Policy Research Working Paper 10671

Estimating Economic Costs of Unhealthy Diets

A Proposed Methodology

Susan Horton
Patrizia Fracassi
Kendra Siekmans
Tomoko Kato
Giles Hanley-Cook

WORLD BANK GROUP
Agriculture and Food Global Practice
January 2024

Abstract

Healthy diets have been characterized as responding to four universal principles—nutrient adequacy, dietary diversity, macronutrient balance, and moderation. With rising incomes, diet concerns globally have shifted from inadequacy of nutrients and lack of diversity, to lack of balance and moderation. This has occurred alongside declining rates of stunting and wasting in children under five and increasing rates of overweight and obesity across a broad age span. Calculations undertaken for low- and middle-income countries for policy and advocacy purposes of the economic cost of unhealthy diets have used nutritional status as a proxy or have made estimates of the impact of noncommunicable diseases by simply adding up known risks of individual diet factors. Both these methods have problems. This paper proposes a new methodology, taking advantage of recent, more holistic, measures of diet quality. Preliminary regression results are presented using cross-country data and the Global Dietary Recommendations Score and Minimum Dietary Diversity for women. The results suggest that diet quality variables generally have the expected signs, but there are also clear limitations of using cross-country data. The methodology could be applied in future to a limited number of broadly representative low- and middle-income countries data sets containing both diet recall data as well as measures of noncommunicable disease risk status. The analysis suggests that this work could inform policies such as the repurposing of existing agrifood policies to complement existing public health policies, to reduce the economic and health burdens imposed by unhealthy diets.

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 sehotrton@uwaterloo.ca.

Estimating Economic Costs of Unhealthy Diets: A Proposed Methodology

Susan Horton,[1] Patrizia Fracassi,[2] Kendra Siekmans,[3] Tomoko Kato,[4] Giles Hanley-Cook[5]

JEL classification: I12, I15, I18, I38, Q18

Keywords: diet quality, food choices, undernutrition, overweight, obesity, non-communicable disease, healthcare costs, agrifood policy

Acknowledgments

This work is a product of the Programmatic ASA *'Repurposing Agrifood Public Policies and Support for Healthy Diets'* (P180735) led by Felipe Dizon (Senior Economist, SAGGL) and Kyoko Shibata Okamura (Senior Nutrition Specialist, HHNGE). The authors would like to thank colleagues from the Healthy Diets project for their support of related work, including Erkan Ozcelik, Ti Kian Seow, and Diana Carter from FAO, and Felipe Dizon, Kyoko Shibata Okamura, and Hina Sherwani from the World Bank. We thank Mireya Vilar, Andrea Cattaneo, and John Hoddinott for their careful review of the paper. We thank Lynnette Neufeld, Bridget Holmes, Harold Alderman, Patrick Webb, and participants in a joint World Bank-FAO seminar on September 14, 2023 for helpful comments on earlier drafts. We thank Sangmin Seo, Rachel Bryant, and Laura Jimenez for expert research assistance for the empirical work. All remaining errors are our own. The findings, interpretations and conclusions expressed herein are those of the authors and do not necessarily reflect the view of the World Bank Group, its Board of Directors, or the governments they represent.

[1] University of Waterloo. Corresponding author: sehorton@uwaterloo.ca
[2] Food and Nutrition Division, FAO. Patrizia.Fracassi@fao.org
[3] Consultant, Food and Nutrition Division, FAO. ksiekmans@nurturedev.com
[4] Food and Nutrition Division, FAO. Tomoko.Kato@fao.org
[5] Consultant, Food and Nutrition Division, FAO. Giles.HanleyCook@fao.org

1. Introduction

This Working Paper aims to develop a methodology to assess the economic costs of unhealthy diets, which can be particularly informative for agrifood policy. We argue that existing work on the economic cost of malnutrition in all its forms has disadvantages, since several factors other than diet can lead to malnutrition, and even individuals with healthy weights are still at risk of the detrimental health impacts of unhealthy diets.

Our understanding of what constitutes a healthy diet has evolved over time. The early literature on food and nutrition in low- and middle-income countries (LMICs) focused on undernutrition (with low height-for-age and low weight-for-height of children under five being major concerns). Initially the major focus was adequate energy intake once an early debate over the importance of calories versus protein was resolved. Subsequently attention turned to other dietary components, especially micronutrients. One estimate of the cost of child stunting, which is affected by both energy and micronutrient intakes, suggested that it was associated with an 8% loss of global GDP over the period 1900-2000 (Horton and Steckel 2013), while FAO estimated that chronic undernutrition (referring to child stunting) caused losses of 3.5% of global GDP in the early 21st century (FAO, 2013). The 2013 *Lancet* Maternal and Child Nutrition series estimated that 46% of deaths of children under five were attributable to malnutrition (also referring to undernutrition) (Black et al. 2013).

In the past two decades, however, there has been rising concern about increases in rates of overweight and obesity globally (Popkin 2004), termed the "nutrition transition", related to unhealthy diets. A large literature discusses the adverse effects of overweight and obesity on health and economic outcomes. While this literature initially focused on impacts in high-income countries, subsequent estimates have also been made for LMICs where the prevalence of overweight and obesity has been rising quickly (Schneider et al. 2020). One recent estimate for 161 countries (comprising high-income countries, as well as LMICs) is that the global economic losses attributable to overweight and obesity amount to 2.2% of global GDP (Okunogbe et al. 2022). The corresponding human cost was estimated at 4.7 million deaths in 2017 (Dai et al. 2020); an update using 2019 data associated this cost with 5 million deaths due to noncommunicable diseases (NCDs), 77% of these occurring in LMICs (Abbafati et al. 2020). Similarly, the World Bank (2020) estimated that 4 million deaths globally were attributable to obesity and projected that by 2035 the costs of obesity in LMICs will amount to $7 trillion.

There is also literature linking dietary factors directly to NCDs (e.g., GBD 2017 Diet Collaborators 2019), with some dietary factors protecting against and others increasing risks of NCDs. GBD 2017 Diet Collaborators (2019) use a bottom-up methodology for each of 15 dietary factors, adding up projected effects and estimating that these dietary risks accounted for 11 million deaths globally in 2017. The effects of some of the dietary risks (e.g., excess consumption of sugar and fat) may be mediated through obesity; while others may operate independently (e.g., GBD 2017 Diet Collaborators, 2019, estimate that 3 million deaths were attributable to excess sodium intake in 2017). Arguably using a more holistic measure of diet quality is preferable to adding up the risks due to multiple individual dietary factors, and less prone to double counting.

Another literature, even broader in scope, ties malnutrition with climate considerations (e.g., The Food and Land Use Coalition – FOLU – 2019). FOLU (2019) presents estimates of the economic costs of, both what they term, undernutrition (stunting, wasting, and underweight among children under five years of age) as 2.0% of global GDP, and of overweight and obesity as 3.1% of global GDP, based on their SYSTEMIQ model.[1] These costs are in turn components of their much larger $12 trillion (13.8% of global GDP) estimates of hidden costs of global agrifood and land use systems. These larger costs use a planetary rather than a human health framework, incorporating environmental costs.

The "double burden" of malnutrition refers to: (1) the co-existence of undernutrition (as evidenced by child stunting, child wasting, women thinness) and adult or child overweight at country level; (2) the co-existence of one or more individuals with wasting, stunting, or thinness and one or more individuals with overweight or obesity within the same household and; (3) the underlying developmental origins biology on what is termed the Developmental Origins and Health and Disease (DOHAD), originating in the work of Barker (2004). The DOHAD theory posits a biological basis for why diets with inadequate energy and nutrients levels during early pre-conception and pregnancy predispose offspring 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 among individuals whose body mass index is within the healthy range (i.e., 18.5-24.9 kg/m^2) (Mwangome and Prentice 2019).

Recent UN statements have referred to "malnutrition in all its forms," for example in Sustainable Development Goal 2. Countries facing both stunting and obesity encounter more complications in policies; Hawkes et al. (2020) propose ten ways to reorient nutrition interventions to address both burdens simultaneously and Luo, Zyba, and Webb (2020) propose an index to measure nutrition in all its forms.

The discussion proceeds as follows. We first outline the important definitions being used throughout this Working Paper and present a basic conceptual framework. We then discuss issues of measurement, and review data sources, focusing on healthy diet metrics collected at national-level across a wide array of countries. This is followed by a brief summary of previous related costing studies, mainly focused on the costs of malnutrition in all its forms. We then propose a methodology for estimating the economic costs of unhealthy diets, along with preliminary cross-country empirical work. The concluding section summarizes key findings in terms of etiological pathways, nutrition and health outcomes, and economic effects, and notes key gaps and areas for future work.

2. Definitions and Conceptual Framework

The 2021 UN Food Systems Summit used the following definition: "A healthy diet is health-promoting and disease-preventing. It provides adequacy without excess, of nutrients and health-promoting substances from nutritious foods and avoids the consumption of health-harming substances." (Neufeld, Henriks and Hugas 2019). Healthy diets respond to the universal principles of nutrient adequacy, dietary diversity, macronutrient balance, and moderation (Verger et al. 2023). In what follows we consider three different diet aspects: energy sufficiency, nutrient adequacy, and food choices which promote health, using Figure 1 published by FAO (2020). These three aspects are also consistent with the "triple burden" of malnutrition discussed above.

Energy insufficient diets have large economic consequences in terms of disability-adjusted life-year (DALY) losses from high child mortality and direct costs of treatment of acute malnutrition. Key pathways

[1] Conversions from the amounts in $ trillion in FOLU (2019), for 2018, to percentage of GDP were undertaken by the present authors, using $86.4 trillion as global GDP in 2018.

to assess are food energy supply, leading to child stunting and wasting, and subsequently mortality and treatment costs (Figure 2). Child stunting is also associated with cognitive deficits and reduced educational attainment, leading to reduced productivity and hence economic costs (Figure 2). For further documentation of the effects of stunting and wasting in early childhood, see systematic reviews by Black et al. (2013) and Olofin et al. (2023). Diets which are insufficient in energy, by definition, cannot be adequate in all nutrients.

Nutrient inadequate diets (which are, however, sufficient in energy) have numerous consequences including reduced immunity to infection, increased rates of stunting, cognitive deficits, and birth defects. Various deleterious effects of nutrient inadequacies are potentially mediated through stunting (e.g., macronutrient and zinc deficiencies), while other nutrient inadequacies such as iodine and folic acid, are not. Anaemia in pregnancy has adverse effects on birth outcomes (Abu-Ouf and Jan 2015) and, if severe, increases the risk of maternal mortality (Daru et al, 2018). Furthermore, in adults, anemia has adverse effects on worker productivity (Marcus Schauer and Zlotkin 2021). For further documentation of the effects of iron deficiency in early childhood, see systematic reviews by Carter et al. (2010) and Grantham-MacGregor and Ani (2001). Policy response to the limited availability of key micronutrients in commonly consumed foods have often included provision of micronutrient supplements to young children and pregnant women, fortification of key foods, and biofortification. There is a large literature on the costs and benefits of supplementation and fortification. The costs of individual micronutrient deficiencies are not included in our study, which focuses on food choices that individuals and households make in their diets.

Diets characterised by excess intakes of unhealthy foods (which are, however, sufficient in energy) and inadequate intakes of healthy foods have their highest economic effect in terms of cost-of-illness from NCDs. Overweight and obesity are mediators for many NCDs (i.e., indirect effects), but there are also NCD risks directly related to specific diet components (e.g. salt, processed meats). Obesity in adults is associated with reduced adult life expectancy, reduced productivity, increased health care costs, early retirement, and reduced length of disability-free life years (Schneider et al. 2020). Key pathways to measure are from including food choices which increase health protection and avoiding food choices which increase health risk (emphasizing dietary balance and moderation), to NCD risks, hence NCD treatment costs and loss of productivity from morbidity and premature mortality.

There are differences in the pathways which are important at different stages in the life cycle (Table 1). More attention has been paid to date on children under 5, and women of reproductive age, not only in terms of research studies, but also development of dietary metrics, and data collection (discussed in the next section).

Non-diet factors also affect nutritional status and health risks (Figure 2). For example, some individuals may be stunted or wasted despite a healthy diet, because of infection or overweight due to a particular genetic predisposition. Some individuals may have healthy weight but increased NCD risk because of exposure to health compromising behaviors like smoking. Some individuals may be overweight or obese due to their exposure to obesogenic environments, whereby low physical activity may be a significant influencing factor together with other health compromising conditions and behaviors. These aspects are taken up later in the presentation of a proposed methodology.

Individual countries may contain a mix of individuals and households in the four different diet categories (insufficient energy intake, inadequate nutrient intake, unhealthy food choices, and healthy diets), depending on levels of income, underlying inequities in terms of food availability and affordability, and disparities in consumption. While Latin America and the Caribbean, Eastern Europe and Central Asia, and East Asia (led by China and Indonesia) show growing rates of overweight and obesity among the poor, in Sub-Saharan Africa and South Asia the largest increases in prevalence are among higher-wealth households in urban areas. In all LMICs, other than in South Asia and Sub-Saharan Africa, rural overweight and obesity is growing faster than in urban areas, albeit originally from lower levels (Popkin, Corvaland and Grummer-Strawn 2020). These different patterns have implications for agrifood and health policies.

3. Metrics for Healthy/Unhealthy Diets (Diet Quality)

Table 2 summarizes information on some commonly used dietary metrics available at different life-cycle stages, discussed in this section. Further details on sources, availability and methods of measurement are given in Appendix Tables 1, 2 and 3.

The growing burden of overweight and obesity, as well as NCDs, has required the development of novel healthy diet metrics to complement the more well-established metrics for energy sufficiency and nutrient adequacy of the diet (Table 2). The focus of the measures of (in)sufficiency and (in)adequacy has primarily been in children under 5 and in women of reproductive age (15-49), perhaps because these are the periods of greatest vulnerability to malnutrition and greatest probability of adverse outcomes. However, the outcomes of unhealthy diets affect all age groups, and new efforts to collect these data therefore also include adolescents (a period where eating habits may be established and maintained into adulthood) and adult men (who are also at risk of diet-related NCDs). In LMICs there has been to date less attention to older adults, while high-income countries with larger proportions of this age-group are already collecting data. There are very few data on younger school-age children (ages 5 through 12).

Detailed definitions and sources for diet variables are described in the Appendix Tables 1, 2 and 3, (corresponding to the lifecycle stages distinguished in Table 2) along with information on the number of countries/LMICs for which data are currently available. Since our focus is global, we have not included metrics specific to individual countries or regions. Data on metrics of nutritional and health status are well established and not reviewed here; UNICEF and WHO maintain global databases in this area (see Appendix Tables 4 and 5). Schooling outcomes and standardized test outcomes are available from UNESCO and key ones are included in the World Bank World Development Indicators database.

To help assess **energy sufficiency**, data on per capita food supply have been collated regularly at national level by FAO (and give some indication as to whether availability meets nutrient requirements). Measures compare food available and distributed and what is needed, according to the composition of the population by age, gender and physical activity levels. The Prevalence of Undernourishment (PoU, one of the suite of food security measures maintained by FAO) provides an estimate on how many people lack enough dietary energy for a healthy and active life. The prevalence of moderate or severe food insecurity based on the Food Insecurity Experience Scale (FIES, also maintained by FAO) provides an estimate on how many people do not have access to nutritious and sufficient food due lack of money or other resources. Energy sufficiency can also be assessed at the individual-level using quantitative dietary recall data.

To assess **nutrient adequacy**, quantitative data from dietary recall is considered to be the preferred source. However, given the difficulties in maintaining nationally-representative, up-to-date, quantitative data, metrics currently in widespread use employ recall to measure whether or not individuals consumed food from each of various food groups. One widespread summary population-level dietary indicator is that of **minimum diet diversity (MDD)**; however, this has been developed only for young children and women. For children 6-23 months of age, MDD is defined as consumption of at least five out of eight food groups including breastmilk in the preceding 24 hours (WHO and UNICEF, 2021). For non-pregnant women of reproductive age (15-49 years), MDD-W is defined as consumption of at least five out of 10 food groups over the last 24 hours (FAO 2021). MDD-W has been validated as a proxy indicator for a minimally acceptable level of dietary adequacy for 11 micronutrients (Martin-Prevel et al. 2017). Diet diversity data have been collected for a sufficient number of years and countries such that there is a body of research linking these measures with nutritional status.

Research suggests that **MDD for young children (6-23 months)** is associated with micronutrient adequacy (Molani-Gol et al. 2023), improved linear growth in some contexts (Gassara and Chen 2021), and lower risk of anemia (Donkor et al. 2021; Kathuria et al. 2023; Molla et al. 2020), but there is no strong indication of links with overweight or obesity. Recently, **egg and flesh food consumption** (which is a component of MDD) was included as an indicator of nutrient-sufficient diets among young children 6-23 months (WHO and UNICEF 2021) and data are widely available for LMICs (UNICEF 2022). Observational studies suggest a strong association for consumption of animal-source foods (ASF) with improved linear growth (Headey, Hirvonen and Hoddinott 2018; Krasevec et al. 2017; Zaharia et al. 2021), while systematic reviews of controlled trials found mixed results (Eaton et al. 2019; Shapiro et al. 2019).

Data collection began more recently for **MDD for non-pregnant women of reproductive age (15-49 years).** MDD-W is now being collected through large-scale DHS surveys in at least 24 countries (although, at the time of writing, results were available for only a limited number) as well as through Gallup World Poll surveys using telephone-based interviews (2021-2022 results available for women 15-49 years for 55 countries plus Palestine). As for children, MDD-W has a strong correlation with nutrient adequacy of diets (Martin-Prevel et al. 2017) but dietary diversity (i.e., not focusing on MDD-W only) has not shown consistent relationship with overweight or obesity and NCDs (Salehi-Abargouei et al. 2016; Vadiveloo, Dixon and Parekh 2013, Verger et al. 2021).

To assess whether a diet is **healthy,** quantitative dietary intake data are viewed as the reference, using detailed data on foods consumed. However, there is only very limited availability of validated metrics based on quantitative data that are well-suited for monitoring healthy diets in LMICs (Miller Micha and Mozaffarian 2020; WHO and UNICEF 2021). When quantitative dietary survey data are not available, the most common alternative approach in LMIC is to assess consumption of specific food groups (both protective and risk-inducing) across the previous day (or other such time interval). These data have only been collected relatively recently, and various alternative metrics have been suggested, such that the methodology for assessing these variables and their link with health and nutritional outcomes is still evolving. Another alternative method of data collection is to use food frequency questionnaires: these have the disadvantages that they are not quantitative and individuals may not recall as accurately over a longer period, but the advantage that better reflect the long-run intake of an individual. What is or is not healthy is frequently defined relative to WHO recommendations for a healthy diet for individuals 15-65 (WHO 2019, reproduced for convenience in Appendix Table 6).

Various metrics have been developed and used to assess whether diets of **adults aged 15 years and older, both men and women** are healthy, a literature which is evolving. Metrics have been developed to assess consumption of specific food groups associated with increased risk of negative nutrition/health outcomes (e.g. ultra-processed foods, sugar-sweetened beverages), as well as combinations of food groups that are recommended either for increased or limited consumption. The strengths and limitations of these indicators for this work are summarized in Table 3.

The Global Diet Quality Project provides new nationally representative data on prevalence of consumption of food groups for 37 LMIC (and up to 54 countries by 2023) (Global Diet Quality Project, 2022), using self-reported consumption of foods from different groups based on non-quantitative 24-hour recalls (Herforth et al. 2020). These data can be used to construct several metrics at the population level. The **Global Dietary Recommendations (GDR) Score** has two components, NCD-Protect and NCD-Risk.

These measures have been validated for two countries (US and Brazil) against an index designed to reflect WHO healthy diet recommendations (2020) along with two additional recommendations from IARC (2018) and constructed using diet recall data (Herforth et al. 2020). Validation for a further eight countries is in the process of publication (Kennedy et al. 2022). The authors state that these metrics, combined with the MDD-W, can be used to assess current performance and track progress towards healthy diets. The only published study found to date that links these measures with outcomes is an observational study in China that assessed the association of the GDR scores with overweight and obesity in children 7-18 years of age, finding a positive association between the NCD-Risk score and obesity as well as a negative association between the overall GDR score and obesity (Wang et al. 2022).

The **Global Diet Quality Score (GDQS)** is a food-based metric composed of 25 food groups (16 healthy, 7 unhealthy and 2 unhealthy when consumed in excessive amounts) that are important contributors to nutrient intake and/or NCD risk (Bromage et al. 2021). It uses self-reported consumption based on a semi-quantitative 24-hour recall. It is currently one of the only diet quality metrics that has been validated against both nutrient adequacy and diet-related NCD risk. A recent study found that the GDQS was better than other metrics (e.g. MDD- W and AHEI, the Alternative Healthy Eating Index from 2010) at predicting changes in weight and waist circumference among women in Mexico (Angulo et al. 2021). Another study for China found that the GDQS was inversely associated with metabolic syndrome and nutrient inadequacy or both (He et al. 2021). The use of the two submetrics allows one to distinguish between diets which are nutrient inadequate due to insufficiency in the diet, and diets which are nutrient-inadequate due to unhealthy food choices. However, this metric has not yet been widely integrated in national surveys and data availability for LMIC are very limited.

There are also two diet quality metrics derived from modeling approaches. The **Global Dietary Database** has sought to consolidate existing quantitative data and produce modeled estimates of individual food and nutrient intake for 188 countries (Miller et al. 2021). These estimates have been used to describe dietary quality at country, regional and global levels using various metrics (Miller et al. 2022) and quantify disease burdens attributable to diet, such as for type 2 diabetes (O'Hearn et al. 2023).

The **Global Burden of Disease Project** uses a set of **15 dietary risk factors**: diets low in: fiber; fruits; legumes; nuts and seeds; polyunsaturated fatty acids (PUFAs); seafood omega-3 fatty acids; vegetables and whole grains; milk; calcium; and diets high in: processed meat; red meat; sodium; sugar-sweetened beverages; and trans fatty acids; these include most of the recommendations from WHO with some additional ones for cancer from IARC (GBD 2017 Diet Collaborators, 2019). They develop Global Burden of Disease estimates of the contribution of dietary risks to the burden of NCDs in adults over the age of 25 across 195 countries, along with their associated impact on mortality and DALYs.

One critique of these modeled estimates points to the fact that evidence on dietary intake from representative populations in LMIC is currently inadequate to produce robust and reliable estimates of intake across countries (Beal et al. 2021). The relevance and face validity of modeled data for country-level work are also often questioned by national stakeholders. Another concern is that GBD 2017 Diet Collaborators' (2019) estimates of adverse effects of dietary factors (11m deaths annually) far exceed the estimates from other studies cited above of adverse effects of overweight and obesity (4m globally). Some dietary risks affect health directly without necessarily being mediated by obesity, for example consumption of processed meats increases risk for colon cancer. There is also likely an indeterminate amount of double counting in the mortality estimates, given the "adding up" methodology employed (i.e., single dietary components are considered as independent and correlated structure or substitution effects not adequately considered). Diets do not tend to be randomly deficient in protective factors, or randomly contain single dietary risk factors. Rather, many households which have insufficient purchasing power are unable to consume several protective dietary factors, in the same way that households with high energy intakes and high levels of ultra-processed food consumption are likely to consume various of the higher-risk items and too few of the protective items.

Another summary measure based on quantitative diet data focuses on **ultra-processed foods** (Monteiro, Cannon, Lawrence et al. 2019; Monteiro, Cannon, Levy et al. 2019). Ultra-processed foods are defined by food processing methods as defined by the Nova classification and include foods such as convenience foods, fast foods, and sugar-sweetened beverages. Monteiro et al. (2019) summarize the relationship between amount of ultra-processed food in the diet and presence of diet risk factors in the diet (positive relation with saturated fat, sugar, trans fats, sodium and energy density) as well as the absence of protective factors in the diet (negative relation with protein, fiber and potassium). Monteiro et al. (2019) also summarize the relationship of amount of ultra-processed food in the diet, and suggest it is associated with increased obesity or obesity-related outcomes, CVD outcomes, increased prevalence of selected cancers. Recent systematic reviews also have found evidence of an increased risk of overweight and obesity, diabetes and other NCD risk factors associated with higher ultra-processed food consumption (Lane et al. 2021; Moradi et al. 2021).

Metrics for unhealthy diets in children are at an early stage of development and currently rely on the monitoring of food groups that are shown to be associated with increased risk of overweight and obesity. In **young children 6-23 months**, zero vegetable or fruit consumption in the previous day is used to measure diet risk, a practice that is linked to both insufficient intake of nutrients presently as well as low intake later in life (WHO & UNICEF, 2021). Similarly, data on child consumption of sweet beverages and sentinel unhealthy foods[2] in the previous day/time interval are now included as unhealthy eating indicators in large-scale surveys (i.e. MICS and DHS) based on evidence showing increased overweight/obesity risk among children consuming unhealthy snack foods and sugar-sweetened beverages (SSB) (Pries, Filteau, et al. 2019; Pries, Rehman, et al. 2019; Rousham et al. 2022).

There are no validated metrics for unhealthy diets in children 2-5 and 6-10 years. In LMIC, consumption of **unhealthy foods and SSBs**, as well as **insufficient intake of fruits and/or vegetables among adolescents** are monitored as health risk behaviors through Global School-based Student Health Surveys administered to school-going children 12-17 years of age (Beal et al. 2019). Eating fruit (Parra et al. 2021) or vegetables is associated with lower risk of overweight/obesity in children 12-17 years, while fast food and soft drinks consumption are associated with higher risk of overweight/obesity (Mahumud et al. 2021).

There are various **other characteristics of diet quality that are not assessed by the measures above** and are considered out of the scope of our work. These include several nutrition and health promoting components such as micronutrients added to fortified foods, dietary supplements, higher levels of nutrients in biofortified food products, and non-nutritive bioactive compounds (e.g. probiotics, polyphenols) present in maternal milk (Andreas et al. 2015; Badillo-Suárez et al. 2017) unprocessed or functional foods (Konstantinidi and Koutelidakis 2019). Similarly, food safety, including food borne contaminants, is beyond the scope of our work.

[2] "Sentinel unhealthy foods" are foods that are likely to be consumed by infants and young children and are high in sugar, salt and/or unhealthy fats. These include four categories of unhealthy foods: 1) candies, chocolates and other sugar confections; 2) frozen treats like ice cream, popsicles, etc.; 3) cakes, pastries, sweet biscuits, etc.; 4) chips, crisps, cheese puffs, French fries, instant noodles, etc.

4. Previous Costing Studies

A scoping review undertaken in parallel with this Working Paper (Siekmans et al, forthcoming) did not identify any published systematic reviews that bring together the evidence for LMIC on the economic costs of unhealthy diets. Candari and colleagues (2017) conducted a review of the literature to estimate the economic costs associated with unhealthy diets and low physical activity. They identified a total of six studies from Australia, China, the United Kingdom, and the United States that varied widely in their definition of unhealthy diets, including single food items, a list of specific food groups, and a dietary pattern compliant with national dietary recommendations. They reported a wide range of cost estimates that were sensitive to both the diet measure and study methodology.

Since that review, several new studies have been published that estimate 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). For LMIC, several studies estimate the cost (mortality and DALYs) of cardiovascular disease or the NCD burden attributable to the dietary risk factors, using the Global Burden of Disease dataset for 204 countries (Liu et al. 2022; Qiao et al. 2022; Zhang et al. 2023) or in specific country contexts (Brazil, Mexico) (Dávila-Cervante, 2020; Machado et al. 2022). Four studies (three in Brazil, one in Costa Rica) estimated the costs associated with excess salt/sodium consumption, one using the Global Burden of Disease dataset (Guedes et al. 2022) and the others assessed health care costs associated with hypertension (Nilson, da Silva et al. 2020; Nilson, Metlzer, et al. 2020; 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), low in fiber (Zhuo et al. 2022), or low in dairy (Javanbakht et al. 2018). One problem with these studies of individual dietary risks, is that 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.

A global Cost of Not Breastfeeding tool is also available to support country quantification of the human and economic losses, including loss of life, lost productivity and increased costs to health systems. The total annual global losses associated with inadequate breastfeeding are estimated to be between US$ 257-341 billion, or 0.37-0.70% of global gross national income (Walters et al. 2019).

There are a sizeable number of studies which estimate the cost of undernutrition, as measured by stunting and/or wasting among children under five years of age. A couple of recent examples, comprehensive in geographic scope, include ECLAC and WFP (2017) and the Cost of Hunger in Africa series, supported by African Union and led by at least 21 individual countries performing national studies (https://www.wfp.org/publications/cost-hunger-africa-series). The main costs included are costs of morbidity, mortality, and cognitive losses associated with undernutrition, measured as the costs of foregone future productivity. To these, the costs of treating severe acute malnutrition or community management of acute malnutrition can be added. These estimates typically focus on children (0-23 months, or 0-59 months) where the impact of diet on the life course is primarily set, and then make lifetime projections on DALY and productivity costs. The mother's diet during pregnancy is also a factor, since that impacts birthweight (i.e., through premature delivery and/or intra-uterine growth retardation).

Estimating the cost of overweight and obesity in LMICs has been undertaken more recently, with examples being ECLAC & WFP (2017), Jackson-Morris and Meyer (2023), Okunogbe et al. (2022) and Brero et al. (2023). The main costs considered are mortality and morbidity associated with noncommunicable diseases, for which overweight/obesity is a major risk factor. These costs include treatment costs, disability-adjusted life-year (DALY) losses, and productivity losses. Table 4 summarizes the major costs included in previous studies, with brief descriptions of how they are calculated. It is proposed to use similar standard methods in the methodology proposed in the next section.

5. A Proposed Methodology for Estimating Economic Costs of Unhealthy Diets at the Country Level

Malnutrition in all its forms (as measured by undernutrition/overweight/obesity) is not synonymous with unhealthy diets. There are individuals who have impaired growth despite nutrient-adequate diets because of other factors. Infection (itself related to vaccine status and the water and sanitation environment) is a key factor (Figure 2). Similarly, there are individuals who are overweight/obese despite their diet because of other factors, such as exposure to an obesogenic environment (Figure 2). Finally, having a healthy weight does not imply having a healthy diet. Individuals may maintain a healthy weight while consuming a diet that is inadequate in micronutrients or not balanced or not moderated. One example of individuals with healthy weight but unhealthy diets is those consuming excess salt which can increase hypertension and risks of cardiovascular disease.

Hence, although it is useful to employ cost methodologies similar to those of existing studies of undernutrition and overweight/obesity, adjustments are required since healthy weight does not imply the diet is healthy, nor is the converse true.

Figure 3 illustrates this. The figure illustrates a hypothetical distribution of nutritional status in the population (in this case the population mean weight is in the healthy range, but that is not necessarily the case). The vertical lines delineate the population fractions who are with underweight, healthy weight, and overweight/obese. The dotted horizontal lines separate those within each nutritional status who have healthy diets and those who do not. We will use these fractions to estimate the associated economic costs, using data on stunting in children under 5 years of age to project productivity costs across the life course, and using data on adults 18 years and over on overweight/obesity since the vast majority of productivity losses are in this age group. Hence while the FOLU (2019) study equates the combined costs of underweight and overweight/obesity on morbidity and mortality to human costs of the food system, Figure 3 shows that the situation is more complex. However, estimating the relative proportions of those with undernutrition, of healthy weight and overweight/obese with healthy diets, is not trivial.

We propose the following methods. To distinguish the share of child undernutrition associated with inadequate dietary intake and that associated with other factors such as infection, we will use the Lives Saved Tool (LiST: https://www.livessavedtool.org). We can then attribute this cost share (projecting forward to lifetime productivity losses) to estimate the proportion of the costs of child undernutrition attributable to unhealthy diets.

NCD costs (both treatment costs and DALY/productivity costs) among the adult population (18 years and older) are the major cost associated with unhealthy diets for those who are healthy weight and those who are overweight/obese. To estimate the proportion of NCD costs attributable to unhealthy diets we propose to use the following two equations:

(1) O&O = f(food choice, other)

(2) NCD risk = g(O&O, food choice, other)

where O&O stands for overweight and obesity, f and g represent functions and food choice is a measure of how healthy the diet is. This will help to identify the proportion of overweight/obesity attributable to unhealthy diet, and also those NCD risks not mediated by overweight and obesity.

There are existing studies linking dietary risks to burden of NCDs in LMICs, reviewed in the previous section. Most of these studies either look at a single NCD, or a single dietary factor. The Global Burden of Disease project has however a comprehensive study, aiming to link 15 dietary factors with the NCD burden (GBD 2017 Diet Collaborators, 2019). Various concerns have been raised about these estimates. First, the relative ranking of different dietary factors changes somewhat markedly between the analysis using the 2017 data and that using the 2019 data (analyzed by Qiao et al. 2022): Stanton et al. (2022) comment on differences regarding red meat. Second, evidence on dietary intake from representative populations in LMIC are currently inadequate to produce robust and reliable estimates of intake across countries (Beal et al. 2021). A third concern conceptually is how the rest of the diet is adjusted in the model when one individual dietary factor is varied in order to understand its impact on NCD risk. GBD 2017 Diet Collaborators (2019) state that the underlying studies they use are unclear on this adjustment. Finally, GBD 2017 Diet Collaborators (2019) estimates of adverse effects of dietary factors (11m global deaths annually) far exceed the estimates from other studies cited above of adverse effects of overweight and obesity (4m globally); and GBD 2017 Diet Collaborators (2019) imply that the 11m do not include the 4m. One likely explanation for the last point is that of double counting. The diets that individuals consume do not necessarily have only one dietary risk factor, and hence these individuals are at higher risk for more than one NCD. Adding the risks across multiple trials for individual NCDs is therefore likely to overestimate dietary risks of NCDs in aggregate.

It may be possible to reduce the double-counting on the side of dietary factors by using a more parsimonious indicator of dietary quality, such as the GDRS-protect and GDRS-risk scores (for cross-country data), or the two GDQS sub-scores (for national data). We propose to try this approach.

This does not solve the problem of multiple NCDs, however. Although deaths from NCDs list a primary cause of death, individuals suffering from (and being treated for) NCDs may have multiple conditions, but the individual should only be counted once when calculating treatment costs and lost productivity costs. The pragmatic approach suggested here is to focus on two of the top two conditions in terms of cause of death globally, namely cardiovascular disease and diabetes. Cancer could be included in future, as ongoing prospective cohort studies provide more information on the dietary risks for a broader range of cancers. This may yield an overly conservative estimate of the impact of unhealthy diets on NCDs, but the underlying rule on such economic calculations is always to err on the side of conservatism in such estimates.

6. Preliminary Test of the Methodology Using Cross-Country Data

Some preliminary regressions were undertaken using cross-country data, while recognizing that analysis using data for individuals and households within one country would be preferable (discussed in the section immediately following this one). This section discusses results of using cross-country data, benefiting from the recent availability of data on several diet quality measures across over 50 LMIC. Data definitions are given in Table 5. Stata 17 ((https://stata.com) was used for the analysis, and the dataset created using data from public databases is available through the World Bank Microdata Library (https://dimewiki.worldbank.org/Microdata_Catalog). Cross-country data have several disadvantages, among them:

- Variables are not always available for the same year (see Table 5);

- Variables are not always available for the same population group, for example the most complete recent data on underweight/overweight (measured using BMI) in adults are for non-pregnant women 20-49, whereas hypertension and diabetes prevalence are available for all adults 18+;
- It is impossible to control for confounding variables;
- There may be differences in reporting methods for the same variables;
- Current prevalence of overweight in adults does not only depend on current diet, but on the diet trajectory over the life course to date;
- Risks of NCD similarly do not only depend on current diet, but on the diet trajectory over the life course to date; and
- Time trends (in per capita calorie supply and overweight/obesity for example) may mean that different age cohorts in the population have different health risks, such that analysis should be undertaken for narrower age cohorts and not for all adults combined.

Hence, the results from cross-country regressions presented here are only exploratory, pending more careful analysis using individual country data. Sample sizes for the regressions are modest (generally around 40 countries). A variety of specifications were tried and those presented here had the best fit (using AIC, Akaike Information Criterion to decide among different specifications using the same observations). Independent variables which were not significant and whose inclusion worsened the overall fit, were removed.

The initial results (summarized in tables 6, 7 and 8) are generally consistent with the literature on diet quality, although not all the independent variables are significant. Child stunting and women's low BMI decrease as per capita calorie supply increases (significantly in both cases) and as diet diversity increases (significant for women but not children). Child wasting is not responsive to per capita calorie supply but decreases significantly as diet diversity increases. Wasting tends to reflect recent factors (e.g. seasonal hunger or epidemics) more sensitively than does stunting. The diet diversity variable may reflect circumstances at time of collection of anthropometric data, while calorie availability represents an annual average.

Women's and children's overweight is positively associated with per capita calorie supply (unsurprisingly) and also with dietary diversity (MDD and MDD-W), although not significantly. This latter finding is consistent with Herforth et al. (2020) who cite two previous studies noting the positive association between dietary energy intake with dietary diversity. The coefficients on the GDRS sub-scores (NCD-Protect and NCD-Risk) have the expected sign for women's overweight but are not significant. There are regional differences, in particular the Southeast Asia region has significantly higher stunting and wasting for children and low BMI for women, controlling for other factors (compared to the Africa region). The Eastern Mediterranean region has significantly more overweight both in children and women, controlling for other variables (compared to the Africa region). The Gini coefficient, a measure of inequality, is not significant in any of the regressions. The effect of calorie supply per capita is non-linear and has the strongest impact at the lower levels of calorie availability.

Results for hypertension and diabetes are mixed, perhaps because the data disadvantages mentioned above are more severe (less consistency of date, lack of age cohort data, and inconsistencies in the population covered, e.g. dependent variables are for all adults whereas some of the independent variables are only for women, etc.). Hypertension and diabetes both go down as ln(per capita calorie supply) increases and (results not presented) average level of hypertension is highest in low income countries and decreases consistently from low to lower-middle to upper-middle to high income countries. In theory this variable is supposed to measure both untreated hypertension (using blood pressure in the survey sample) but also to include treated hypertension (presumably by asking the respondent about medications at the time blood pressure is measured). It is possible that surveys are less good at capturing treated hypertension. The NCD-Protect score has the expect effect on reducing hypertension (significant) and is negative but not significant in the equation for diabetes. There are significant regional differences for diabetes. The NCD variables are likely to be affected by the quality of the health system. NCDs are more likely to be detected and treated in higher income countries. Thus, although one might expect incidence of NCDs to rise with income, premature mortality from NCDs (prior to age 70) is higher in LMICs. The results, given the data constraints noted, provide some encouragement for finding the expected effects of diet quality variables within individual countries.

7. Potential Testing of the Methodology Using National Datasets

National health and nutrition survey data provide potential for further testing of the methodology. National data have several advantages. Within countries there is less variation in the ability of health services to screen and treat diseases including NCDs, although there remain problems of socio-economic gradients and rural/urban differences affecting decisions to seek care and obtain access. In a large dataset, it is possible to conduct analysis separately for different age cohorts. Given the progression of the nutritional transition, different age cohorts will face different conditions throughout their lifespan, and cross section data can permit modeling of this. Six datasets were noted above as being potentially suitable, namely health and nutrition surveys for Brazil, Mexico, China, Philippines, Andhra Pradesh (India), and South Africa. These include three lower-middle income countries/states and three upper-middle income countries.

A disadvantage is that, to our knowledge, there are no low-income countries with such datasets. A suggested methodology for how to apply this to low-income countries in the same region is as follows. One could use the health and nutrition dataset from a given region to estimate the probability of cardiovascular risk and diabetes risk (via hypertension and blood glucose) among adults over 25 by BMI, by age cohorts and by socioeconomic group. These rates could then be applied to similar socioeconomic groups in low-income countries who, it is predicted, will follow similar paths.

This is possible for cardiovascular disease, the number one cause of death globally, as well as for diabetes. Although it would be desirable to extend this to the number two risk, all cancers combined, making estimates is more difficult. Unlike cardiovascular disease, there are no readily measurable biomarkers indicating longer-term risk, and the term cancer covers a large number of heterogeneous conditions affecting different sites such that prospective studies of cancer require very large populations. There are fewer large scale prospective cohort studies of cancer than there are involving CVD. Our understanding of the dietary risks for cancer is still evolving.

8. Potential for Testing Using Prospective Cohort Studies

Prospective cohort studies have become more common as researchers note their usefulness for NCD conditions whose antecedents begin even prior to adulthood, but which mainly manifest in disease outcomes three or more decades later. Ongoing prospective cohort studies which include dietary recall and health measures include PURE (in 27 high, middle and low income countries: https://www.phri.ca/research/pure/), ELSA-Brazil (began 2008-2010: Aquino et al. 2012), the US Nurses Health Study (https://nurseshealthstudy.org), the EPIC study (https://iarc.epic.fr) in a number of European countries, focusing on cancer, the Young Lives study in 4 LMICs (https://www.younglives.org.uk) and HELTI (https://cihr-irsc.gc.ca/e/49510.html) with linked studies in four middle and high-income countries, among others. It might be worth exploring some of these regarding cancer risks.

Prospective cohort studies do have strengths and limitations: they may aim to measure "usual" consumption of food groups, rather than a 24-hour recall as in most cross-sectional surveys; however, unless the cohort is recruited in early adulthood, current diet may not be a good reflection of previous diet. Prospective cohorts have advantages over cross-sectional studies, where an individual's diagnosis with elevated blood pressure or blood glucose may have led the individual already to change diet and thus attenuate the estimated link between diet and NCD risk.

9. Data Limitations

While we propose a life cycle approach, we acknowledge that certain age groups are not adequately covered in terms of evidence and dietary data. These are: children from 2 to 5 years, primary school children (6 to 10-12 years) and older adults (over 65 years). Evidence and data for adolescents is limited but growing. Dietary data for adult males (15 and above) are significantly less covered than for women.

Data on MDD-W are growing both through DHS and the Diet Quality Project (2022) but there appear to be some differences in the national prevalence estimates, some of which may reflect different sampling and data collection methods (face-to-face, as compared to by telephone). Few countries currently have open-data access for DHS MDD-W. MDD-W was not designed to measure risks of obesity and NCDs, and Herforth et al (2021) advise that caution is needed in using this in high income countries to indicate nutrient adequacy. The two GDRS subcomponent scores (NCD-Protect or NCD-Risk) perform better than MDD-W in relation to compliance with WHO dietary recommendations (Herforth et al. 2020). In general, the underlying continuous food score data are preferable as they provide more information than a dichotomous summary of a score, although this may require going back to the original datasets rather than the summary statistics available in online databases.

Caution should be exercised when linking diet metrics with the burden of malnutrition and diet-related NCDs as many of these dietary metrics still need additional validation with health outcomes. This issue should be further explored when applying the approach at the country level.

10. Discussion and Conclusions

Evidence on the hidden costs of undernutrition in children is well understood, and there is a large literature on the cost-benefit of investing in reducing undernutrition in young children, implemented in actions aimed at reaching the Millennium and Sustainable Development Goals. It is also well understood that unhealthy diets are associated with increased NCD risk. However, despite policy efforts, there were no examples of countries which have successfully reduced overweight and obesity out of 188 countries studied over 33 years from 1980 to 2013 (Ng et al. 2014). Short- and medium-term solutions to reduce undernutrition have in some cases failed to emphasize the basic principles of a healthy diet, namely adequacy, diversity, balance, and moderation.

Although current methodologies for estimating the hidden costs of child undernutrition and of adult overweight and obesity are informative, it is important to note that other risk factors are at play beyond unhealthy diets. Anthropometric measurements such as weight cannot entirely be associated with diets. For example, despite being given an adequate diet, children may still face an impaired growth or not gain weight because of underlying inflammations linked to infection. Conversely, individuals with healthy weight may have unhealthy diets and be at high risk of NCDs. Hence, estimating the hidden costs of unhealthy diets differs from estimating the cost of malnutrition in all its forms.

The new suites of healthy diet metrics have promise for policy analysis. They have potential for tracking the impact of nutrition-sensitive agrifood system policies, especially if they go beyond a focus on supply chain and also consider food environments and consumer behaviors. Using a more holistic indicator of healthy diets can avoid the double counting problems inherent in trying to add up the costs of failing to reach a dozen or more dietary guidelines. Work is underway to further validate these new measures against health outcomes.

Regressions undertaken for the current study using cross-country data suggest that increased calorie availability and greater dietary diversity, as expected, tend to be associated with less child stunting and wasting, and less underweight in women. Calorie availability and dietary diversity also are associated with increased overweight and obesity in both children and women, although these results are less significant than for undernutrition. The new GDR score's submetrics, NCD-Protect and NCD-Risk, have the expected effects on obesity in women, although not significantly so. Finally, cross-country data on NCD risks (hypertension and diabetes) have measurement issues but have the expected negative relation (although significant only for hypertension) with the NCD-Protect score.

In this note we have suggested that a way to proceed further would be to partner with national researchers to obtain similar regression results using national (or state-level) health and nutrition survey data to elucidate the relationship between overweight and/or cardiovascular risk or diabetes, and the new diet quality variables from individual-level data. This could then inform analysis for other countries in the same region of policy interest, which have individual quantitative dietary recall data but not associated with data on NCD risk factors.

The new data quality variables could help identify how diets vary across different population subgroups, and what the key issues are, such as insufficient diet diversity, insufficient consumption of foods protective against NCDs, or excess consumption of foods with risks for NCDs.

Knowledge of the economic costs of unhealthy food choices for different population subgroups could then inform policy priorities and be compared with estimates of the costs of different agrifood policies aimed at supporting better food choices. Examples of agrifood policies which were adopted with short- and medium-term goals of increasing farmer income and meeting nutrient needs of undernourished populations are subsidies on sugarcane and palm oil. These subsidies aimed to provide inexpensive calories and fat. However, being cognizant of the long-run costs of these policies in the context of the nutrition transition, with growing risks of diabetes and risks associated with saturated fat, can help guide the evolution of agrifood policy. There are also implications for public health nutrition policy, in that information on costs can underscore the importance of policies such as nutrition information and communication, and nutrition and exercise interventions in school-age children and adolescents.

References

Abbafati, Cristiana, Kaja M. Abbas, Mohsen Abbasi-Kangevari, Foad Abd-Allah, Ahmed Abdelalim, Mohammad Abdollahi, Ibrahim Abdollahpour, et al. 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." *The Lancet* 396 (10258): 1223–49. https://doi.org/10.1016/S0140-6736(20)30752-2.

Abu-Ouf, Noran M., and Mohammed M. Jan. 2015. "The Impact of Maternal Iron Deficiency and Iron Deficiency Anemia on Child's Health." *Saudi Medical Journal* 36 (2): 146. https://doi.org/10.15537/SMJ.2015.2.10289.

Andreas, Nicholas J., Beate Kampmann, and Kirsty Mehring Le-Doare. 2015. "Human Breast Milk: A Review on Its Composition and Bioactivity." *Early Human Development* 91 (11): 629–35. https://doi.org/10.1016/J.EARLHUMDEV.2015.08.013.

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 (12 Suppl 2): 152S-161S. https://doi.org/10.1093/JN/NXAB171.

Aquino, Estela M. L., Sandhi M. Barreto, Isabela M. Benseñor, Marilia S. Carvalho, Dóra Chor, Bruce B. Duncan, et al. 2012. "Brazilian Longitudinal Study of Adult Health (ELSA-Brasil): Objectives and Design." *American Journal of Epidemiology* 175 (4): 315–24. https://doi.org/10.1093/aje/kwr294.

Badillo-Suárez, Pilar Amellali, Maricela Rodríguez-Cruz, and Xóchitl Nieves-Morales. 2017. "Impact of Metabolic Hormones Secreted in Human Breast Milk on Nutritional Programming in Childhood Obesity." *Journal of Mammary Gland Biology and Neoplasia* 22 (3): 171–91. https://doi.org/10.1007/S10911-017-9382-Y/METRICS.

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, David 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.

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

Beal, Ty, Saul S. Morris, and Alison Tumilowicz. 2019. "Global Patterns of Adolescent Fruit, Vegetable, Carbonated Soft Drink, and Fast-Food Consumption: A Meta-Analysis of Global School-Based Student Health Surveys." *Food and Nutrition Bulletin* 40 (4): 444–59. https://doi.org/10.1177/0379572119848287/ASSET/IMAGES/LARGE/10.1177_0379572119848287-FIG6.JPEG.

Bertram, Melanie Y, Jeremy A. Lauer, Karin Stenberg and Tessa Tan Torres Edejer. 2021. Methods for the Economic Evaluation of Health Care Interventions for Priority Setting in the Health System: An Update From WHO CHOICE. *International Journal of Health Policy and Management*, 10(11): 673–677

Black, Robert E, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, et al. 2013. "Maternal and Child Undernutrition and Overweight in Low-Income and Middle-Income Countries." *The Lancet* 382 (9890): 427–51. https://doi.org/10.1016/s0140-6736(13)60937-x.

Brero, Mauro, Christina L. Meyer, Angela Jackson-Morris, Garrison Spencer, Elizabeth Ludwig-Borycz, Daphne Wu, Anabel Fiorella Espinosa De Candido, et al. 2023. "Investment Case for the Prevention and Reduction of Childhood and Adolescent Overweight and Obesity in Mexico." *Obesity Reviews* 24 (9). https://doi.org/10.1111/obr.13595.

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.

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, R. Colin, Joseph L. Jacobson, Matthew J. Burden, Rinat Armony-Sivan, Neil C. Dodge, Mary Lu Angelilli, Betsy Lozoff, and Sandra W. Jacobson. 2010. "Iron Deficiency Anemia and Cognitive Function in Infancy." *Pediatrics* 126 (2): e427–34. https://doi.org/10.1542/peds.2009-2097.

Dai, Haijiang, Tariq A. Alsalhe, Nasr Chalghaf, Matteo Riccò, Nicola Luigi Bragazzi, and Jianhong Wu. 2020. "The Global Burden of Disease Attributable to High Body Mass Index in 195 Countries and Territories, 1990–2017: An Analysis of the Global Burden of Disease Study." *PLoS Medicine*. https://doi.org/10.1371/journal.pmed.1003198.

Daru, Jahnavi, Javier Zamora, Borja M. Fernández-Félix, Joshua Vogel, Olufemi T. Oladapo, Naho Morisaki, Özge Tunçalp, et al. 2018. "Risk of Maternal Mortality in Women with Severe Anaemia during Pregnancy and Post Partum: A Multilevel Analysis." *The Lancet Global Health* 6 (5): e548–54. https://doi.org/10.1016/S2214-109X(18)30078-0.

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.

Donkor, William E.S., Seth Adu-Afarwuah, Rita Wegmüller, Helena Bentil, Nicolai Petry, Fabian Rohner, and James P. Wirth. 2021. "Complementary Feeding Indicators in Relation to Micronutrient Status of Ghanaian Children Aged 6–23 Months: Results from a National Survey." *Life* 11 (9). https://doi.org/10.3390/LIFE11090969/S1.

Eaton, Jacob C., Pamela Rothpletz-Puglia, Margaret R. Dreker, Lora Iannotti, Chessa Lutter, Joyceline Kaganda, and Pura Rayco-Solon. 2019. "Effectiveness of Provision of Animal-Source Foods for Supporting Optimal Growth and Development in Children 6 to 59 Months of Age." *Cochrane Database of Systematic Reviews* 2019 (5). https://doi.org/10.1002/14651858.CD012818.PUB2/MEDIA/CDSR/CD012818/IMAGE_N/NCD012818-CMP-003-02.PNG

Economic Commission for Latin America, and World Food Programme (ECLAC & WFP). 2017. "The Cost of the Double Burden of Malnutrition ." https://docs.wfp.org/api/documents/WFP-0000110372/download/ Accessed July 7, 2023

FAO. 2013. “The State of Food and Agriculture 2013: Food System for Better Nutrition.” Rome.

———. 2021. “Minimum Dietary Diversity for Women: An Updated Guide to Measurement - from Collection to Action.” Rome.

FAO, IFAD, UNICEF, WFP, and WHO. 2020. “The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets.” Rome. https://doi.org/10.4060/ca9692en.

Gassara, Goudja, and Jihua Chen. 2021. “Household Food Insecurity, Dietary Diversity, and Stunting in Sub-Saharan Africa: A Systematic Review.” *Nutrients* 13 (12): 4401. https://doi.org/10.3390/NU13124401/S1.

GBD 2017 Diet Collaborators. 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.

Global Diet Quality Project. 2022. “Measuring What the World Eats: Insights from a New Approach.” Geneva and Cambridge, MA. https://doi.org/10.36072/dqq2022.

Grantham-McGregor, S., and Charles C Ani. 2001. “A Review of Studies on the Effect of Iron Deficiency on Cognitive Development in Children.” *The Journal of Nutrition* 131 (2S-2). https://doi.org/10.1093/JN/131.2.649S.

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.

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.

He, Yuna, Yuehui Fang, Sabri Bromage, Teresa T Fung, Shilpa N Bhupathiraju, Carolina Batis, Megan Deitchler, et al. 2021. “Application of the Global Diet Quality Score in Chinese Adults to Evaluate the Double Burden of Nutrient Inadequacy and Metabolic Syndrome.” *The Journal of Nutrition* 151 (October): 93S-100S. https://doi.org/10.1093/jn/nxab162.

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.

Horton, Sue, and Richard H. Steckel. 2013. “Malnutrition: Global Economic Losses Attributable to Malnutrition 1900–2000 and Projections to 2050.” In *How Much Have Global Problems Cost the World?*, edited by B. Lomborg, 247–72. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139225793.010.

International Agency for Research on Cancer (IARC). 2018. *Red Meat and Processed Meat IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. Vol. 114.

Isanaka, Sheila, Nicholas A. Menzies, Jessica Sayyad, Mudasiru Ayoola, Rebecca F. Grais, and Stéphane Doyon. 2017. Cost analysis of the treatment of severe acute malnutrition in West Africa. *Maternal and Child Nutrition*, *13*(4), e12398. https://doi.org/10.1111/mcn.12398

Jackson-Morris, Angela, and Christina L Meyer. 2023. "The Case for Investing in the Prevention and Treatment of Overweight and Obesity among Children and Adolescents in Three Middle-Income Countries." *The Lancet Global Health* 11 (March): S18. https://doi.org/10.1016/S2214-109X(23)00101-8.

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.

Kathuria, Nishtha, Prasanta Bandyopadhyay, Shobhit Srivastava, Priyanka Rani Garg, Kshetrimayum Surmala Devi, Kauma Kurian, Suresh Kumar Rathi, and Sunil Mehra. 2023. "Association of Minimum Dietary Diversity with Anaemia among 6–59 Months' Children from Rural India: An Evidence from a Cross-Sectional Study." *Journal of Family Medicine and Primary Care* 12 (2): 313. https://doi.org/10.4103/JFMPC.JFMPC_926_22.

Kennedy, Gina, Anna Herforth, Chris Vogliano, Cecilia Gonzalez, Kristina Sokourenko, Betul Uyar, Rhys Manners, Tesfaye Hailu Bekele, and Ty Beal. 2022. "New Tools and Data for Global Diet Quality Monitoring." In *22nd IUNS-ICN International Congress of Nutrition, Tokyo*.

Kent, Seamus, Francesco Fusco, Alastair Gray, Susan A. Jebb, Benjamin J. Cairns, and Borislava Mihaylova. 2017. Body mass index and healthcare costs: a systematic literature review of individual participant data studies. *Obesity Reviews* 18: 869-879.

Konstantinidi, Melina, and Antonios E. Koutelidakis. 2019. "Functional Foods and Bioactive Compounds: A Review of Its Possible Role on Weight Management and Obesity's Metabolic Consequences." *Medicines* 6 (3): 94. https://doi.org/10.3390/medicines6030094.

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.

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.

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.

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.

Luo, Hanqi, Sarah J. Zyba, and Patrick Webb. 2020. "Measuring Malnutrition in All Its Forms: An Update of the Net State of Nutrition Index to Track the Global Burden of Malnutrition at Country Level." *Global Food Security* 26 (September): 100453. https://doi.org/10.1016/j.gfs.2020.100453.

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.

Mahumud, Rashidul Alam, Berhe W. Sahle, Ebenezer Owusu-Addo, Wen Chen, Rachael Lisa Morton, and Andre M.N. Renzaho. 2021. "Association of Dietary Intake, Physical Activity, and Sedentary Behaviours with Overweight and Obesity among 282,213 Adolescents in 89 Low and Middle Income to High-Income Countries." *International Journal of Obesity 2021 45:11* 45 (11): 2404–18. https://doi.org/10.1038/s41366-021-00908-0.

Marcus, Hannah, Claudia Schauer, and Stanley Zlotkin. 2021. "Effect of Anemia on Work Productivity in Both Labor- and Nonlabor-Intensive Occupations: A Systematic Narrative Synthesis." *Food and Nutrition Bulletin* 42 (2): 289–308. https://doi.org/10.1177/03795721211006658/ASSET/IMAGES/LARGE/10.1177_03795721211006658-FIG2.JPEG.

Martin-Prevel, Yves, Mary Arimond, Pauline Allemand, Doris Wiesmann, Terri J. Ballard, Megan Deitchler, Marie Claude Dop, et al. 2017. "Development of a Dichotomous Indicator for Population-Level Assessment of Dietary Diversity in Women of Reproductive Age." *Current Developments in Nutrition* 1 (12): cdn.117.001701. https://doi.org/10.3945/CDN.117.001701.

Miller, Victoria, Gitanjali M Singh, Jennifer Onopa, Julia Reedy, Peilin Shi, Jianyi Zhang, Adeem Tahira, et al. 2021. "Global Dietary Database 2017: Data Availability and Gaps on 54 Major Foods, Beverages and Nutrients among 5.6 Million Children and Adults from 1220 Surveys Worldwide." *BMJ Global Health* 6 (2): e003585. https://doi.org/10.1136/bmjgh-2020-003585.

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.

Miller, Victoria, Patrick Webb, Renata Micha, and Dariush Mozaffarian. 2020. "Defining Diet Quality: A Synthesis of Dietary Quality Metrics and Their Validity for the Double Burden of Malnutrition." *The Lancet Planetary Health* 4 (8): e352–70. https://doi.org/10.1016/S2542-5196(20)30162-5.

Molani-Gol, Roghayeh, Sorayya Kheirouri, and Mohammad Alizadeh. 2023. "Does the High Dietary Diversity Score Predict Dietary Micronutrients Adequacy in Children under 5 Years Old? A Systematic Review." *Journal of Health, Population, and Nutrition* 42 (1). https://doi.org/10.1186/S41043-022-00337-3.

Molla, Abebaw, Gudina Egata, Firehiwot Mesfin, Mikyas Arega, and Lemma Getacher. 2020. "Prevalence of Anemia and Associated Factors among Infants and Young Children Aged 6–23 Months in Debre Berhan Town, North Shewa, Ethiopia." *Journal of Nutrition and Metabolism* 2020. https://doi.org/10.1155/2020/2956129.

Monteiro, Carlos A, Geoffrey Cannon, Renata B Levy, Jean-Claude Moubarac, Maria LC Louzada, Fernanda Rauber, Neha Khandpur, et al. 2019. "Ultra-Processed Foods: What They Are and How to Identify Them." *Public Health Nutrition* 22 (5): 936–41. https://doi.org/10.1017/S1368980018003762.

Monteiro, Carlos Augusto, Geoffrey Cannon, Mark Lawrence, Maria Laura Costa Louzada, and Pricilla Pereira Machado. 2019. *Ultra-Processed Foods, Diet Quality, and Health Using the NOVA Classification System*. *Fao*. Rome: FAO. https://www.fao.org/3/ca5644en/ca5644en.pdf.

Moradi, Sajjad, Mohammad ali Hojjati Kermani, Reza Bagheri, Hamed Mohammadi, Ahmad Jayedi, Melissa M. Lane, Omid Asbaghi, Sanaz Mehrabani, and Katsuhiko Suzuki. 2021. "Ultra-Processed Food Consumption and Adult Diabetes Risk: A Systematic Review and Dose-Response Meta-Analysis." *Nutrients* 13 (12): 4410. https://doi.org/10.3390/nu13124410.

Murray, Christopher J L, Aleksandr Y Aravkin, Peng Zheng, Cristiana Abbafati, Kaja M Abbas, Mohsen Abbasi-Kangevari, Foad Abd-Allah, et al. 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." *The Lancet* 396 (10258): 1223–49. https://doi.org/10.1016/S0140-6736(20)30752-2.

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 Child. 2023. NCD Global Burden of Disease Dashboard. https://www.ncdchild.org/global-burdens-of-disease-dashboard/

Neufeld, Lynnette M, Sheryl Hendriks, and Marta Hugas. 2023. "Healthy Diet: A Definition for the United Nations Food Systems Summit 2021." *Science and Innovations for Food Systems Transformation*, 21–30. https://doi.org/10.1007/978-3-031-15703-5_3.

Ng, Marie, Tom Fleming, Margaret Robinson, Blake Thomson, Nicholas Graetz, Christopher Margono, Erin C Mullany, et al. 2014. "Global, Regional, and National Prevalence of Overweight and Obesity in Children and Adults during 1980–2013: A Systematic Analysis for the Global Burden of Disease Study 2013." *The Lancet* 384 (9945): 766–81. https://doi.org/10.1016/S0140-6736(14)60460-8.

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.

O'Hearn, Meghan, Laura Lara-Castor, Frederick Cudhea, Victoria Miller, Julia Reedy, Peilin Shi, Jianyi Zhang, et al. 2023. "Incident Type 2 Diabetes Attributable to Suboptimal Diet in 184 Countries." *Nature Medicine* 29 (4): 982–95. https://doi.org/10.1038/s41591-023-02278-8.

Okunogbe, Adeyemi, Rachel Nugent, Garrison Spencer, Jaynaide Powis, Johanna Ralston, and John Wilding. 2022. "Economic Impacts of Overweight and Obesity: Current and Future Estimates for 161 Countries." *BMJ Global Health* 7 (9): e009773. https://doi.org/10.1136/BMJGH-2022-009773.

Olofin, Ibironke, Christine M. McDonald, Majid Ezzati, Seth Flaxman, Robert E. Black, Wafaie W. Fawzi, Laura E. Caulfield, and Goodarz Danaei. 2013. "Associations of Suboptimal Growth with All-Cause and Cause-Specific Mortality in Children under Five Years: A Pooled Analysis of Ten Prospective Studies." *PLoS ONE* 8 (5): e64636. https://doi.org/10.1371/journal.pone.0064636.

Parra, Kimberly L., Halimatou S. Alaofe, John E. Ehiri, Velia Leybas Nuño, Manolo Mazariegos, Brenda Garcia, Estefania Martinez, Anna Junkins, and Pauline Jolly. 2021. "Prevalence and Determinants of Underweight, Overweight, and Obesity: A Cross-Sectional Study of Sociodemographic, Dietary, and Lifestyle Factors Among Adolescent Girls in Jutiapa, Guatemala." *Food and Nutrition Bulletin* 42 (4): 502–19. https://doi.org/10.1177/03795721211019638.

Popkin, Barry M. 2004. "The Nutrition Transition: An Overview of World Patterns of Change." *Nutrition Reviews* 62 (July): S140–43. https://doi.org/10.1111/j.1753-4887.2004.tb00084.x.

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.

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.

Pries, Alissa M., Andrea M. Rehman, Suzanne Filteau, Nisha Sharma, Atul Upadhyay, and Elaine L. Ferguson. 2019. "Unhealthy Snack Food and Beverage Consumption Is Associated with Lower Dietary Adequacy and Length-for-Age z-Scores among 12-23-Month-Olds in Kathmandu Valley, Nepal." *Journal of Nutrition* 149 (10): 1843–51. https://doi.org/10.1093/JN/NXZ140.

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.

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.

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.

Rousham, Emily K, Sophie Goudet, Oonagh Markey, Paula Griffiths, Benjamin Boxer, Christopher Carroll, E. S. Petherick, and R. Pradeilles. 2022. "Unhealthy Food and Beverage Consumption in Children and Risk of Overweight and Obesity: A Systematic Review and Meta-Analysis." *Advances in Nutrition* 13 (5): 1669–96. https://doi.org/10.1093/ADVANCES/NMAC032.

Salehi-Abargouei, Amin, Faezeh Akbari, Nick Bellissimo, and Leila Azadbakht. 2016. "Dietary Diversity Score and Obesity: A Systematic Review and Meta-Analysis of Observational Studies." *European Journal of Clinical Nutrition*. 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." *Human Development Perspectives*, February, 69–94. https://doi.org/10.1596/978-1-4648-1491-4_CH3.

Shapiro, Myra J, Shauna M Downs, Haley J Swartz, Megan Parker, Diana Quelhas, Katharine Kreis, Klaus Kraemer, Keith P West, and Jessica Fanzo. 2019. "A Systematic Review Investigating the Relation Between Animal-Source Food Consumption and Stunting in Children Aged 6–60 Months in Low and Middle-Income Countries." *Advances in Nutrition*, June. https://doi.org/10.1093/advances/nmz018.

Siekmans, Kendra, Patrizia Fracassi, Tomoko Kato, Ti Kian Siow, Diana Carter, and Susan Horton. forthcoming. "Narrative Review on the Hidden Health and Nutrition Costs of Unhealthy Diets in LMIC (Draft)." Rome.

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.

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

UNICEF. 2022. "UNICEF Global Databases: Infant and Young Child Feeding." New York. https://data.unicef.org/topic/nutrition/infant-and-young-child-feeding/

Vadiveloo, Maya, L. Beth Dixon, and Niyati Parekh. 2013. "Associations between Dietary Variety and Measures of Body Adiposity: A Systematic Review of Epidemiological Studies." *The British Journal of Nutrition*. https://doi.org/10.1017/S0007114512006150.

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 EO, Agnes Le Port, Augustin Borderon, Gabriel Bourbon, Mourad Moursi, Mathilde Savy, François Mariotti and Yves Martin-Prevel. 2021. Dietary Diversity Indicators and Their Associations with Dietary Adequacy and Health Outcomes: A Systematic Scoping Review. *Advances in Nutrition*, 12(5): 1659-1672.

Verger EO, Savy M, Martin-Prével Y, Coates J, Frongillo E, Neufeld L et al. Healthy diet metrics: a suitability assessment of indicators for global and national monitoring purposes. Geneva: World Health Organization; 2023.

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.

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. 2019. "Healthy Diet." Cairo. https://apps.who.int/iris/bitstream/handle/10665/325828/EMROPUB_2019_en_23536.pdf.

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

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.

WHO, UNICEF, and FAO. 2021. "Report of the Technical Consultation on Measuring Healthy Diets: Concepts, Methods and Metrics." Geneva.

World Bank. 2020. *Obesity: Health and Economic Consequences of an Impending Global Challenge*. *Obesity: Health and Economic Consequences of an Impending Global Challenge*. https://doi.org/10.1596/978-1-4648-1491-4.

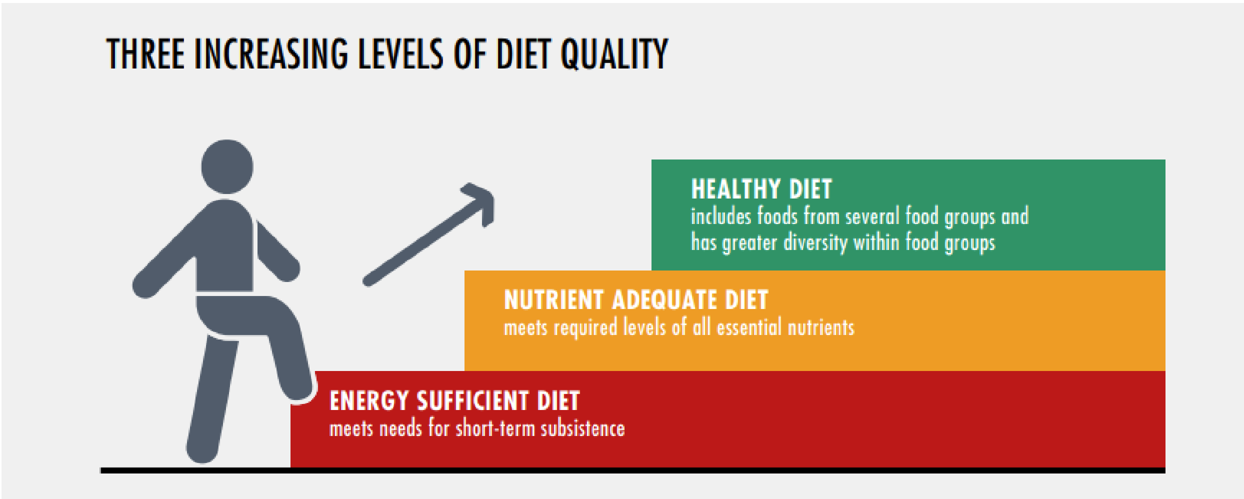
World Cancer Research Fund, and American Institute for Cancer Research. 2018. "Continuous Update Project Expert Report 2018. Recommendations and Public Health and Policy Implications." https://www.wcrf.org/wp-content/uploads/2021/01/Recommendations.pdf.

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.

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.

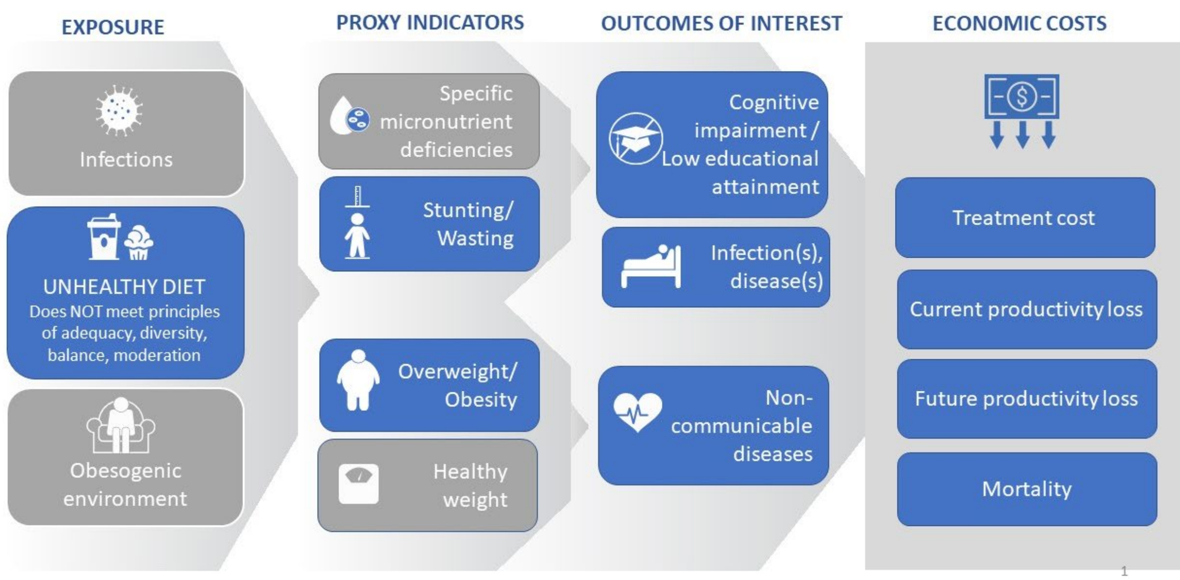
Zhuo, Ming, Ze Chen, Mao-Lin Zhong, Ye-Mao Liu, Fang Lei, Juan-Juan Qin, Tao Sun, et al. 2022. "The Global Disease Burden Attributable to a Diet Low in Fibre in 204 Countries and Territories from 1990 to 2019." *Public Health Nutrition* 26 (4): 1–12. https://doi.org/10.1017/S1368980022001987

Figure 1: Increasing levels of diet quality



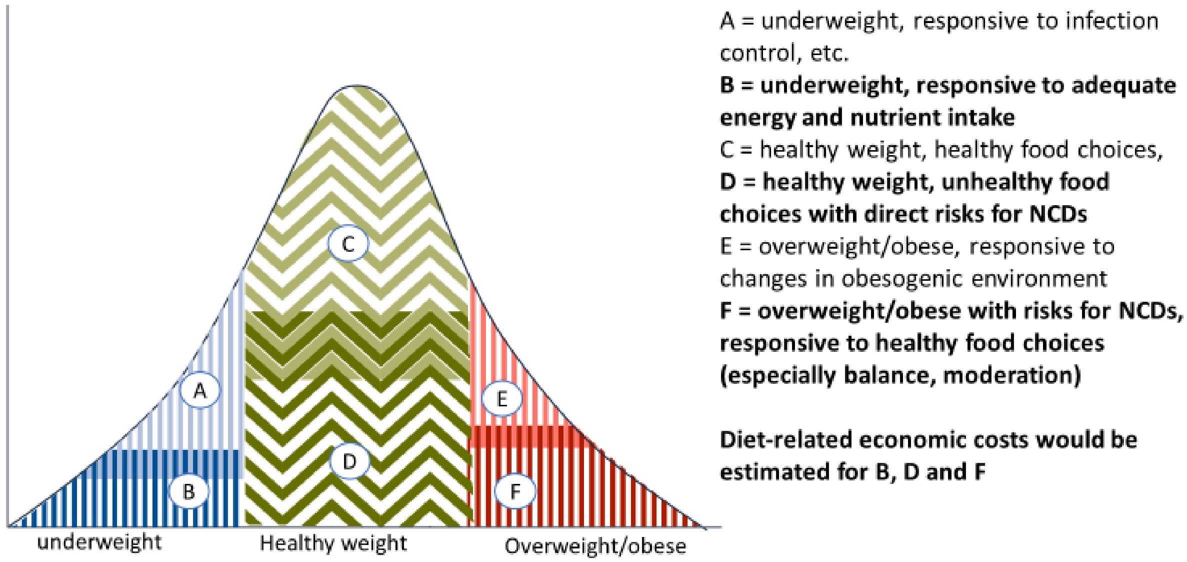
Source: FAO (2020).

Figure 2 Pathways from diet quality to costs



Source: authors

Figure 3. Attribution of diet-related economic costs of child underweight and NCD risks in the adult population



Source: authors

Note: the share of different surface areas, for example A and B as shares of undernutrition, are not known exactly but are estimated as described in the text, and hence the boundary between them is indicated as a fuzzy line. Also **note that the LIST model uses child stunting, hence for calculation purposes stunting will be used rather than underweight**.

Table 1: Selected manifestations and consequences of malnutrition in all its forms over the life course

Consequences	Manifestations	Lifecycle Phase	Manifestations	Consequences
Energy-insufficient, nutrient inadequate diets			**Energy-excess diets**	
• Inadequate foetal growth & development (intra uterine growth retardation) • Increased risk of maternal mortality • Preterm birth	• Underweight • Inadequate GWG • Nutrient deficiencies	Pregnant & lactating women	• Overweight • Obesity	• Gestational diabetes • Epigenetic changes • Increased risk of maternal mortality • Pre-term birth
• Inadequate growth • Inadequate brain development & cognitive impairment • Compromised function of the immune system • Increased risk for neonatal mortality and morbidity	• Small for gestational age • Low birth weight • Preterm birth	Newborns & Infants (U2)	• Large for gestational age	Increased risk for neonatal mortality and morbidity Overweight and obesity in adulthood Type II diabetes in adulthood Cardiovascular disease in adulthood
• Inadequate brain development & cognitive impairment • Compromised function of the immune system	• Nutrient deficiencies • Underweight • Stunting • Wasting	Children (up to 9 years)	• Overweight • Obesity	Development of non-communicable diseases[3]
• Cognitive impairment	• Underweight • Nutrient deficiencies	Adolescents (10-19 years UN)	• Overweight • Obesity	• Development of neurological disorders • Development of non-communicable diseases
• Cognitive impairment • Neurological disorders	• Underweight • Nutrient deficiencies	Adults (>19 to 64 years)	• Overweight • Obesity	• Cardiovascular diseases, cancer, type II diabetes
• Frailty • Cognitive impairment • Neurological disorders	• Nutrient deficiencies • Sudden weight loss	Older adults (65>)	• Overweight • Obesity • Sarcopenic obesity	• Cardiovascular diseases, cancer, type II diabetes • Risk for frailty • Cognitive impairment • Neurological disorders

[3] NCD Child (2023).

Table 2. Available global healthy diet metrics over the lifecycle

Level of diet quality	Children 6-23 months	Adolescents (10-19 years)	Women of reproductive age (15-49 years)	Adults (>15 years)
Energy (in)sufficiency	Per capita calorie supply (compared to age/sex specific requirements)			
Micronutrient (in)adequacy	**MDD** (minimum diet diversity, previous day) **EFF** (egg and/or flesh food consumption, previous day)	NO VALIDATED INDICATOR **MDD-W/Food Group Diversity Score for girls/boys 15-19 years**[4] Prevalence of less than daily… - fruit consumption - vegetable consumption	**MDD-W** (minimum diet diversity – women, previous day)	**Food Group Diversity Score** (previous day)
(Un)Healthy diets	**ZVF** (zero vegetable or fruit consumption, previous day) **SwB** (sweet beverage consumption, previous day) **Unhealthy food consumption** (sentinel unhealthy foods, previous day)	NO VALIDATED METRIC Average number of times per day adolescents reported consuming… - carbonated soft drinks - fruit - vegetables - fast food Prevalence of at least weekly fast food consumption	**Global Dietary Recommendations Score (GDRS)** to be used combined with MDD (for nutrient adequacy) per Herforth et al. 2020 - NCD-Protect score - NCD-Risk score **Global Diet Quality Score (GDQS)** - GDQS+ - GDQS- **Sentinel food group consumption** - whole grains, unprocessed red meat, processed meat, sweet foods **-Sugar-sweetened drink consumption** **-Zero vegetable or fruit consumption**	

Key: light blue shading indicates measures particularly relevant for energy-(in)sufficiency; no shading indicates measures particularly relevant for micronutrient (in)adequacy; and orange shading indicates measures particularly relevant for (un)healthy diets

Note: there are key gaps in measures for children 24-59 months and children in primary school grades (ages 5-9), as well as for older adults (age 50+ years) in LMIC. For children under the age of 6 months, the recommendation is that they should be exclusively breastfed. Data are available on prevalence of exclusive breastfeeding, some breastfeeding and no breastfeeding, but are not listed in the table.

---

[4] These metrics have not been validated specifically for this age group but they are captured as part of the survey sample. Sample sizes may not be sufficient for disaggregation of results for this age range (WHO and UNICEF 2021).

Table 3: Summary of potential global healthy diet metrics for adults and their strengths and limitations for country study purposes

Metric	Description	Strengths	Limitations
Minimum Diet Diversity – Women	• Gender-sensitive dichotomous indicator of whether women 15-49 years have consumed at least 5 out of 10 defined food groups the previous day or night. • Food group indicator	• Valid indicator of better micronutrient adequacy • Available from Gallup World Poll surveys for 55 LMIC plus Palestine & DHS for 3 countries (as of 20-Jun-2023)	• Does not include food groups associated with greater NCD risk • Not validated for men
Food Group Diversity Score	• Measure of the number of food groups consumed the previous day or night, of the ten food groups used to construct the MDD-W indicator • Food group indicator	• Valid measure of greater nutrient intakes for men and women • Available from Gallup World Poll surveys for 55 LMIC plus Palestine (as of 20-Jun-2023)	• Does not include food groups associated with greater NCD risk
Global Diet Recommendation (GDR) Score) (Two sub-scores)	• Measure based on food consumption from nine health-protective food groups and eight food groups to avoid/limit the previous day or night • Validated against quantitative intakes aligned with each of 11 WHO recommendations on healthy diets • DQ-Q asks yes/no questions about consumption of a sentinel set of individual foods[5]; no data on quantity of consumption	• Indicator (GDR Score >=10) is a valid indicator of adhering to >=6 of current 11 global dietary recommendations (and by proxy, NCD risk) for men and women • Food group questions adapted for each country • Available from Gallup World Poll surveys for 55 LMIC plus Palestine (as of 20-Jun-2023)	• Does not indicate nutrient adequacy (unless paired with Food Group Diversity Score or MDD-W) • Not validated against health outcomes • Using both sub-scores is more informative than using combined score
Global Diet Quality Score (GDQS) (Two sub-scores)	• Food-based metric consisting of 25 food groups classified as healthy, unhealthy, or unhealthy when consumed in excessive amounts • Uses open recall of foods and beverages consumed, requires some data on quantity of consumption	• Valid quantitative measure of nutrient adequacy and NCD risk for men and women 15+ years • Validated against health outcomes	• Limited availability of nationally representative datasets (~7 LMIC, as of 23-Jun-2023) • Using both sub-scores is more informative than using combined score
Global Dietary Database (GDD) – 54 dietary risk factors	• Derived from modeling approach using nationally or subnationally representative surveys • Model generates means for 54 dietary factors for 185 countries	• Dietary intakes estimated for most food groups, stratified by demographic characteristics (education, urban/rural residence) • Validated with health outcomes	• For countries without 24-hour dietary recall data, GDD estimates are modeled based on existing data sources • Modeled data may be unclear to non-experts

[5] DQ-Q also allows for monitoring intake of ultra-processed foods and is tracked in a way that has some relevance for sustainable diets.

Metric	Description	Strengths	Limitations
	• Includes 14 foods, 7 beverages and 33 nutrients	• GDD data can be used to estimate disease burdens attributable to poor diet quality	
Global Burden of Disease – 13 dietary risk factors	• Derived from modelling approach using multiple sources of dietary data (24-hr recall, supply utilization, FFQ, sales data, Household Budget Surveys) • Dietary risk factors are those with convincing or probable evidence of health effect	• Validated with health outcomes • GBD data can be used to estimate disease burdens attributable to poor diet quality	• For countries without 24-hour dietary recall data, GBD estimates are modeled based on existing data sources (data on food availability or food sales) • Modeled data may be unclear to non-experts

Adapted from WHO and UNICEF (2021)

Table 4. Summary of types of costs included in previous costing studies

Cost item, age-group to which item applies and summary of calculation method	Example
Undernutrition	
Direct costs: treatment costs of acute malnutrition: calculat*e from unit costs per child from existing studies, multiplied by numbers of under-five children treated.*	Isanaka et al., 2017
Indirect costs: Present value of future productivity losses due to premature mortality: *calculate projected annual deaths in 0-59 months group from prevalence of stunting multiplied by corresponding mortality risk. Project lifetime losses of productivity over the working life age 15-64, proxied by current wage of those 15-64, adjusted by real growth of per capita GDP and discounted by 3%*	ECLAC and WFP, 2017; see Bertram et al. 2017 for discussion of discounting
Indirect cost: Present value of future productivity losses due to cognitive losses which lead to reduced educational attainment: *calculate from prevalence of stunting in children 0-59 months, multiplied by corresponding projected loss of wages associated with the associated underachievement of education, adjusted by real growth of per capita GDP and discounted by 3%**	ECLAC and WFP, 2017.
Overweight and obesity	
Direct costs: treatment costs for obesity-related illnesses: *both medical treatment costs and patient out-of-pocket costs e.g. travel and time for treatment*;	Okunogbe et al.,2022
Indirect costs: costs of premature mortality*: lost years of life expectancy for those currently 20 and older in the population*	ECLAC and WFP, 2017
Indirect costs: costs of productivity losses due to morbidity: *for those 20-64 due to absenteeism (either of individual who is sick, or caregiver)***	ECLAC and WFP, 2017

*ECLAC and WFP (2017) also include additional costs of grade repetition to the education system: these costs are relatively small compared to future wage losses and may not be worth the effort to calculate

**Note that some, e.g. Okunogbe et al. (2022) included losses due to presenteeism, i.e. lower work effort associated with overweight/obesity; others include lower employment rates or decreased full-time work by those with overweight/obesity; however it is less clear what the direction of causality is, hence whether or not this should be included.

Table 5 Definition and source of variables for exploratory regression analyses.

Variable name	Definition	Source
Per capita calorie supply (kcal/capita/day)	Estimates of per capita food supplies available for human consumption during the reference period in terms of quantity, caloric value, protein and fat content (2020). Calorie supplies are reported in kilocalories (1 calorie = 4.19 kJ. Availability does not imply actual consumption due to intervening factors such as food waste, and likely exceeds values from dietary intake surveys	FAOSTAT
MDD-W	% of women who consumed at least five out of ten predefined food groups, 2021	Gallup World Poll (2021) / Food systems dashboard;
MDD (6-23 months)	Percentage of children 6–23 months of age who consumed foods and beverages from **at least five out of eight** defined food groups during the previous day. Various years, 2014-2019 (1 observation from 2011, 1 from 2008 and 1 from 2006)	UNICEF
NCD-Protect score among adults ≥ 15	NCD-Protect scores are on a scale of 0 to 9; higher scores indicate greater protection against noncommunicable diseases. Data are for individuals ≥15 years of age from the 2021 Gallup World Poll for 2022	World Gallup Poll (GDQP) / Food systems dashboard
NCD-Risk score among adults ≥ 15	NCD-Risk scores are on a scale of 0 to 9; higher scores indicate greater risk for noncommunicable diseases. Data are for individuals ≥15 years of age from the 2021 Gallup World Poll for 2022	World Gallup Poll (GDQP) / Food systems dashboard
Prevalence of **overweight & obesity** among women (20 - 49 years) %	Percentage of women 20–49 years of age with a BMI greater than or equal to 25 kg/m2 in 2016	UNICEF Global Database (based on NCD-RisC)
Prevalence of **underweight** among women (20 - 49 years) %	Percentage of women 20–49 years of age with a BMI less than 18.5 kg/m2 in 2016	UNICEF Global Database (based on NCD-RisC)
Adult **diabetes** prevalence	Proportion of adults aged 18+ years with diabetes. Diabetes is defined as having a fasting glucose of 7.0 mmol/L or higher, being on medication for raised blood glucose, or having a past diagnosis of diabetes. Data for 2014, except 1 country 2003, 1 country 2005, 2 countries 2010, 1 country 2012.	NCD-RisC / Food systems dashboard
Adult **raised blood pressure** prevalence	Percent of adult population (18+ years) with systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg in 2015	NCD-RisC / Food systems dashboard
Gini coefficient	Index of inequality, 0=perfect equality, 100=perfect inequality, latest year available (ranges by country from 2010 to 2021)	World Bank
Region = AFRO (omitted dummy)	Benin, Burkina Faso, Cameroon, Chad, Gabon, Ghana, Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Senegal, Sierra Leone, Tunisia, Uganda, United Republic of Tanzania, Zimbabwe	World Health Organization
Region = AMRO	Bolivia, Chile, Colombia, Ecuador, Honduras, Mexico, Nicaragua, USA,	

Region = EMRO	Afghanistan, Bahrain, Egypt, Jordan, Lebanon, Morocco, Pakistan, Yemen	
Region = EURO	Albania, Armenia, Azerbaijan, Greece, Israel, Kazakhstan, Kyrgyzstan, Russian Federation, Tajikistan, Türkiye, Uzbekistan,	
Region = SEARO	Bangladesh, India, Nepal, Sri Lanka,	
Region = WPRO	Cambodia, China, Indonesia, Lao (People's Democratic Republic of), Philippines, Vietnam	

Table 6. Summary of cross-country regression results, children 6-23 months

Independent variables	Dependent variable		
	Child stunting	**Child wasting**	**Child overweight**
MDD	-0.137 (0.096)	0.053 (0.041)	0.053 (0.041)
Gini index	0.184 (0.253)	0.154 (0.108)	0.154 (0.108)
Daily calorie supply (Kcal/capita/day)	-0.013*** (0.004)	0.003 (0.002)	0.003 (0.002)
Region Americas (AMRO)	-3.853 (6.744)	-0.413 (2.882)	-0.413 (2.882)
Region Eastern Mediterranean (EMRO)	8.593 (6.240)	8.245*** (2.667)	8.245*** (2.667)
Region Europe (EURO)	-6.553 (6.648)	-0.548 (2.841)	-0.548 (2.841)
Region Western Pacific (WPRO)	7.663 (4.545)	2.254 (1.942)	2.254 (1.942)
Region Southeast Asia (SEARO)	9.795** (4.523)	-2.137 (1.933)	-2.137 (1.933)
Constant	51.958*** (17.973)	-10.049 (7.681)	-10.049 (7.681)
Observations	40	40	40
R2	0.511	0.360	0.469
Adjusted R2	0.385	0.195	0.332
Residual Std. Error	8.635 (df = 31)	3.726 (df = 31)	3.690 (df = 31)
F Statistic	4.047*** (df = 8; 31)	2.179* (df = 8; 31)	3.424*** (df = 8; 31)
AIC Score	295.7882	227.777	227.777

Note: *p<0.1; **p<0.05; ***p<0.01; Omitted region dummy is Africa

Table 7. Summary of cross-country regression results, non-pregnant women 20-49 years

	Dependent variable	
Independent variable	Women's low BMI#	Women's overweight/obesity
Calories (Kcal/capita/day)	-0.000447 (0.000164) **	-0.0117138 (0.0298)
Calories squared	-	3.87e-6 (5.09e-6)
MDD-W	-0.00822 (0.00542)	-
GINI Index	-0.0222 (0.0109)**	-
NCDProtect	-	1.332622 (2.550)
NCDRisk	-	4.662309 (2.258)**
Region Americas	-0.948 (0.232)***	13.22596 (4.657)***
Region Eastern Mediterranean	-0.743 (0.223)***	15.75202 (3.799)***
Region European	-0.667 (0.259)**	1.158839 (4.771)
Region Western Pacific	0.587 (0.281)**	-18.46418 (4.849)***
Region Southeast Asia	0.664 (0.235)***	-13.44361 (4.467)***
Constant	4.679 (0.639)***	24.38325 (43.935)
Observations	53	55
R2	0.841	0.7670
Adjusted R2	0.7448	0.7204
F Statistic	19.97*** (df=8,44)	16.46*** (df=8,46)
AIC Score	63.77	395.7938

Note: # indicates that ln(underweight) was used, based on better fit; *p<0.1 **p<0.05; ***p<0.01; omitted region is Africa. .

Table 8: Summary of cross-country regression results, adults

	Dependent variable	
Independent variable	**Hypertension**	**Diabetes#**
Calories (Kcal/capita/day	0.0167183 (0.0107)	-0.0031879 (0.00948)
Calories squared	-3.41e-6 (1.83e-6)*	8.74e-7 (1.70e-6)
Overweight	Omitted (model fit worse)	Omitted (model fit worse)
NCDProtect	-0.632 (0.884)	-0.3880131 (0.687)
NCDRisk	Omitted (model fit worse)	Omitted (model fit worse)
Region Americas	-7.66973 (1.558)***	2.28057 (1.213)*
Region Eastern Mediterranean	-1.99171 (1.398)	7.087293 (1.024)***
Region European	-1.264047 (1.483)	1.840187 (1.204)
Region Western Pacific	-4.08404 (1.72)**	0.2327971 (1.271)
Region South East Asian	-2.668754 (1.646)	2.412013 (1.845)**
Constant	10.14608 (15.828)	10.21116 (13.82)
Observations	55	41
R2	0.6048	0.6753
Adjusted R2	0.5361	0.5941
F Statistic	8.80*** (df=7,47)	8.32*** (df=7,33)
AIC Score	285.2234	176.2193

#Used square root of diabetes to normalize distribution

Note: *p<0.1; **p<0.05; ***p<0.01; omitted region is Africa

Appendix. Data sources – technical annex

Measures of diet characteristics, by age group

This appendix provides additional detail and sources for the measures required to model the economic impact of unhealthy diets. Tables 1, 2 and 3 provide further detail to Table 2 of the main text, organized according to the same age groups (6-23 months; adolescents; women of reproductive age; adults). For each age group, there are dietary recommendations as to foods to include, and foods to avoid. Tables 4 and 5 provide details on data sources, and Table 6 summarizes the current WHO dietary guidelines.

1. **Exclusive breastfeeding under six months (EBF) infants < 6 months**

The WHO Global Strategy for Infant and Young Child Feeding recommends that infants be exclusively breastfed until they turn six months of age. Exclusive breastfeeding is the safest and healthiest option for children everywhere, guaranteeing infants a food source that is uniquely adapted to their needs while also being safe, clean, healthy and accessible.

2. **Infants and young children 6-23 months**

To measure diets of young children, a set of 17 indicators for assessing infant and young child feeding practices were updated and published in 2021 by WHO and UNICEF.[6] The recommended indicators are population-level indicators designed for data collection in large-scale surveys to support program assessment, planning and monitoring. UNICEF currently maintains a global database for these indicators, with the most recent update in October 2022.[7]

3. **Children 3-5 years, school-age children and adolescents**

There are no global guidelines on older children and adolescent diets. WHO (2018)[8] does have a guideline on promoting physical activity in this age group.

4. **Women of reproductive age (15-49 years)**

For women of reproductive age, various dietary measures have been developed to assess the level of nutrient adequacy (or risk of micronutrient inadequacy) as well as consumption of foods that are associated with lower or higher risk of overweight, obesity and related NCDs.

Minimum dietary diversity for women is an indicator designed and validated as a proxy for one dimension of diet quality (micronutrient adequacy) for non-pregnant women 15-49 years of age. MDD-W is calculated based on reported intake of 10 food groups and is defined as consumption of at least five out of these 10 food groups.

There is currently no harmonized database for MDD-W globally, due in part to varying methods of data collection (open and sentinel list-based recalls, national and subnational surveys). The **Food Systems Dashboard** currently hosts MDD-W meta-data for 55 countries plus Palestine (54 LMIC), based on Gallup World Poll data that are not open-access and were collected using a telephone-based interview. In the future, additional MDD-W data are expected to be available from at least 21 nationally representative DHS surveys.

---

[6] Indicators for assessing infant and young child feeding practices: definitions and measurement methods (World Health Organization and UNICEF 2021).

[7] UNICEF (2022). https://data.unicef.org/topic/nutrition/infant-and-young-child-feeding/

[8] WHO (2018). Guideline: implementing effective actions for improving adolescent nutrition. Geneva: World Health Organization. https://apps.who.int/iris/handle/10665/260297

Appendix Table 1: Dietary metrics for infants and young children – definitions and data source characteristics

Dietary intake variables	Indicator definition	Data source	Data availability	Notes
Infants < 6 months				
Exclusive breastfeeding under six months (EBF)	percentage of infants 0–5 months of age who were fed exclusively with breast milk during the previous day	UNICEF Global Database	N=136 countries; most recent survey year	EBF is defined as breastfeeding with no other food or drink, not even water.
Infants and young children 6-23 months				
Minimum Diet Diversity 6-23 months (MDD)	percentage of children 6–23 months of age who consumed foods and beverages from at least five out of eight defined food groups during the previous day	UNICEF Global Database	N=107 countries; most recent survey year	The eight food groups are: 1. breast milk; 2. grains, roots, tubers and plantains; 3. pulses (beans, peas, lentils), nuts and seeds; 4. dairy products (milk, infant formula, yogurt, cheese); 5. flesh foods (meat, fish, poultry, organ meats); 6. eggs; 7. vitamin-A rich fruits and vegetables; and 8. other fruits and vegetables. There is no minimum quantity of food or beverage from a food group required to count.
Egg and/or flesh food consumption 6-23 months (EFF)	Percentage of children 6–23 months of age who consumed egg and/or flesh food during the previous day	UNICEF Global Database	N=106 countries, most recent survey year	Based on consumption of food groups 5 (flesh foods: meat, fish, poultry, organ meats) and 6 (eggs). Children are counted if either food group has been consumed.
Zero vegetable or fruit consumption 6-23 months (ZVF)	Percentage of children 6–23 months of age who did not consume any vegetables or fruits during the previous day	UNICEF Global Database	N=106 countries, most recent survey year	Based on consumption of food groups 7 (vitamin A-rich fruits and vegetables) and 8 (other fruits and vegetables). Plantains, starchy roots and tubers in food group 2 (such as white potatoes, yams and cassava) do not count.
Sweet beverage consumption 6-23 months (SwB)	Percentage of children 6–23 months of age who consumed a sweet beverage during the previous day	https://data.unicef.org/wp-content/uploads/2021/09/UNICEF_Expanded_Global_Databases_Unhealthy_practices_2022.xlsx	Recently added to DHS and MICS surveys; very few country data as yet	Sweet beverages include commercially produced and packaged, sweetened beverages such as soda pop, fruit-flavoured drinks, sports drinks, chocolate and other flavoured milk drinks, malt drinks, etc; 100% fruit juice as well as fruit-flavoured drinks; home-made drinks of any kind to which sweeteners have been added.
Unhealthy food consumption 6-23 months (UFC)	Percentage of children 6–23 months of age who consumed selected sentinel unhealthy foods during the previous day	https://data.unicef.org/wp-content/uploads/2021/09/UNIC	Recently added to DHS and MICS: only	"sentinel unhealthy foods" are foods that are likely to be consumed by IYC and are high in sugar, salt and/or unhealthy fats. These include four categories of unhealthy foods: 1) candies, chocolates and other sugar confections;

Dietary intake variables	Indicator definition	Data source	Data availability	Notes
		EF_Expanded_Global_Databases_Unhealthy_practices_2022.xlsx	few country data as yet	2) frozen treats like ice cream, popsicles, etc.; 3) cakes, pastries, sweet biscuits, etc.; 4) chips, crisps, cheese puffs, French fries, instant noodles, etc.

Appendix Table 2: Dietary metrics for school-age and adolescent children – definitions and data source characteristics

Dietary intake variables	Definition	Data source	Year	Data availability	Notes
Frequency of carbonated soft drink consumption	Average number of times per day adolescents (12-17 years) reported consuming carbonated soft drinks	Data collected from Global School-based Student Health Surveys https://www.foodsystemsdashboard.org/	year of survey varies by country (range 2009 to 2015)	N=63 countries with data	Assesses behavioural risk factors and protective factors in 10 key areas using a self-administered questionnaire administered in schools ‘*during the past 30 days, how many times per day do you usually drink/eat…*’ Meta-analysis by Beal et al. 2019
Frequency of fruit consumption	Average number of times per day adolescents (12-17 years) reported consuming fruit				
Frequency of vegetable consumption	Average number of times per day adolescents (12-17 years) reported consuming vegetables				
Frequency of fast food consumption	Average number of times per week adolescents (12-17 years) reported consuming fast food				
At least daily carbonated soft drink consumption	Proportion of adolescents (12-17 years) who reported consuming carbonated soft drinks at least 1 time per day over the last 30 days				
At least weekly fast food consumption	Proportion of adolescents (12-17 years) who reported consuming fast food at least 1 time per week				
Less than daily fruit consumption	Proportion of adolescents (12-17 years) who reported consuming fruit less than 1 time per day over the last 30 days				
Less than daily vegetable consumption	Proportion of adolescents (12-17 years) who reported consuming vegetables less than 1 time per day over the last 30 days				

Appendix Table 3: Dietary metrics for adults – definitions and data source characteristics

Dietary intake variables	Indicator definition	Data source	Year	Data availability[1]	Notes
Women of reproductive age					
Minimum Diet Diversity for women (MDD-W)	Percentage of women (15-49 y) who consumed at least 5 of 10 defined food groups the previous day or night.	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	The food groups include: 1. Grains, white roots and tubers and plantains; 2. Pulses (beans, peas and lentils); 3. Nuts and seeds; 4. Milk and milk products; 5. Meat, poultry and fish; 6. Eggs; 7. Dark green leafy vegetables; 8. Other vitamin A-rich fruits and vegetables; 9. Other vegetables; 10. Other fruits.
Adults (age ≥ 15 years):					
Food group diversity score	The number of food groups consumed the previous day or night, of the ten food groups used in the MDD-W indicator	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	The score ranges from 0 to 10 expressed as an average score for the population with a higher score indicating inclusion of more food groups in the diet.
Global Dietary Recommendations (GDR) score	Score based on food consumption from nine health-protective food groups (NCD-Protect) and eight food groups to limit or avoid (NCD-Risk) during the previous day or night, which are associated with meeting WHO global dietary recommendations.	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55countri es	The score ranges from 0 to 18 expressed as an average score.
NCD-Protect score	Score based on consumption during the previous day or night of nine food groups that are associated with meeting WHO recommendations on fruits, vegetables, whole grains, pulses, nuts and seeds, and fiber.	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	An indicator of dietary factors protective against NCDs The score ranges from zero to nine expressed as an average score.
NCD-Risk score	Score based on consumption during the previous day or night of eight food groups that are negatively associated with meeting WHO recommendations on free	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	An indicator of dietary risk factors for NCDs

Dietary intake variables	Indicator definition	Data source	Year	Data availability[1]	Notes
	sugar, salt, total and saturated fat, and red and processed meat.				The score ranges from zero to nine expressed as an average score.
All-5	% of adults ≥ 15 years who consumed all five food groups typically recommended for daily consumption in food-based dietary guidelines around the world	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	Proportion of the population who consumed all five food groups [*as well as each one individually*] at least one **vegetable**, at least one **fruit**, at least one **pulse, nut or seed**, at least one **animal-source food**, and at least one **starchy staple** in the previous day or night.
Zero vegetable or fruit consumption	Proportion of the population who consumed no vegetables or fruits during the previous day or night.	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	
Soft drink consumption	Proportion of the population who consumed a sugar-sweetened soft drink during the previous day or night. Sugar-sweetened soft drinks include soda, energy drinks, and sports drinks.	World Gallup Poll (Global Diet Quality Project)	2021-2022	N=55 countries	

[1] Data are also available for Palestine

Appendix Table 4. Nutrition/health metrics for children and adolescents

Outcome measure	Data source	Data availability	Notes
Children under 5			
Neonatal mortality rate and number of neonatal deaths	UNICEF Global Database		https://data.unicef.org/topic/child-survival/neonatal-mortality/
U5 mortality rate and number of deaths of children U5	UNICEF Global Database		https://data.unicef.org/topic/child-survival/under-five-mortality/
Child stunting (survey estimates, updated Dec 2022)	UNICEF Global Database	N=202 countries (date depends on survey year)	https://data.unicef.org/wp-content/uploads/2022/05/UNICEF_WHO_WB_Global_Expanded_Databases_Stunting_Dec_2022.xlsx
Child wasting (survey estimates, updated Dec 2022)	UNICEF Global Database	N=202 countries (date depends on survey year)	https://data.unicef.org/wp-content/uploads/2022/05/UNICEF_WHO_WB_Global_Expanded_Databases_Wasting_Dec_2022.xlsx
Child overweight (survey estimates, updated Dec 2022)	UNICEF Global Database	N=202 countries (date depends on survey year)	https://data.unicef.org/wp-content/uploads/2022/05/UNICEF_WHO_WB_Global_Expanded_Databases_Overweight_Dec_2022.xlsx
Child anaemia: Percentage of children aged 6−59 months with a Hb concentration less than 110 g/L, adjusted for altitude.	WHO Global Health Observatory	n=124 countries, 2019	https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-anaemia-in-children-under-5-years-(-)
Children and adolescents 5-19			
Overweight	https://www.foodsystemsdashboard.org/	2016	Proportion of 5-19 year olds with BMI-for-age > 1 SD above median of WHO growth reference for this age group; Based on NCD-RisC estimates
Obesity	As above		As above, but with BMI-for-age > 2 SD above growth reference
Underweight	As above		As above, but with BMI-for-age <1 SD below growth reference

Appendix Table 5. Nutrition/health metrics for women of reproductive age

Nutrition/health outcome variables	Data source	Data availability	Notes
Anaemia pregnant women (15-49 years) and non-pregnant women (15-49 years)	UNICEF Global Database (based on WHO GHO)	All countries, Latest year: 2019	
Underweight in WRA (20-49 years)	UNICEF Global Database (based on NCD-RisC)	All countries, Latest year: 2016	Percentage of women 20-49 years of age with a BMI <18.5 kg/m² Data also available for men from NCD-RisC.
Overweight and obesity in WRA	UNICEF Global Database (based on NCD-RisC)	All countries, Latest year: 2016	Percentage of women 20–49 years of age with a BMI ≥ 25 kg/m² Data also available for men from NCD-RisC.
Low-birth weight prevalence and prevalence of newborns without birthweight data	UNICEF Global Database	N=148 (54 no LBW estimate) Latest year: **2015** (will be updated later this year)	
Stillbirth rate and number of stillbirths	UNICEF Global Database	Latest year: 2021	
Preterm birth	Modeled estimates by Chawanpaiboon et al. 2019[5]	Latest year: 2014	

Appendix Table 6. World Health Organization guidelines for a healthy diet; World Cancer Research Fund recommendation regarding meat

For adults A healthy diet includes the following: • Fruit, vegetables, legumes (e.g. lentils and beans), nuts and whole grains (e.g. unprocessed maize, millet, oats, wheat and brown rice). • At least 400 g (i.e. five portions) of fruit and vegetables per day *(2)*, excluding potatoes, sweet potatoes, cassava and other starchy roots. • Less than 10% of total energy intake from free sugars *(2, 7)*, which is equivalent to 50 g (or about 12 level teaspoons) for a person of healthy body weight consuming about 2000 calories per day, but ideally is less than 5% of total energy intake for additional health benefits *(7)*. Free sugars are all sugars added to foods or drinks by the manufacturer, cook or consumer, as well as sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates. • Less than 30% of total energy intake from fats *(1, 2, 3)*. Unsaturated fats (found in fish, avocado and nuts, and in sunflower, soybean, canola and olive oils) are preferable to saturated fats (found in fatty meat, butter, palm and coconut oil, cream, cheese, ghee and lard) and *trans*-fats of all kinds, including both industrially-produced *trans*-fats (found in baked and fried foods, and pre-packaged snacks and foods, such as frozen pizza, pies, cookies, biscuits, wafers, and cooking oils and spreads) and ruminant *trans*-fats (found in meat and dairy foods from ruminant animals, such as cows, sheep, goats and camels). It is suggested that the intake of saturated fats be reduced to less than 10% of total energy intake and *trans*-fats to less than 1% of total energy intake *(5)*. In particular, industrially-produced *trans*-fats are not part of a healthy diet and should be avoided *(4, 6)*. • Less than 5 g of salt (equivalent to about one teaspoon) per day *(8)*. Salt should be iodized. **For infants and young children** In the first 2 years of a child's life, optimal nutrition fosters healthy growth and improves cognitive development. It also reduces the risk of becoming overweight or obese and developing NCDs later in life. Advice on a healthy diet for infants and children is similar to that for adults, but the following elements are also important: • Infants should be breastfed exclusively during the first 6 months of life. • Infants should be breastfed continuously until 2 years of age and beyond. • From 6 months of age, breast milk should be complemented with a variety of adequate, safe and nutrient-dense foods. Salt and sugars should not be added to complementary foods.
If you eat red meat, limit consumption to no more than about three portions per week. Three portions is equivalent to about 300 to 500 grams cooked weight of red meat. Consume very little, if any, processed meat.

Source: WHO (2020); World Cancer Research Fund and American Institute for Cancer Research