietary Patterns and Risk of Gestational Diabetes Mellitus: A Systematic Review and Meta-Analysis of Cohort Studies.” *Clinical Nutrition ESPEN* 36 (April): 1–9. https://doi.org/10.1016/j.clnesp.2020.02.009.

Hawkes, Corinna, Marie T. Ruel, Leah Salm, Bryony Sinclair, and Francesco Branca. 2020. “Double-Duty Actions: Seizing Programme and Policy Opportunities to Address Malnutrition in All Its Forms.” *The Lancet* 395 (10218): 142–55. https://doi.org/10.1016/S0140-6736(19)32506-1.

Headey, Derek, Kalle Hirvonen, and John Hoddinott. 2018. “Animal Sourced Foods and Child Stunting.” *American Journal of Agricultural Economics* 100 (5): 1302–19. https://doi.org/10.1093/ajae/aay053.

Herforth, Anna W., Doris Wiesmann, Euridice Martínez-Steele, Giovanna Andrade, and Carlos A. Monteiro. 2020. “Introducing a Suite of Low-Burden Diet Quality Indicators That Reflect Healthy Diet Patterns at Population Level.” *Current Developments in Nutrition* 4 (12). https://doi.org/10.1093/cdn/nzaa168.

Horta, Bernardo Lessa, and Natalia Peixoto de Lima. 2019. “Breastfeeding and Type 2 Diabetes: Systematic Review and Meta-Analysis.” *Current Diabetes Reports* 19 (1): 1. https://doi.org/10.1007/s11892-019-1121-x.

Horta, Bernardo Lessa, Nigel Rollins, Mariane S. Dias, Valquiria Garcez, and Rafael Pérez-Escamilla. 2023. “Systematic Review and Meta-analysis of Breastfeeding and Later Overweight or Obesity Expands on Previous Study for World Health Organization.” *Acta Paediatrica* 112 (1): 34–41. https://doi.org/10.1111/apa.16460.

Horton, Susan, Patrizia Fracassi, Kendra Siekmans, Tomoko Kato, and Giles Hanley-Cook. 2024. “Estimating Economic Costs of Unhealthy Diets : A Proposed Methodology.” WPS 10671. *World Bank Policy Research Working Papers*. Washington DC. http://documents.worldbank.org/curated/en/099839401162431298/IDU152ca6b541085314ca41a22a1bf67750bec89.

Jakobsen, Dorthe Dalstrup, Lea Brader, and Jens Meldgaard Bruun. 2023. “Association between Food, Beverages and Overweight/Obesity in Children and Adolescents—A Systematic Review and Meta-Analysis of Observational Studies.” *Nutrients* 15 (3): 764. https://doi.org/10.3390/NU15030764/S1.

Javanbakht, Mehdi, Ahmad Reza Jamshidi, Hamid Reza Baradaran, Zahra Mohammadi, Atefeh Mashayekhi, Farhad Shokraneh, Mohsen Rezai Hamami, et al. 2018. “Estimation and Prediction of Avoidable Health Care Costs of Cardiovascular Diseases and Type 2 Diabetes Through Adequate Dairy Food Consumption: A Systematic Review and Micro Simulation Modeling Study.” *Archives of Iranian Medicine* 21 (5): 213–22.

Jensen, Christopher F. 2023. “Vitamin B12 Levels in Children and Adolescents on Plant-Based Diets: A Systematic Review and Meta-Analysis.” *Nutrition Reviews* 81 (8): 951–66. https://doi.org/10.1093/NUTRIT/NUAC096.

Jiang, Karen, Zhen Zhang, Lee Ann Fullington, Terry T. Huang, Catherine Kaliszewski, Jingkai Wei, Li Zhao, et al. 2022. "Dietary Patterns and Obesity in Chinese Adults: A Systematic Review and Meta-Analysis." *Nutrients* 14 (22): 4911. https://doi.org/10.3390/nu14224911.

Khoramdad, Malihe, Yousef Alimohamadi, Saeed Safiri, Reza Pakzad, Ebrahim Shakiba, Jabbar Shafiei, and Alireza Firouzi. 2017. "Dairy Products Consumption and Risk of Type 2 Diabetes: A Systematic Review and Meta-Analysis of Prospective Cohort Studies." *Iranian Red Crescent Medical Journal* 19 (7). https://doi.org/10.5812/ircmj.14140.

Kibret, Kelemu Tilahun, Catherine Chojenta, Ellie Gresham, Teketo K Tegegne, and Deborah Loxton. 2019. "Maternal Dietary Patterns and Risk of Adverse Pregnancy (Hypertensive Disorders of Pregnancy and Gestational Diabetes Mellitus) and Birth (Preterm Birth and Low Birth Weight) Outcomes: A Systematic Review and Meta-Analysis." *Public Health Nutrition* 22 (3): 506–20. https://doi.org/10.1017/S1368980018002616.

Kinshella, Mai Lei Woo, Shazmeen Omar, Kerri Scherbinsky, Marianne Vidler, Laura A. Magee, Peter Von Dadelszen, Sophie E. Moore, and Rajavel Elango. 2021. "Maternal Dietary Patterns and Pregnancy Hypertension in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis." *Advances in Nutrition* 12 (6): 2387–2400. https://doi.org/10.1093/ADVANCES/NMAB057.

Krasevec, Julia, Xiaoyi An, Richard Kumapley, France Bégin, and Edward A. Frongillo. 2017. "Diet Quality and Risk of Stunting among Infants and Young Children in Low- and Middle-Income Countries." *Maternal & Child Nutrition* 13 (October): e12430. https://doi.org/10.1111/MCN.12430.

Kumanyika, Shiriki, Ashkan Afshin, Mary Arimond, Mark Lawrence, Sarah A. McNaughton, and Chizuru Nishida. 2020. "Approaches to Defining Healthy Diets: A Background Paper for the International Expert Consultation on Sustainable Healthy Diets." *Food and Nutrition Bulletin* 41 (2_suppl): 7S-30S. https://doi.org/10.1177/0379572120973111.

Lane, Melissa M., Jessica A. Davis, Sally Beattie, Clara Gómez-Donoso, Amy Loughman, Adrienne O'Neil, Felice Jacka, et al. 2021. "Ultraprocessed Food and Chronic Noncommunicable Diseases: A Systematic Review and Meta-analysis of 43 Observational Studies." *Obesity Reviews* 22 (3). https://doi.org/10.1111/obr.13146.

Lee, Yujin, and Kyong Park. 2017. "Adherence to a Vegetarian Diet and Diabetes Risk: A Systematic Review and Meta-Analysis of Observational Studies." *Nutrients* 9 (6): 603. https://doi.org/10.3390/nu9060603.

Leyvraz, Magali, Angeline Chatelan, Bruno R. da Costa, Patrick Taffé, Gilles Paradis, Pascal Bovet, Murielle Bochud, and Arnaud Chiolero. 2018. "Sodium Intake and Blood Pressure in Children and Adolescents: A Systematic Review and Meta-Analysis of Experimental and Observational Studies." *International Journal of Epidemiology* 47 (6): 1796–1810. https://doi.org/10.1093/IJE/DYY121.

Li, Baoyu, Ni Yan, Hong Jiang, Meng Cui, Min Wu, Lina Wang, Baibing Mi, et al. 2023. "Consumption of Sugar Sweetened Beverages, Artificially Sweetened Beverages and Fruit Juices and Risk of Type 2 Diabetes, Hypertension, Cardiovascular Disease, and Mortality: A Meta-Analysis." *Frontiers in Nutrition* 10 (March). https://doi.org/10.3389/fnut.2023.1019534.

Li, Man, Xiaojie Li, Yanfang Zhao, Lu Zhang, Jing Yang, Maigeng Zhou, and Zhuoqun Wang. 2021. "The Burden of Ischemic Heart Disease and Type 2 Diabetes Mellitus Attributable to Diet High in Sugar-Sweetened Beverages in China: An Analysis for the Global Burden of Disease Study 2017." *Journal of Diabetes* 13 (6): 482–93. https://doi.org/10.1111/1753-0407.13132.

Liao, Yan Ping, Qing Xiang Zheng, Xiu Min Jiang, Xiao Qian Chen, Xiao Xia Gao, and Yu Qing Pan. 2023. "Fruit, Vegetable, and Fruit Juice Consumption and Risk of Gestational Diabetes Mellitus: A Systematic Review and

Meta-Analysis: List of All Authors." *Nutrition Journal* 22 (1): 27. https://doi.org/10.1186/S12937-023-00855-8.

Liu, Dan, Qingyang Shi, Gaiping Cheng, Qiaorong Huang, and Sheyu Li. 2022. "Worldwide Burden Attributable to Diet High in Red Meat from 1990 to 2019." *Archives of Medical Science*, October. https://doi.org/10.5114/aoms/156017.

Lu, L., P. Xun, Y. Wan, K. He, and W. Cai. 2016. "Long-Term Association between Dairy Consumption and Risk of Childhood Obesity: A Systematic Review and Meta-Analysis of Prospective Cohort Studies." *European Journal of Clinical Nutrition 2016 70:4* 70 (4): 414–23. https://doi.org/10.1038/ejcn.2015.226.

Machado, Ísis Eloah, Magda Do Carmo Parajára, Larissa Fernanda Fonseca Guedes, Adriana Lúcia Meireles, Mariana Carvalho de Menezes, Mariana Santos Felisbino-Mendes, Eliseu Verly-Junior, and Deborah Carvalho Malta. 2022. "Burden of Non-Communicable Diseases Attributable to Dietary Risks in Brazil, 1990-2019: An Analysis of the Global Burden of Disease Study 2019." *Revista Da Sociedade Brasileira de Medicina Tropical* 55. https://doi.org/10.1590/0037-8682-0282-2021.

Maghsoudi, Zahra, Reza Ghiasvand, and Amin Salehi-Abargouei. 2016. "Empirically Derived Dietary Patterns and Incident Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis on Prospective Observational Studies." *Public Health Nutrition* 19 (2): 230–41. https://doi.org/10.1017/S1368980015001251.

McEvoy, Claire T., Christopher R. Cardwell, Jayne V. Woodside, Ian S. Young, Steven J. Hunter, and Michelle C. McKinley. 2014. "A Posteriori Dietary Patterns Are Related to Risk of Type 2 Diabetes: Findings from a Systematic Review and Meta-Analysis." *Journal of the Academy of Nutrition and Dietetics* 114 (11): 1759-1775.e4. https://doi.org/10.1016/j.jand.2014.05.001.

Miller, Victoria, Patrick Webb, Frederick Cudhea, Peilin Shi, Jianyi Zhang, Julia Reedy, Josh Erndt-Marino, et al. 2022. "Global Dietary Quality in 185 Countries from 1990 to 2018 Show Wide Differences by Nation, Age, Education, and Urbanicity." *Nature Food* 3 (9): 694–702. https://doi.org/10.1038/s43016-022-00594-9.

Mishali, Moshe, Shiri Prizant-Passal, Tova Avrech, and Yehuda Shoenfeld. 2019. "Association between Dairy Intake and the Risk of Contracting Type 2 Diabetes and Cardiovascular Diseases: A Systematic Review and Meta-Analysis with Subgroup Analysis of Men versus Women." *Nutrition Reviews* 77 (6): 417–29. https://doi.org/10.1093/nutrit/nuz006.

Monteiro, C. A., J. C. Moubarac, G. Cannon, S. W. Ng, and B. Popkin. 2013. "Ultra-Processed Products Are Becoming Dominant in the Global Food System." *Obesity Reviews*. https://doi.org/10.1111/obr.12107.

Moradi, Sajjad, Mohammad Hassan Entezari, Hamed Mohammadi, Ahmad Jayedi, Anastasia-Viktoria Lazaridi, Mohammad ali Hojjati Kermani, and Maryam Miraghajani. 2023. "Ultra-Processed Food Consumption and Adult Obesity Risk: A Systematic Review and Dose-Response Meta-Analysis." *Critical Reviews in Food Science and Nutrition* 63 (2): 249–60. https://doi.org/10.1080/10408398.2021.1946005.

Morze, Jakub, Anna Danielewicz, Georg Hoffmann, and Lukas Schwingshackl. 2020. "Diet Quality as Assessed by the Healthy Eating Index, Alternate Healthy Eating Index, Dietary Approaches to Stop Hypertension Score, and Health Outcomes: A Second Update of a Systematic Review and Meta-Analysis of Cohort Studies." *Journal of the Academy of Nutrition and Dietetics* 120 (12): 1998-2031.e15. https://doi.org/10.1016/j.jand.2020.08.076.

Mu, Min, Li-Fa Xu, Dong Hu, Jing Wu, and Ming-Jie Bai. 2017. "Dietary Patterns and Overweight/Obesity: A Review Article." *Iranian Journal of Public Health* 46 (7): 869–76.

Mwangome, Martha, and Andrew M. Prentice. 2019. "Tackling the Triple Threats of Childhood Malnutrition." *BMC Medicine* 17 (1): 210. https://doi.org/10.1186/s12916-019-1464-9.

NCD Risk Factor Collaboration (NCD-RisC). 2024. “Worldwide Trends in Underweight and Obesity from 1990 to 2022: A Pooled Analysis of 3663 Population-Representative Studies with 222 Million Children, Adolescents, and Adults.” *The Lancet*. https://doi.org/10.1016/S0140-6736(23)02750-2.

Neelakantan, Nithya, Su Hyun Park, Guo-Chong Chen, and Rob M van Dam. 2021. “Sugar-Sweetened Beverage Consumption, Weight Gain, and Risk of Type 2 Diabetes and Cardiovascular Diseases in Asia: A Systematic Review.” *Nutrition Reviews* 80 (1): 50–67. https://doi.org/10.1093/nutrit/nuab010.

Nguyen, Michelle, Sarah E. Jarvis, Maria G. Tinajero, Jiayue Yu, Laura Chiavaroli, Sonia Blanco Mejia, Tauseef A. Khan, et al. 2023. “Sugar-Sweetened Beverage Consumption and Weight Gain in Children and Adults: A Systematic Review and Meta-Analysis of Prospective Cohort Studies and Randomized Controlled Trials.” *The American Journal of Clinical Nutrition* 117 (1): 160–74. https://doi.org/10.1016/J.AJCNUT.2022.11.008.

Nguyen, Phuong Hong, Lan Mai Tran, Nga Thu Hoang, Megan Deitchler, Mourad Moursi, and Gilles Bergeron. 2023. “The Global Diet Quality Score Is Associated with Nutrient Adequacy and Depression among Vietnamese Youths.” *Annals of the New York Academy of Sciences*, August. https://doi.org/10.1111/nyas.15053.

Nilson, Eduardo Augusto Fernandes, Adriana Blanco Metlzer, Marie Eve Labonté, and Patrícia Constante Jaime. 2020. “Modelling the Effect of Compliance with WHO Salt Recommendations on Cardiovascular Disease Mortality and Costs in Brazil.” *PloS One* 15 (7): e0235514. https://doi.org/10.1371/journal.pone.0235514.

Nilson, Eduardo Augusto Fernandes, Everton N. da Silva, and Patrícia C. Jaime. 2020. “Developing and Applying a Costing Tool for Hypertension and Related Cardiovascular Disease: Attributable Costs to Salt/Sodium Consumption.” *The Journal of Clinical Hypertension* 22 (4): 642. https://doi.org/10.1111/JCH.13836.

Obita, George, and Ahmad Alkhatib. 2022. “Disparities in the Prevalence of Childhood Obesity-Related Comorbidities: A Systematic Review.” *Frontiers in Public Health* 10 (July): 923744. https://doi.org/10.3389/FPUBH.2022.923744/BIBTEX.

Onis, Mercedes de. 2006. “WHO Child Growth Standards Based on Length/Height, Weight and Age.” *Acta Paediatrica* 95 (S450): 76–85. https://doi.org/10.1111/j.1651-2227.2006.tb02378.x.

Pagliai, G., M. Dinu, M. P. Madarena, M. Bonaccio, L. Iacoviello, and F. Sofi. 2021. “Consumption of Ultra-Processed Foods and Health Status: A Systematic Review and Meta-Analysis.” *British Journal of Nutrition* 125 (3): 308–18. https://doi.org/10.1017/S0007114520002688.

Paula, Walkyria O., Erika S.O. Patriota, Vivian S.S. Gonçalves, and Nathalia Pizato. 2022. “Maternal Consumption of Ultra-Processed Foods-Rich Diet and Perinatal Outcomes: A Systematic Review and Meta-Analysis.” *Nutrients* 14 (15): 3242. https://doi.org/10.3390/NU14153242/S1.

Pérez-Roncero, Gonzalo R., María T. López-Baena, Peter Chedraui, and Faustino R. Pérez-López. 2020. “The Effect of Consuming Milk and Related Products during Human Pregnancy over Birth Weight and Perinatal Outcomes: A Systematic Review and Meta-Analysis.” *European Journal of Obstetrics & Gynecology and Reproductive Biology* 251 (August): 235–45. https://doi.org/10.1016/J.EJOGRB.2020.05.061.

Poorolajal, Jalal, Fatemeh Sahraei, Younes Mohamdadi, Amin Doosti-Irani, and Leila Moradi. 2020. “Behavioral Factors Influencing Childhood Obesity: A Systematic Review and Meta-Analysis.” *Obesity Research & Clinical Practice* 14 (2): 109–18. https://doi.org/10.1016/J.ORCP.2020.03.002.

Popkin, Barry M., Camila Corvalan, and Laurence M. Grummer-Strawn. 2020. “Dynamics of the Double Burden of Malnutrition and the Changing Nutrition Reality.” *The Lancet* 395 (10217): 65–74. https://doi.org/10.1016/S0140-6736(19)32497-3.

Pradhananga, Priza, Archana Shrestha, Nabin Adhikari, Namuna Shrestha, Mukesh Adhikari, Nicole Ide, Saurya Dhungel, Swornim Bajracharya, and Anu Aryal. 2022. “Double Burden of Malnutrition in Nepal: A Trend

Analysis of Protein-Energy Malnutrition and High Body Mass Index Using the Data from Global Burden of Disease 2010–2019." *PLOS ONE* 17 (9): e0273485. https://doi.org/10.1371/journal.pone.0273485.

Pries, Alissa M., Suzanne Filteau, and Elaine L. Ferguson. 2019. "Snack Food and Beverage Consumption and Young Child Nutrition in Low- and Middle-Income Countries: A Systematic Review." *Maternal & Child Nutrition* 15 (June): e12729. https://doi.org/10.1111/mcn.12729.

Qiao, Jie, Xiling Lin, Yiwen Wu, Xin Huang, Xiaowen Pan, Jingya Xu, Jun Yun Wu, Yuezhong Ren, and Peng Fei Shan. 2022. "Global Burden of Non-Communicable Diseases Attributable to Dietary Risks in 1990–2019." *Journal of Human Nutrition and Dietetics* 35 (1): 202–13. https://doi.org/10.1111/jhn.12904.

Qin, Pei, Quanman Li, Yang Zhao, Qing Chen, Xizhuo Sun, Yu Liu, Honghui Li, et al. 2020. "Sugar and Artificially Sweetened Beverages and Risk of Obesity, Type 2 Diabetes Mellitus, Hypertension, and All-Cause Mortality: A Dose–Response Meta-Analysis of Prospective Cohort Studies." *European Journal of Epidemiology* 35 (7): 655–71. https://doi.org/10.1007/s10654-020-00655-y.

Qin, Pei, Dechen Liu, Xiaoyan Wu, Yunhong Zeng, Xizhuo Sun, Yanyan Zhang, Yang Li, et al. 2022. "Fried-Food Consumption and Risk of Overweight/Obesity, Type 2 Diabetes Mellitus, and Hypertension in Adults: A Meta-Analysis of Observational Studies." *Critical Reviews in Food Science and Nutrition* 62 (24): 6809–20. https://doi.org/10.1080/10408398.2021.1906626.

Qorbani, Mostafa, Armita Mahdavi-Gorabi, Nasim Khatibi, Hanieh-Sadat Ejtahed, Maryam Khazdouz, Shirin Djalalinia, Amirhossein Sahebkar, Mohammad Esmaeili-Abdar, and Motahareh Hasani. 2022. "Dietary Diversity Score and Cardio-Metabolic Risk Factors: An Updated Systematic Review and Meta-Analysis." *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity* 27 (1): 85–100. https://doi.org/10.1007/s40519-020-01090-4.

Quan, Wei, Maomao Zeng, Ye Jiao, Yong Li, Chaoyi Xue, Guoping Liu, Zhaojun Wang, Fang Qin, Zhiyong He, and Jie Chen. 2021. "Western Dietary Patterns, Foods, and Risk of Gestational Diabetes Mellitus: A Systematic Review and Meta-Analysis of Prospective Cohort Studies." *Advances in Nutrition* 12 (4): 1353–64. https://doi.org/10.1093/advances/nmaa184.

Reardon, Thomas, David Tschirley, Lenis Saweda O. Liverpool-Tasie, Titus Awokuse, Jessica Fanzo, Bart Minten, Rob Vos, et al. 2021. "The Processed Food Revolution in African Food Systems and the Double Burden of Malnutrition." *Global Food Security* 28 (March). https://doi.org/10.1016/J.GFS.2020.100466.

Riaz, Muhammad, Ghazala Shah, Muhammad Asif, Asma Shah, Kaustubh Adhikari, and Amani Abu-Shaheen. 2021. "Factors Associated with Hypertension in Pakistan: A Systematic Review and Meta-Analysis." *PLOS ONE* 16 (1): e0246085. https://doi.org/10.1371/journal.pone.0246085.

Rocha, Carla Eduarda Faustino, Magda do Carmo Parajára, Ísis Eloah Machado, Aline Siqueira Fogal Vegi, Mariana Carvalho de Menezes, and Adriana Lúcia Meireles. 2023. "Chronic Diseases Attributable to a Diet Rich in Processed Meat in Brazil: Burden and Financial Impact on the Healthcare System." *Frontiers in Nutrition* 10 (March). https://doi.org/10.3389/FNUT.2023.1114766.

Rouhani, M. H., A. Salehi-Abargouei, P. J. Surkan, and L. Azadbakht. 2014. "Is There a Relationship between Red or Processed Meat Intake and Obesity? A Systematic Review and Meta-analysis of Observational Studies." *Obesity Reviews* 15 (9): 740–48. https://doi.org/10.1111/obr.12172.

Saha, Jay, Pradip Chouhan, Farooq Ahmed, Tanmoy Ghosh, Sabbir Mondal, Muhammad Shahid, Saireen Fatima, and Kun Tang. 2022. "Overweight/Obesity Prevalence among Under-Five Children and Risk Factors in India: A Cross-Sectional Study Using the National Family Health Survey (2015–2016)." *Nutrients* 14 (17): 3621. https://doi.org/10.3390/nu14173621.

Salehi-Abargouei, A, F Akbari, N Bellissimo, and L Azadbakht. 2016. "Dietary Diversity Score and Obesity: A Systematic Review and Meta-Analysis of Observational Studies." *European Journal of Clinical Nutrition* 70 (1): 1–9. https://doi.org/10.1038/ejcn.2015.118.

Schneider, Pia, Barry Popkin, Meera Shekar, Julia Dayton Eberwein, Charlotte Block, and Kyoko Shibata Okamura. 2020. "Health and Economic Impacts of Overweight/Obesity." In *Obesity: Health and Economic Consequences of an Impending Global Challenge*, 69–94. The World Bank. https://doi.org/10.1596/978-1-4648-1491-4_ch3.

Schwingshackl, Lukas, Georg Hoffmann, Tamara Kalle-Uhlmann, Maria Arregui, Brian Buijsse, and Heiner Boeing. 2015. "Fruit and Vegetable Consumption and Changes in Anthropometric Variables in Adult Populations: A Systematic Review and Meta-Analysis of Prospective Cohort Studies." *PLOS ONE* 10 (10): e0140846. https://doi.org/10.1371/journal.pone.0140846.

Schwingshackl, Lukas, Georg Hoffmann, Carolina Schwedhelm, Tamara Kalle-Uhlmann, Benjamin Missbach, Sven Knüppel, and Heiner Boeing. 2016. "Consumption of Dairy Products in Relation to Changes in Anthropometric Variables in Adult Populations: A Systematic Review and Meta-Analysis of Cohort Studies." *PLOS ONE* 11 (6): e0157461. https://doi.org/10.1371/journal.pone.0157461.

Schwingshackl, Lukas, Carolina Schwedhelm, Georg Hoffmann, Sven Knüppel, Khalid Iqbal, Violetta Andriolo, Angela Bechthold, Sabrina Schlesinger, and Heiner Boeing. 2017. "Food Groups and Risk of Hypertension: A Systematic Review and Dose-Response Meta-Analysis of Prospective Studies." *Advances in Nutrition* 8 (6): 793–803. https://doi.org/10.3945/an.117.017178.

Scrinis, Gyorgy. 2020. "Reframing Malnutrition in All Its Forms: A Critique of the Tripartite Classification of Malnutrition." *Global Food Security* 26 (September): 100396. https://doi.org/10.1016/j.gfs.2020.100396.

Scrinis, Gyorgy, and Carlos Monteiro. 2022. "From Ultra-Processed Foods to Ultra-Processed Dietary Patterns." *Nature Food* 3 (9): 671–73. https://doi.org/10.1038/s43016-022-00599-4.

Seid, Awole, Desta Dugassa Fufa, Misrak Weldeyohannes, Zuriyash Tadesse, Selamawit Lake Fenta, Zebenay Workneh Bitew, and Getenet Dessie. 2023. "Inadequate Dietary Diversity during Pregnancy Increases the Risk of Maternal Anemia and Low Birth Weight in Africa: A Systematic Review and Meta-analysis." *Food Science & Nutrition*, May. https://doi.org/10.1002/fsn3.3388.

Smith, Julie P. 2019. "Counting the Cost of Not Breastfeeding Is Now Easier, but Women's Unpaid Health Care Work Remains Invisible." *Health Policy and Planning* 34 (6): 479–81. https://doi.org/10.1093/heapol/czz064.

Stanton, Alice V, Frédéric Leroy, Christopher Elliott, Neil Mann, Patrick Wall, and Stefaan De Smet. 2022. "36-Fold Higher Estimate of Deaths Attributable to Red Meat Intake in GBD 2019: Is This Reliable?" *The Lancet* 399 (10332): e23–26. https://doi.org/10.1016/S0140-6736(22)00311-7.

Stevens, Gretchen A., Ty Beal, Mduduzi N.N. Mbuya, Hanqi Luo, Lynnette M. Neufeld, O. Yaw Addo, Seth Adu-Afarwuah, et al. 2022. "Micronutrient Deficiencies among Preschool-Aged Children and Women of Reproductive Age Worldwide: A Pooled Analysis of Individual-Level Data from Population-Representative Surveys." *The Lancet. Global Health* 10 (11): e1590–99. https://doi.org/10.1016/S2214-109X(22)00367-9.

Tan, Chang, Yudi Zhao, and Suqing Wang. 2019. "Is a Vegetarian Diet Safe to Follow during Pregnancy? A Systematic Review and Meta-Analysis of Observational Studies." *Critical Reviews in Food Science and Nutrition* 59 (16): 2586–96. https://doi.org/10.1080/10408398.2018.1461062.

The Food and Land Use Coalition. 2019. "Growing Better: Ten Critical Transitions to Transform Food and Land Use." https://www.foodandlandusecoalition.org/global-report/.

Tricco, Andrea C., Erin Lillie, Wasifa Zarin, Kelly O'Brien, Heather Colquhoun, Monika Kastner, Danielle Levac, et al. 2016. "A Scoping Review on the Conduct and Reporting of Scoping Reviews." *BMC Medical Research Methodology* 16 (1): 15. https://doi.org/10.1186/s12874-016-0116-4.

Tricco, Andrea C., Erin Lillie, Wasifa Zarin, Kelly K. O'Brien, Heather Colquhoun, Danielle Levac, David Moher, et al. 2018. "PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation." *Annals of Internal Medicine* 169 (7): 467–73. https://doi.org/10.7326/M18-0850.

Uloko, Andrew E., Baba M. Musa, Mansur A. Ramalan, Ibrahim D. Gezawa, Fabian H. Puepet, Ayekame T. Uloko, Musa M. Borodo, and Kabiru B. Sada. 2018. "Prevalence and Risk Factors for Diabetes Mellitus in Nigeria: A Systematic Review and Meta-Analysis." *Diabetes Therapy* 9 (3): 1307–16. https://doi.org/10.1007/s13300-018-0441-1.

Vanderhout, Shelley M., Mary Aglipay, Nazi Torabi, Peter Jüni, Bruno R. Da Costa, Catherine S. Birken, Deborah L. O'Connor, Kevin E. Thorpe, and Jonathon L. Maguire. 2020. "Whole Milk Compared with Reduced-Fat Milk and Childhood Overweight: A Systematic Review and Meta-Analysis." *The American Journal of Clinical Nutrition* 111 (2): 266–79. https://doi.org/10.1093/AJCN/NQZ276.

Vega-Solano, Jaritza, Karol Madriz-Morales, Adriana Blanco-Metzler, and Eduardo Augusto Fernandes-Nilson. 2023. "Estimation of the Economic Benefits for the Public Health System Related to Salt Reduction in Costa Rica." *PLOS ONE* 18 (2): e0279732. https://doi.org/10.1371/JOURNAL.PONE.0279732.

Verger, Eric O., Mathilde Savy, Yves Martin-Prével, Jennifer Coates, Edward Frongillo, and Lynnette Neufeld. 2023. "Healthy Diet Metrics: A Suitability Assessment of Indicators for Global and National Monitoring Purposes." Geneva.

Walters, Dylan D, Linh T H Phan, and Roger Mathisen. 2019. "The Cost of Not Breastfeeding: Global Results from a New Tool." *Health Policy and Planning* 34 (6): 407–17. https://doi.org/10.1093/heapol/czz050.

Wang, Huan, Anna W. Herforth, Bo Xi, and Zhiyong Zou. 2022. "Validation of the Diet Quality Questionnaire in Chinese Children and Adolescents and Relationship with Pediatric Overweight and Obesity." *Nutrients* 14 (17): 3551. https://doi.org/10.3390/nu14173551.

Wang, Mei, Xinyi Du, Wei Huang, and Yong Xu. 2022. "Ultra-Processed Foods Consumption Increases the Risk of Hypertension in Adults: A Systematic Review and Meta-Analysis." *American Journal of Hypertension* 35 (10): 892–901. https://doi.org/10.1093/ajh/hpac069.

Wang, Weijing, Yili Wu, and Dongfeng Zhang. 2016. "Association of Dairy Products Consumption with Risk of Obesity in Children and Adults: A Meta-Analysis of Mainly Cross-Sectional Studies." *Annals of Epidemiology* 26 (12): 870-882.e2. https://doi.org/10.1016/J.ANNEPIDEM.2016.09.005.

Wells, Jonathan C., Ana Lydia Sawaya, Rasmus Wibaek, Martha Mwangome, Marios S. Poullas, Chittaranjan S. Yajnik, and Alessandro Demaio. 2020. "The Double Burden of Malnutrition: Aetiological Pathways and Consequences for Health." *The Lancet* 395 (10217): 75–88. https://doi.org/10.1016/S0140-6736(19)32472-9.

WHO. 2020. "Healthy Diet Fact Sheet." 2020. https://www.who.int/news-room/fact-sheets/detail/healthy-diet.

———. 2023a. "WHO Guideline for Complementary Feeding of Infants and Young Children 6–23 Months of Age." Geneva. https://iris.who.int/bitstream/handle/10665/373358/9789240081864-eng.pdf?sequence=1.

———. 2023b. "Malnutrition Fact Sheet." December 20, 2023. https://www.who.int/news-room/fact-sheets/detail/malnutrition.

———. n.d. "STEPwise Approach to NCD Risk Factor Surveillance (STEPS)." Noncommunicable Disease Surveillance, Monitoring and Reporting. Accessed January 23, 2024. https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/steps.

WHO, and UNICEF. 2021. "Indicators for Assessing Infant and Young Child Feeding Practices: Definitions and Measurement Methods." Geneva. https://apps.who.int/iris/bitstream/handle/10665/340706/9789240018389-eng.pdf?sequence=1.

World Cancer Research Fund International, and The NCD Alliance. 2014. "The Link between Food, Nutrition, Diet and Non-Communicable Diseases." London, UK. https://www.wcrf.org/wp-content/uploads/2021/07/WCRF-NCD-A4-WEB.pdf.

Yang, Xiu, Yuqian Li, Chongjian Wang, Zhenxing Mao, Wen Zhou, Lulu Zhang, Mengying Fan, Songyang Cui, and Linlin Li. 2020. "Meat and Fish Intake and Type 2 Diabetes: Dose–Response Meta-Analysis of Prospective Cohort Studies." *Diabetes & Metabolism* 46 (5): 345–52. https://doi.org/10.1016/j.diabet.2020.03.004.

Yu, Jiayue, Bhavadharini Balaji, Maria Tinajero, Sarah Jarvis, Tauseef Khan, Sudha Vasudevan, Viren Ranawana, et al. 2022. "White Rice, Brown Rice and the Risk of Type 2 Diabetes: A Systematic Review and Meta-Analysis." *BMJ Open* 12 (9): e065426. https://doi.org/10.1136/bmjopen-2022-065426.

Zaharia, Sonia, Shibani Ghosh, Robin Shrestha, Swetha Manohar, Andrew L. Thorne-Lyman, Bernard Bashaasha, Nassul Kabunga, et al. 2021. "Sustained Intake of Animal-Sourced Foods Is Associated with Less Stunting in Young Children." *Nature Food* 2 (4): 246–54. https://doi.org/10.1038/s43016-021-00259-z.

Zeinalabedini, Mobina, Behzad Zamani, Ensieh Nasli-Esfahani, and Leila Azadbakht. 2023. "A Systematic Review and Meta-Analysis of the Association of Dietary Diversity with Undernutrition in School-Aged Children." *BMC Pediatrics* 23 (1): 269. https://doi.org/10.1186/s12887-023-04032-y.

Zhang, Bei, Liyuan Pu, Tian Zhao, Li Wang, Chang Shu, Shan Xu, Jing Sun, Ruijie Zhang, and Liyuan Han. 2023. "Global Burden of Cardiovascular Disease from 1990 to 2019 Attributable to Dietary Factors." *The Journal of Nutrition*, March. https://doi.org/10.1016/j.tjnut.2023.03.031.

Zhang, Jing, Quanhong Li, Ying Song, Liping Fang, Lei Huang, and Yu Sun. 2022. "Nutritional Factors for Anemia in Pregnancy: A Systematic Review with Meta-Analysis." *Frontiers in Public Health* 10 (October): 1041136. https://doi.org/10.3389/FPUBH.2022.1041136/BIBTEX.

Zhao, Rongping, Liyun Zhao, Xiang Gao, Fan Yang, Yuxiang Yang, Hongyun Fang, Lahong Ju, et al. 2022. "Geographic Variations in Dietary Patterns and Their Associations with Overweight/Obesity and Hypertension in China: Findings from China Nutrition and Health Surveillance (2015–2017)." *Nutrients* 14 (19): 3949. https://doi.org/10.3390/NU14193949/S1.

Zhou, Yunping, Changwei Tian, and Chongqi Jia. 2012. "Association of Fish and Omega-3 Fatty Acid Intake with the Risk of Type 2 Diabetes: A Meta-Analysis of Prospective Studies." *British Journal of Nutrition* 108 (3): 408–17. https://doi.org/10.1017/S0007114512002036.

Zhuo, Ming, Ze Chen, Mao-Lin Zhong, Ye-Mao Liu, Fang Lei, Juan-Juan Qin, Tao Sun, et al. 2022. "The Global Disease Burden Attributable to a Diet Low in Fibre in 204 Countries and Territories from 1990 to 2019." *Public Health Nutrition* 26 (4): 1–12. https://doi.org/10.1017/S1368980022001987.

Annex 1: Search terms

Search 1: Web of Science database search terms by target group and outcome

Search terms were selected for each of the essential search component topics – i.e. diet (either inadequate diet or unhealthy diet), nutrition or health outcomes, and cost, which were combined using the operator ‘AND’. Within the broader search topics, more specific search terms were combined with the operator “OR”.

Filters used for all searches:

- Publication Year 2000-2023
- Language English
- Document types: article, review article, proceeding paper, book chapter, early access, meeting abstract
- Exclude Countries/Regions (AUSTRALIA or AUSTRIA or BAHRAIN or BELGIUM or BULGARIA or CANADA or CROATIA or CYPRUS or CZECH REPUBLIC or DENMARK or ENGLAND or FRANCE or FINLAND or GERMANY or GREECE or GREENLAND or HUNGARY or ICELAND or IRELAND or ISRAEL or ITALY or JAPAN or LATVIA or LITHUANIA or LUXEMBOURG or NETHERLANDS or NEW ZEALAND or NORTH IRELAND or NORWAY or OMAN or POLAND or PORTUGAL or QATAR or ROMANIA or RUSSIA or SAUDI ARABIA or SCOTLAND or SINGAPORE or SLOVAKIA or SLOVENIA or SOUTH KOREA or SPAIN or SWEDEN or SWITZERLAND or TAIWAN or UKRAINE or U ARAB EMIRATES or USA or WALES)

Searches conducted between April 13-19, 2023.

Population	Intervention	Comparison	Outcome
Children 0-59 months of age			

PICO ELEMENTS	KEYWORDS	SEARCH TERMS	SEARCH STRATEGIES
P (**P**atient or **P**opulation)	Patients undergoing abdominal surgery	Abdominal Surgery	Abdominal surgery OR Surgery OR Postoperative OR Recovery
I (**I**ntervention)	Chewing gum	Chewing Gum	Chewing Gum OR Gum
C (**C**omparison)	Not chewing gum		
O (**O**utcome)	Affects post-operative ileus	Postoperative Ileus	Postoperative Ileus OR Paralytic Ileus OR Ileus

Fig. 2

Children U5 - stunting

Component 1: Diet	Component 2: Nutrition/Health Outcome	Component 3: Cost
“inadequate diet*” OR “poor diet*” OR “diet* diversity” OR “suboptimal diet*” OR diet* OR food	Stunt* OR “height-for-age” OR “growth faltering”	Cost* OR “healthcare cost” OR “health care cost” OR “economic cost” OR “economic analysis” OR “disability adjusted life year*” OR DALY

(TS=("inadequate diet*") OR TS=("poor diet*") OR TS=("diet* diversity") OR TS=("suboptimal diet*") OR TS=(diet*) OR TS=(food))
AND (TS=(stunt*) OR TS=("height-for-age") OR TS=("growth faltering"))
AND (TS=(cost*) OR TS=("healthcare cost") OR TS=("health care cost") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))
N=152 articles

Children U5 wasting

(TS=("inadequate diet*") OR TS=("poor diet*") OR TS=("diet* diversity") OR TS=("suboptimal diet*") OR TS=(diet*) OR TS=(food))
AND (TS=(wasting) OR TS=("weight-for-height") OR TS=("acute malnutrition") OR TS=(kwashiorkor) OR TS=(marasmus))
AND (TS=(cost*) OR TS=("healthcare cost*") OR TS=("health care cost*") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))
AND (TS=(child*))

Child or adolescent overweight/obesity

(TS=(“diet* quality”) OR TS=(“unhealthy diet*”) OR TS=(diet*) OR TS=(food))
AND (TS=(overweight) OR TS=(obes*) OR TS=("weight-for-height") OR TS=("body mass index") OR TS=(BMI))
AND (TS=(cost*) OR TS=("healthcare cost*") OR TS=("health care cost*") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))
AND (TS=(child*) OR TS=(adolescen*))

Micronutrient deficiencies

(TS=("inadequate diet*") OR TS=("poor diet*") OR TS=("diet* diversity") OR TS=("suboptimal diet*") OR TS=(diet*) OR TS=(food) OR TS=(“micronutrient intake”) OR TS=(“micronutrient adequacy”))
AND (TS=(“micronutrient deficien*”) OR TS=(“iron deficien*”) OR TS=(“vitamin A deficien*”) OR TS=(anemia) OR TS=(“zinc deficien*”))
AND (TS=(cost*) OR TS=("healthcare cost*") OR TS=("health care cost*") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))

Pregnant/Lactating Women

(TS=("inadequate diet*") OR TS=("poor diet*") OR TS=("diet* diversity") OR TS=("suboptimal diet*") OR TS=("unhealthy diet") OR TS=(diet*) OR TS=("food intake") OR TS=(“micronutrient intake”) OR TS=(“micronutrient adequacy”))
AND (TS=(“micronutrient deficien*”) OR TS=(“iron deficien*”) OR TS=(an*emia) OR TS=(overweight) OR TS=(obes*))

AND (TS=(cost*) OR TS=("healthcare cost*") OR TS=("health care cost*") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))
AND (TS=(pregnan*) OR TS=(lactating))

Adult overweight and obesity

(TS=("diet* quality") OR TS=("unhealthy diet*") OR TS=(diet*) OR TS=(food))
AND (TS=(overweight) OR TS=(obes*) OR TS=("body mass index") OR TS=(BMI))
AND (TS=(cost*) OR TS=("healthcare cost*") OR TS=("health care cost*") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))

Diabetes and Hypertension

(TS=("inadequate diet*") OR TS=("poor diet*") OR TS=("diet* diversity") OR TS=("suboptimal diet*") OR TS=("unhealthy diet*") OR TS=("unhealthy food*") OR TS=(diet*) OR TS=("food consum*"))
AND (TS=(diabet*) OR TS=("raised blood glucose") OR TS=("diabetes mellitus") OR TS=(hypertens*) OR TS=("high blood pressure") OR TS=("raised blood pressure"))
AND (TS=(cost*) OR TS=("healthcare cost*") OR TS=("health care cost*") OR TS=("economic analysis") OR TS=("economic cost*") OR TS=("disability adjusted life year") OR TS=(DALY))

Search 2: Web of Science and Cochrane Database search terms by life stage group and outcome

	Web of Science	Cochrane Database
U5 stunting	(TS=(diet*) OR TS=(food)) AND (TS=(stunt*) OR TS=("height-for-age") OR TS=("growth faltering")) AND (TS=("meta-analysis")) and **English** (Languages) and **Review Article** (Document Types) N=49	11 **Cochrane Reviews matching** (diet* OR food) in Title Abstract Keyword AND (stunt* OR "height-for-age" OR "growth faltering") in Title Abstract Keyword AND ("meta-analysis") in Title Abstract Keyword NOT fortification in Record Title - with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)
U5 wasting	**(TS=(diet*) OR TS=(food)) AND (TS=(wasting) OR TS=("weight-for-height") OR TS=("acute malnutrition") OR TS=(kwashiorkor) OR TS=(marasmus)) AND (TS=(child*)) AND (TS=("meta-analysis"))** and **English** (Languages) and **Review Article** (Document Types) N=49	20 **Cochrane Reviews matching** (diet* OR food) in Title Abstract Keyword AND (wasting OR "weight-for-height" OR "acute malnutrition" OR kwashiorkor OR marasmus) in Title Abstract Keyword AND ("meta-analysis") in Title Abstract Keyword - with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)
Micronutrient Deficiency	**(TS=(diet*) OR TS=(food) OR TS=(“micronutrient”)) AND (TS=(“micronutrient deficien*”) OR TS=(“iron deficien*”) OR TS=(“vitamin A deficien*”) OR TS=(anemia) OR TS=(“zinc deficien*”)) AND (TS=(“meta-analysis”)) NOT (TS=(fortific*))** and **English** (Languages) and **Review Article** (Document Types) N=129	22 **Cochrane Reviews matching** (diet* OR food OR micronutrient) in Title Abstract Keyword AND (micronutrient NEXT deficien*) OR (iron NEXT deficien*) OR (vitamin NEXT A NEXT deficien*) OR anemia OR (zinc NEXT deficien*) in Title Abstract Keyword AND (“meta-analysis”) in Title Abstract Keyword NOT fortification in Record Title NOT supplementation in Record Title – with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)

	Web of Science	Cochrane Database
Child overweight and obesity	(TS=(diet*) OR TS=(food)) AND (TS=(overweight) OR TS=(obes*) OR TS=("weight-for-height") OR TS=("body mass index") OR TS=(BMI)) AND (TS=(child*) OR TS=(adolescen*)) AND (TS=("meta-analysis")) NOT (TI=(intervention*)) N=310	38 **Cochrane Reviews matching** (diet* OR food) in Title Abstract Keyword AND (overweight) OR (obes*) OR ("weight-for-height") OR ("body mass index") OR (BMI) in Title Abstract Keyword AND child OR adolescen* in Title Abstract Keyword AND ("meta-analysis") in Title Abstract Keyword - with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)
Pregant and Lactating Women	(TS=(diet*) OR TS=("food intake") OR TS=("micronutrient")) AND (TS=("micronutrient deficien*") OR TS=("iron deficien*") OR TS=(an*emia) OR TS=(overweight) OR TS=(obes*) OR TS=(BMI)) AND (TS=(pregnan*) OR TS=(lactat*)) AND (TS=("meta-analysis")) NOT (TI=(fortific*)) NOT (TI=(supplement*)) N=146	99 **Cochrane Reviews matching** (diet OR food OR micronutrient) in Title Abstract Keyword AND (overweight OR obes* OR "body mass index" OR BMI OR "micronutr*" OR "iron deficien*" OR anemia) in Title Abstract Keyword AND (pregnan* OR lactat*) in Title Abstract Keyword NOT fortific* OR supplement* in Record Title - with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)
Adult overweight and obesity	(TS=(diet*) OR TS=("food intake") OR TS=("ultra-processed food*")) AND (TS=(overweight) OR TS=(obes*) OR TS=(BMI) OR TS=("body mass index")) AND (TS=("meta-analysis")) NOT TI=(cancer) N=1456	48 **Cochrane Reviews matching** (diet* OR food OR (ultra-processed NEXT food*)) AND (overweight OR obes* OR "body mass index" OR BMI) AND ("meta-analysis") NOT (cancer) - with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)

	Web of Science	**Cochrane Database**
Diabetes and Hypertension	(TS=(diet*) OR TS=("food consum*") OR TS=("ultra-processed food*") OR TS=("unhealthy food*")) AND (TS=(diabet*) OR TS=("raised blood glucose") OR TS=("diabetes mellitus") OR TS=(hypertens*) OR TS=("high blood pressure") OR TS=("raised blood pressure")) AND TS=("meta-analysis") NOT TI=(cancer) N=1122	67 **Cochrane Reviews matching** (diet* OR "food consumption" OR "ultra-processed food" OR "unhealthy food") in Title Abstract Keyword AND (diabetes OR "raised blood glucose" OR hypertension OR "high blood pressure" OR "raised blood pressure") in Title Abstract Keyword AND ("meta-analysis") in Title Abstract Keyword NOT cancer in Record Title - with Cochrane Library publication date Between Jan 2000 and Dec 2023, in Cochrane Reviews (Word variations have been searched)