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Accounting for nutrition-related health impacts in food life cycle assessment: Insights from an expert workshop

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Abstract

Sub-optimal dietary patterns make major contributions to the global burden of disease and are among the most pressing issues affecting human health. Consequently, they are key to consider when assessing the human health and other environmental impacts of foods and diets within life cycle assessments. The UN Environment Life Cycle Initiative convened a task force on nutrition-related human health impacts as part of the Global Life Cycle Impact Assessment Method (GLAM) project. The health impacts of dietary patterns can be expressed in disability-adjusted life years (DALYs), in line with reporting human health impacts of other impact categories within the life cycle impact assessment (LCIA) framework. The task force held a workshop with nutrition experts to receive guidance in its process to develop a consensus-based impact assessment framework for addressing nutrition-related health impacts in LCIA. The workshop aimed to 1) evaluate the general assessment framework, 2) discuss scientific questions for quantifying human health impacts from nutrition for food items and diets, and 3) provide initial guidance for further development. The proposed framework based on the Global Burden of Disease (GBD) risk ratios was regarded as a good

starting point to assess the relative health risks of the general population, provided that the dietary context is considered and several limitations, such as incomplete disease coverage, are acknowledged. The experts advised against a potentially misleading use of adult-derived dietary risk factors for children. To improve global coverage of the GLAM framework, it is important to consider a wider range of dietary patterns. The experts also recommended using a metric complementary to DALYs, such as nutrient adequacy, also considering, e.g., vitamin A and iron, to complement the assessment.

Introduction

Life cycle assessment (LCA) is a method to quantify the potential environmental impacts of goods and services, including food items and diets, throughout their life cycle and is used as a decision-support tool (Cucurachi et al. 2019). The life cycle impact assessment (LCIA) phase thereof translates inventory data, such as emissions and resource use, to environmental impacts. LCA aims to be comprehensive and considers a variety of impact categories to minimize burden-shifting among them (Curran 2014). Such impact categories can be linked to damages to three commonly used areas of protection: ecosystem quality, natural resources, and human health. Impact categories that lead to human health damages and are considered within widely used LCIA methods include climate change, ozone depletion, ionizing radiation, photochemical ozone formation, particulate matter formation, human toxicity, and water stress (Bulle et al. 2019; Verones et al. 2020).

Nutrition-related health impacts are still missing in such methods. ISO 14044 (International Organization for Standardization 2006) explains that “LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product’s life cycle”. It refers to ISO 14001 (International Organization for Standardization 2015) for a definition of environmental aspects, in which the environment also includes humans. The intakes of nutrients and food groups could be considered as releases from the food into the human body during the use stage. So, it fits into the framework of LCA, although it goes beyond a traditional LCA. The framework of LCA has later been broadened to life cycle sustainability assessment, considering also social and economic impacts. Among the social impacts, studies currently focus on the health and safety of workers, but consumers are also captured as stakeholders within the framework (Kühnen and Hahn 2017). So, there is a potential overlap with social LCA as well. Independent of the definition, it is important to consider nutrition as a key impact on the area of protection of human health. Disregarding it could lead to potential burden-shifting, for example, if a dietary transition towards lower greenhouse gas emissions promotes a higher intake of sugar or sugar-sweetened beverages due to their relatively low emission intensity (Briggs et al. 2016).

Well-balanced nutrition is crucial for human health. Both low consumption of beneficial foods and high consumption of detrimental foods can adversely affect human health. Dietary factors are among the top 5 out of 20 level 2 risk factors that contribute to the global human disease burden (Murray et al. 2020). In 2017, dietary risks were responsible for about 11 million deaths and 255 million disability-adjusted life years (DALYs) globally, corresponding to 22% and 15% of all deaths and DALYs among adults (Afshin et al. 2019). For example, a recent analysis shows that a shift towards healthier diets in the United Kingdom could increase life expectancy by up to 10 years (Fadnes et al. 2023). While the consumption of healthy foods improved globally between 1990 and 2018, the consumption of unhealthy foods worsened, leading to only a slight increase in a generally modest dietary quality (Miller et al. 2022). This highlights the importance of considering nutrition-related positive and negative human health effects in LCA (Stylianou et al. 2016).

It is debated whether nutrition should be considered within the functional unit of an LCA, within the impact assessment (Weidema and Stylianou 2020), or in both. While nutrition can be the main function of food and, therefore, a logical choice as a functional unit, this is often not the case, since food is generally multifunctional. Other functions are, for example, the delivery of satiety (Weidema and Stylianou 2020) or simply enjoyment (McLaren et al. 2022). In addition, selecting one nutrient (e.g., protein) or a score that includes several nutrients as the only function would not usually cover all of the health impacts of foods. This is also why epidemiological studies often focus on food groups and why there is a trend in dietary guidelines from nutrients towards food groups (Drewnowski et al. 2019). Including the nutrients to limit within a functional unit can potentially result in a negative functional unit, which would create a conceptual challenge for LCA, as pointed out by Heller et al. (2013).

Considering nutrition within impact assessment avoids the above issues concerning functional units and provides additional information through the health impacts of nutrition. After a consensus-building process initiated by the Food and Agriculture Organization of the United Nations (FAO), McLaren et al. (2022) suggest that the choice of considering nutrition within the functional unit or impact assessment depends on the use case. For example, a nutritional indicator in the functional unit may be meaningful for functional foods (Weidema and Stylianou 2020), i.e. novel foods that have been designed to be possibly health-enhancing or disease-preventing (Temple 2022), or food served in nursing homes, considering that older adults are especially vulnerable to malnutrition (Dent et al. 2023). In contrast, nutrition hardly represents the function of junk food and sweets. In some cases, it may even be desirable to use both approaches in parallel, especially when supporting policymaking (Jolliet 2022; McLaren et al. 2022). Some argue that it may be desirable to always consider nutrition in the impact assessment, independent of the choice of functional unit, as the consideration of nutritional health impacts enables valid comparisons across a wide range of scenarios (e.g., meal or diet alternatives with very different nutritional properties), whereas the health impacts might just be more similar across scenarios with a nutrient-based functional unit (Jolliet 2022).

Nutrition-related health impacts are often overlooked in LCA but are starting to gain more attention. Stylianou et al. (2016) pioneered the potential incorporation of nutrition-related health impacts into LCA based on a case study on milk. They later applied their developed framework to >5800 food items consumed in a US diet (Stylianou et al. 2021), and others have applied it elsewhere in case studies (e.g., Ernstoff et al. 2020). Complementarily, Walker et al. (2019) developed a similar framework to assess the nutrition-related health impacts of diets and applied it to European diets, again by expressing the health impacts in DALYs, the typical unit used in LCA, and by comparing them to environmental impacts from a traditional LCA.

In the third phase of the Global Life Cycle Impact Assessment Method (GLAM) project (2019-2023), implemented under the auspices of the Life Cycle Initiative hosted by UN Environment, a task force on nutrition-related health impacts has been established. The work of this task force builds on the study by Stylianou et al. (2021) and other GBD-based approaches (e.g., Walker et al. 2019), with the aim to improve these approaches, build consensus, and harmonize them with other LCA impact categories. As part of this process, a workshop with nutrition experts was held. This commentary aims to describe the framework for nutrition-related health impact assessment and synthesize the insights from the expert workshop.

Workshop description

The task force members identified relevant nutrition experts within and beyond the life cycle assessment community based on literature. Out of 18 invitations sent to experts based in Europe, Australia, and North America (some of Asian origin), six nutrition experts eventually participated in the workshop, along with another six task force members and one representative of the United Nations Environment Programme that is hosting the Life Cycle Initiative. The nutrition experts came mostly from institutions in the United States but also Australia and the United Kingdom.

With the workshop invitation, the organizers shared details about the workshop, a document with background information on LCA and the Life Cycle Initiative, a short introduction to the nutritional health impact assessment framework in LCA, and the questions they planned to discuss during the workshop, as well as two reference papers that illustrated nutritional health impact assessment in LCA, namely by Walker et al. (2019) and Stylianou et al. (2021).

The workshop aimed to 1) validate the general assessment framework, 2) identify and discuss the main scientific questions and challenges for quantifying human health impacts from nutrition for food items and diets, and 3) provide initial guidance to the further development of the framework by, e.g., proposing data and approaches.

The workshop took place virtually on 18 August 2021 for 2.5 hours, with the relatively short duration enabling intense exchanges and a high level of commitment (Jack and Glover 2021). After a personal introduction by all participants, the workshop organizers gave a short presentation to further present background information and acquaint experts with the principles of LCA. The main part of the workshop was guided by predefined questions based on the scoping phase of the GLAM project and further discussions among the task force members (Table 1), with a short introduction to the context followed by a plenary discussion. The following sections present the findings from each of the questions.

Table 1. Questions addressed to experts.

#	Aspect	Question
1	Framework and its requirements	What are your comments on the proposed framework?
2	Critical appraisal and extension	Are there major studies, main references, and available data, including additional dietary risks, that should be considered in addition to the GBD to assess DALYs from nutrition and would be available for worldwide calculations?
3	Food consumption data	What would be an appropriate database? How would we get access to the GBD exposure database?
4	Food groups	Are there possibilities to differentiate the health effects within food groups based on bioavailability, nutrients, or additional parameters? What could be the best basis to achieve this?
5	Age aggregation	What are your comments on the age aggregation?
6	Excess energy intake	Are there additional effects mediated by the body mass index (BMI) beyond sweetened sugared beverages that should be considered at the diet level based, e.g., on total caloric intake and activity? How could we account for such added health damages from caloric intake excess?

7	Other issues	Which dietary risks can be influenced by cooking, processing, environmental conditions, food safety, and farming practices? What data and models exist to quantify these influences?

Impact assessment framework

The impact assessment framework builds on epidemiology, i.e., the study of the occurrence, distribution, and determinants of health outcomes. At its core, it includes the definition of dietary risk factors (Figure 1), which represent the characterization factors similar to those applied to emissions and resource use in LCA. Dietary risks can refer to high consumption of nutrients (e.g., sodium) or food groups (e.g., red meat) that generally increase the risk of a detrimental health outcome and should be limited, whereas the consumption of nutrients or food groups to encourage (generally beneficial) can reduce the risk of a detrimental health outcome. Such dietary risks lead to potential changes in human health if certain nutritional thresholds are exceeded or not yet reached.

During the goal and scope definition, the object of investigation, e.g., a food item or a dietary pattern, is defined. The functional unit is also defined, which can, for example, be a serving size as a standard amount of a single food item or a person's daily consumption of foods (dietary pattern). Moreover, the population affected, e.g., a specific country and adults or children, would influence the potential health impacts caused by dietary risks.

During the inventory analysis phase, the consumption levels of given dietary risk components are estimated by collecting detailed data on the investigated food item or dietary pattern in relation to the functional unit and their food composition in the different risk components (e.g., amount of sodium or red meat per serving).

The impact assessment considers dose-response relationships that are specific to the dietary risk, disease outcome (e.g., ischemic heart disease), gender, age, and region. They are based on risk ratios (or relative risks, the probability of a disease outcome in an exposed group relative to an unexposed group) and outcome incidence rates (the number of cases per person per year). Data on risk ratios and incidence rates can, for example, be obtained from the Global Burden of Disease (GBD) study series (Institute for Health Metrics and Evaluation 2022a). The GBD study also provides burden rates (burden per person per year) that determine the severity, measured in disability-adjusted life years (DALYs) per number of cases. Together, the dose response and the severity form the dietary risk factors expressed in, e.g., $DALY/g_{sodium}$ or $DALY/g_{red\ meat}$. When health impacts are estimated for a region (or other population sub-group), the gender and age groups per region are aggregated as a population-weighted average, and the disease outcomes are aggregated to yield a cumulative dietary risk factor that depends on the dietary risk and geographical region.

Coupling the dietary risk factors with the consumption levels of dietary risk components from the inventory phase results in health impacts (Figure 1, Figure 2), considering both morbidity (years of life disabled) and mortality (years of life lost). These aggregate the individual dietary risks in DALYs or µDALY per functional unit. They can also be expressed as a Health Nutritional Index (HENI) converted into minutes of healthy life gained (+) or lost (−) for communication to the general public (Stylianou et al., 2021). The effects of individual dietary risks on a disease outcome (or the fraction of a disease outcome attributable to a certain dietary risk) are assumed to be multiplicative at the level of diets or dietary changes (Murray et al. 2020; Walker et al. 2019) and can be simplified to additive effects for the marginal (incremental) impacts of a single food item (Stylianou et al. 2021). Single food items still need to be considered within the context of an overall diet. The assessment accounts for the fraction of the population within the active range of a dietary risk, i.e., the population whose intake is at or above (for detrimental foods) or below (for beneficial foods) a given theoretical minimum risk exposure level (TMREL). In other words, nutrients and food groups to limit do not always cause harm and start having an effect only if the TMREL is met or exceeded.

There are two key differences from a traditional, environmental LCA. First, the use stage is the only life cycle stage relevant to nutritional health effects, so considering a full life cycle is not necessary for this impact category. Second, the affected population differs. Only the person who consumes the food is affected by its dietary risks (internal health effects). For environmental impacts, the general population is affected (external health effects). For example, if a person consumes beef, only that person is exposed to the detrimental nutritional health effects of beef. At the same time, beef contributes to climate change, which, in turn, can lead to health impacts, but these are not limited to the person consuming beef. Therefore, it is also important not to add up such internal and external health impacts even if the unit is the same.

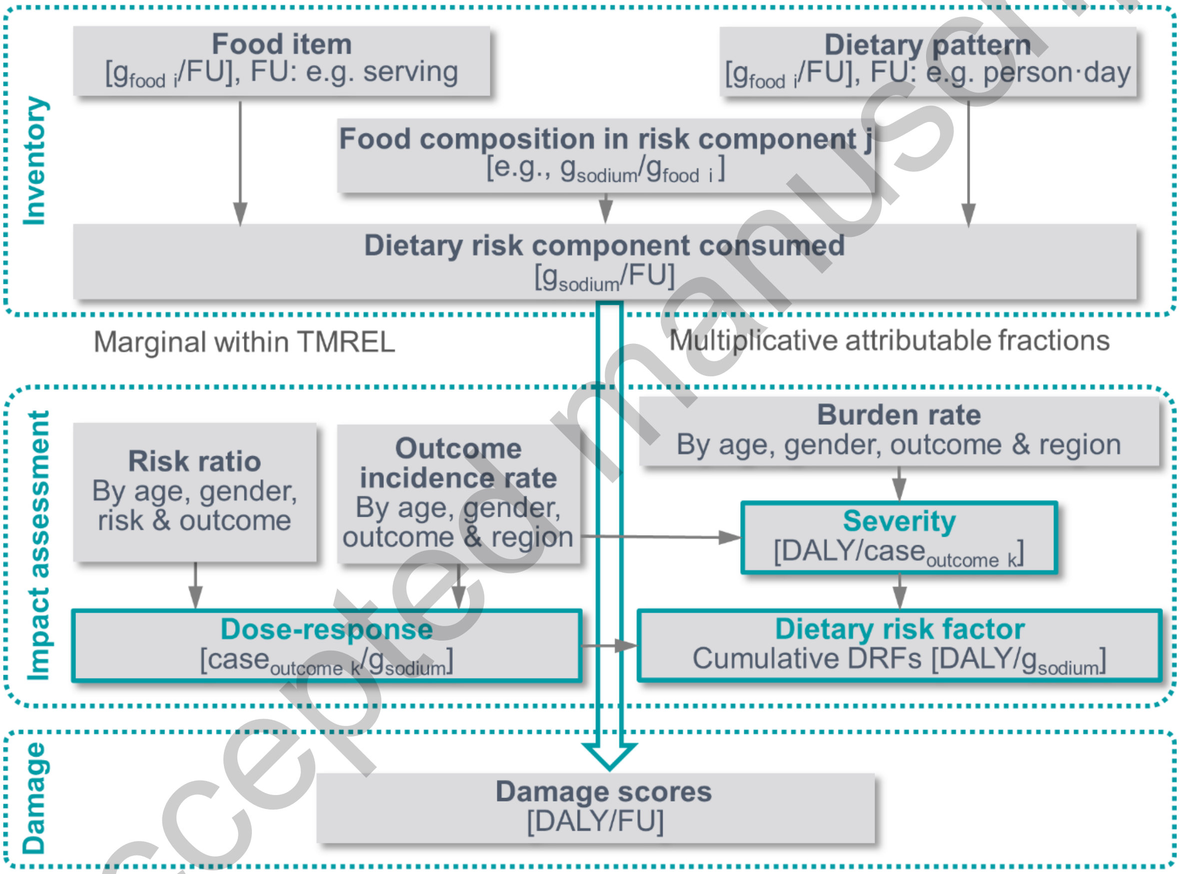

Figure 1. Consumption-to-damage framework for nutritional health impacts expressed in disability-adjusted life years (DALYs), for the example of sodium as a dietary risk.

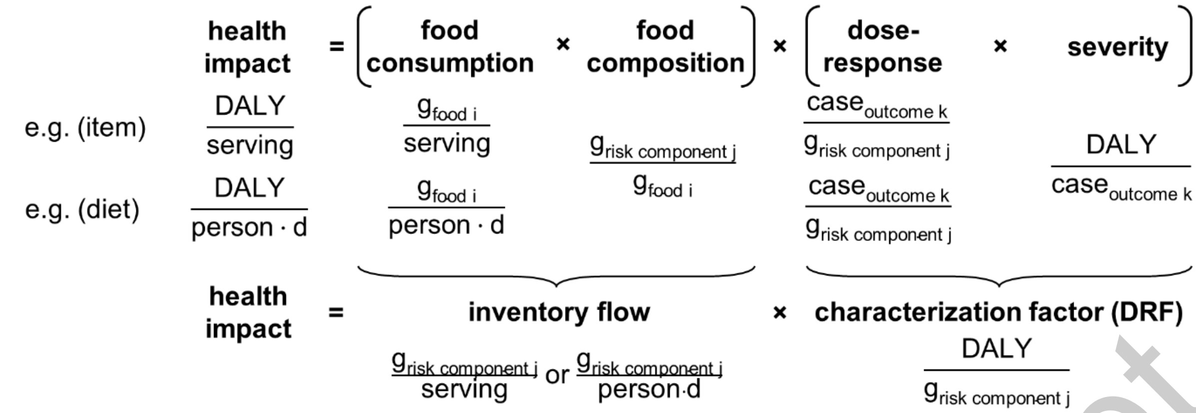

Figure 2. Set of equations and exemplary units to calculate nutritional health impacts.

Requirements of and justifications for the framework

The various applications of LCA require the framework to be suitable for both whole diets (Walker et al. 2019) and single food items (Stylianou et al. 2021). For single food items, the dietary context must still be considered, assessing whether the marginal consumption of the nutrients or food groups associated with the considered food item are in the active range, i.e., below or above the TMREL. Therefore, the marginal impacts of single food items differ among countries' populations, depending on the prevailing average diet within the countries. Very few people in the United States or the United Kingdom (Scheelbeek et al. 2020) follow an optimal diet, and this implies that every change in a single item will have an impact apart from a minority with consumption above (for beneficial foods) or below the TMREL (for detrimental foods). When we evaluate marginal changes in diets, e.g., by reducing the intake of single food items with adverse health impacts, we must also consider what replaces the reduced food item, as humans typically keep their diets isocaloric (Willett 2013) and the substitution determines the net health gains (Afshin et al. 2019). So, the substituting and the substituted food items both need to be assessed, and their difference in impacts calculated.

Despite individual differences, the health benefits or risks of total dietary patterns are fairly universally applicable. Humans have the capacity to be healthy on a wide range of very different diets (Willett et al. 2019). While some people are more susceptible to certain disease outcomes and more sensitive to certain nutrients, such as sodium (Kanbay et al. 2011), than the general population, overall, it appears that the same nutrients and food groups are generally beneficial to all populations (Afshin et al. 2019). This implies that the proposed framework can be applied to assess the relative health risks of the general population when considering their dietary context.

Non-linearities exist for some nutrients like sodium and some food groups like fruits and vegetables in association with several disease outcomes and all-cause mortality (Mente et al. 2021; Yip et al. 2019). The development of dietary risk factors needs to account for such non-linearities. The final slope of a dose-response curve retained in the dietary risk factors is adjustable depending on dietary risk component consumption levels in the population of different countries. Only the application of dietary risk factors in LCA assumes linear relationships between inventory (here, dietary risk components) and associated impacts (here, health). This seems acceptable, given that there is an approximately linear relationship between an overall dietary score and mortality, as found in the United States (Gicevic et al. 2021).

Critical appraisal of the Global Burden of Disease study underlying the framework

The GBD study provides a good first estimate of the potential health impacts of dietary risks despite being imperfect and an approximation. One of the limitations is that, for certain risk components, it only considers a limited number of health outcomes, such as ischemic heart disease (i.e., involving reduced blood flow to the heart), colorectal cancer (also known as bowel cancer), type 2 diabetes (i.e., a metabolic disorder), other cardiovascular diseases (i.e., involving the heart or blood vessels), other neoplasms (i.e., involving abnormal tissue growth), and seldom other diseases (such as kidney disease). While the GBD analyses consider dozens of disease outcomes for BMI- and hypertension-mediated dietary risks, for other dietary risks, the number of disease outcomes considered varies from only 1 (for six dietary risks) to 9 (for a diet low in fruits) (Afshin et al. 2019). Oral diseases (such as dental caries, i.e., tooth decay), for example, are widespread globally, are influenced by diets (Peres et al. 2019), and influence the risk of other diseases, including premature mortality (Kotronia et al. 2021), but their link to diets is not covered by the GBD study. The same applies to bone fractures due to low bone mineral density resulting from inadequate calcium intake (Shlisky et al. 2022).

Other limitations of the GBD study concern the associations between the included nutrients or food groups and disease outcomes. The analyses were not adjusted adequately for all potentially confounding factors. Thus, the estimated associations might be spurious and not indicate a causal link, or they might be overestimated or underestimated. Age, gender, smoking, and physical activity have been considered confounders, but there might be residual confounding (Afshin et al. 2019). For example, countries have been assigned to groups based on their socio-demographic index (Afshin et al. 2019), but the socio-economic status of individuals within a country has not been considered. Moreover, many studies only use a single dietary assessment to collect information on habitual dietary intake (Brouwer-Brolsma et al. 2018), which is subject to multiple sources of error (Naska et al. 2017), and might underestimate the magnitude of the associations (Verly-Jr et al. 2017). The EAT-Lancet report estimated the impact of shifting diets to the EAT-Lancet dietary targets in two different ways: 1) building on the GBD study findings and 2) using their own well-established cohort data collected among health professionals, which is less confounded. The two approaches led to similar relative risks (Willett et al. 2019), indicating that the GBD study might provide fairly realistic estimates despite its shortcomings.

Extension of the framework to more countries

The proposed nutritional health impact framework has so far only been applied to the United States, but the intention is to apply it also to other countries or regions to eventually reach global coverage. If covering all countries is not feasible, the goal should at least be to conduct the analyses for a set of complementary countries representing different regional archetypes, e.g., with similar nutritional patterns.

Evidence for the relationship between nutrition and disease outcomes in low- and middle-income countries is sparse (Forouhi and Unwin 2019). This includes countries currently undergoing a nutrition transition. Not only do the background diets differ among countries, but also nutritional needs and susceptibility to diseases. For example, there is a rising incidence of type 2 diabetes in low- and middle-income countries (Zhou et al. 2016), which is occurring in people with a lower body mass index than would be common in high-income, Western countries (Ma and Chan 2013). Some data on nutrition and disease outcomes are starting to become available from China and Japan. However, it will likely take some decades to establish relationships. For example, it takes that long to build up atherosclerosis (i.e., abnormalities in the arteries), which is why adolescents do not get heart attacks.

The incidence of type 2 diabetes goes up first. Therefore, monitoring type 2 diabetes can be a good indicator of upcoming health issues as these countries go through a nutrition transition.

Food consumption data

An extension to more countries requires, among others, country-specific food consumption data. Such data is available and could be obtained from the exposure database of the GBD study, the Global Dietary Database (Miller et al. 2021), and, in the future, also the Global Individual Food consumption data Tool (GIFT) by FAO and WHO (FAO and WHO 2022). Both the GBD study (Afshin et al. 2019) and the Global Dietary Database (Miller et al. 2021) involve the imputation of some of their data to fill gaps. The GBD exposure estimates were made publicly available following a request after this workshop (Institute for Health Metrics and Evaluation 2022b).

Food groups and nutrients

The GBD study does not provide sufficient detail to distinguish the health outcomes of different foods within a food group and only covers a limited number of nutrients. From a Western perspective, vitamin D (Holick and Chen 2008) and potassium (Sun and Weaver 2020) would be valuable to consider additionally, and from a global perspective, vitamin A (Stevens et al. 2015), iron (Pasricha et al. 2021), iodine (Pearce et al. 2016), and vitamin B12 (Stabler and Allen 2004). The GBD study includes vitamin A, iron, and zinc deficiency under child and maternal malnutrition but not under adult dietary risks (Murray et al. 2020). The type of dose-response differs for child and maternal malnutrition, which complicates their assessment within the same framework. Thus, currently, the proposed framework does not capture such dietary risks that are of concern for chronic undernutrition in low-income countries. While it seems challenging to distinguish the health impacts of foods within a certain food group, nutrient adequacy of foods (e.g. by using the Nutrient-Rich Foods index) allows for differentiation and could be considered as a secondary metric to check how robust the results are, although the definitions of nutrient adequacy come with their own uncertainties (Bier and Willett 2016).

Age aggregation

The proposed framework entails aggregating age-specific risks and calculating adjusted cumulative dietary risk factors that reflect the entire distribution of the adult population under study. This procedure was considered necessary due to the time lag between exposure to a dietary risk and disease onset (Willett 2013). The experts confirmed that this is a reasonable approach. Although a method has recently been defined to estimate the age-specific effects of different diets on life expectancy (Fadnes et al. 2022), it is generally difficult to find reliable data on age-specific relative risks. The lag, also called latency, is highly variable and depends on the exposure and disease. For example, for breast cancer, what happens at a young age might be more important than as an adult for some exposures like ionizing radiation, although breast cancer only develops many decades later (Golubicic et al. 2008). In contrast, overweight and obesity can develop within a few years and can be reversed within a few years (Lean et al. 2018). The onset and recovery can also be asymmetrical. For heart disease, for example, it takes decades to build up atherosclerosis to have a heart attack, but with the right dietary intervention, within a couple of years, atherosclerosis reverses (Shai et al. 2010), reducing heart disease rates.

The epidemiological data for dietary risks regarding children is very limited. As such, we do not have sufficient evidence for an association between childhood nutrition and long-term health outcomes, with some exceptions, such as obesity (Horesh et al. 2021). As a perhaps rare example, obesity in girls during childhood protects them from breast cancer for the rest of their lives, whereas gaining weight during adulthood increases breast cancer risk (Baer et al. 2010). As another example, milk, which is generally assumed to benefit bone strength through its high calcium content, makes people taller when consumed during growth and adolescence, and this tallness rather makes the bones more vulnerable to fractures later in life (Feskanich et al. 2014). In contrast, for heart diseases generally, nutritional factors will probably act in the same direction (Kaikkonen et al. 2013). Overall, the experts advised against using adult-derived dietary risk factors for children, as it would give misleading results.

Excess energy intake

Food consumption that leads to excess energy intake and increases the risk of obesity constitutes a notable public health problem globally. The only food group covered in the GBD study for which the health effects are mediated through the body mass index is sugar-sweetened beverages, which do not reflect the variety of energy-rich foods commonly consumed. Theoretically, one could estimate the energy needs of persons in a population based on their body weight (if known) and their estimated energy expenditure, which could then be compared to actual energy intake. However, human beings are fairly adept at regulating their energy intake, usually within 1% (Willett 2013). People do not completely compensate their energy intake for sugar-sweetened beverages but partially (Woodward-Lopez et al. 2011). The little margin of uncompensated energy accumulates over time. For example, 10 - 15 kcal per day over time can lead to considerable obesity over a couple of decades (Willett 2013). Such a small difference demands high precision and makes it challenging to estimate excess energy intake and mediated health effects.

The epidemiological evidence for health impacts is much stronger for sugar-sweetened beverages than for added sugar itself. With sugar-sweetened beverages, large quantities of sugar are consumed very quickly. Other sugar in solid form might be compensated more (Woodward-Lopez et al. 2011), intake of added sugar is also more difficult to estimate accurately, and possibly some ratio could be applied to such other sweet food items. Stylianou et al. (2021) did a sensitivity analysis, where they assumed the effect of sugar was half that of sugar-sweetened beverages. While the effect on most food items was minor, some food items, such as desserts, candy, and sweet bakery products, considerably reduced their nutritional performance, leading to higher estimated health impacts.

Most cereal foods are refined before being cooked and eaten – a process that destroys the cell structure and lowers the concentration of dietary fiber and some nutrients. Low intakes of dietary fiber are associated with higher intakes of low-fiber foods and consequently increased all-cause and cardiovascular-related mortality and incidence of coronary heart disease, stroke incidence and mortality, type 2 diabetes, and colorectal cancer (Reynolds et al. 2019). White bread, white rice, and certain ultra-processed foods, for example, contain such refined grains. Refined grains only partly displace other foods, leading to excess energy intake. The effect on blood sugar is just as detrimental or worse than added sugar (Atkinson et al. 2021). Refined grains are only indirectly and partially considered in the GBD study and the proposed framework through the remaining consumption of whole grains and fibers, which are considered beneficial risk components.

Although not mediated through body mass index, the GBD study captures the detrimental health effects of trans fatty acids, which can also lead to weight gain (Field et al. 2007). In contrast, saturated fatty acids are also associated with weight gain and are not directly included in the GBD study but could potentially be considered indirectly in sensitivity analyses through their association with cholesterol (Stylianou et al. 2021). Finally, weight gain is also one of the many problems associated with heavy alcohol drinking (Traversy and Chaput 2015). Alcohol use is included in the GBD study but not under dietary risks (Murray et al. 2020), which complicates the compatibility with the proposed framework.

Other unresolved issues

Farming practices and cooking can influence the content and bioavailability of nutrients in food. This applies especially to micronutrients. Some work has been done on the nutritional value of food produced in organic compared with conventional farming (Reganold and Wachter 2016). Moreover, some food composition databases include information on both raw and cooked foods. However, the GBD study includes very few micronutrients (except for, e.g., calcium). At that level of detail, one also has to consider the interactions between different nutrients (Sandström 2001), which makes it even more complicated to assess their effects on health. Indeed, in nutrition science, foods are increasingly understood as complex matrices of multiple factors (of which nutrients are one), which can influence health (Mozaffarian 2019). For example, many bioactive ingredients of foods, such as polyphenols (Koch 2019), are not considered in the GBD study.

Conclusions and next steps

Accounting for nutrition-related health impacts is better than not accounting for them, even if the approach inevitably requires simplifications of a highly complex reality, as is typical for LCA (Curran 2014). The nutrition experts confirmed that the task force is going in the right direction. The GBD study provides a good first estimate of the potential health impacts of dietary risks, and the experts supported the use of the cumulative dietary risk factors that reflect the entire distribution of the adult population. However, there are also several caveats around it and limitations it has to account for and make explicit when doing such assessments. Its coverage of nutrients, diseases, and confounding factors is incomplete. Analyses ideally account for non-linearities in the development of dietary risk factors. For energy intakes, epidemiological evidence is much stronger for sugar-sweetened beverages than for other types of energy intakes (incl. added sugar, fatty acids, refined grains, and alcohol); thus, it is the only food group covered in the GBD study that is mediated through the body mass index. The experts advised against a potentially misleading use of adult-derived dietary risk factors for children. As the next steps, analyses should take due consideration of the dietary risk component consumption levels in the population of interest, and the country coverage for applying the GLAM framework needs to be extended to at least cover a wide range of dietary patterns worldwide. To characterize food consumption patterns, the GBD exposure estimates were made publicly available following a request after this workshop. The experts also recommended using a metric complementary to DALYs, such as nutrient adequacy, also considering, e.g., vitamin A and iron, to complement the assessment and verify if both approaches lead to the same conclusions. The findings from the workshop proved valuable to improve our understanding on two fronts: the limits of the impact assessment framework that need to be communicated to potential users and the feasibility of desired improvements. Overall, the framework helps to put the nutrition-related health impacts into the context of other environmental impacts derived from a traditional LCA, thereby guiding a transition towards healthy and sustainable food systems.

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Conflict of Interest Statement

The authors have no relevant financial or non-financial interests to disclose.

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