Measuring Diet Quality for Women of Reproductive Age in Low- and Middle-Income Countries: Towards new metrics for changing diets

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About *Intake*

Intake is a Center for Dietary Assessment at FHI 360. We aim to contribute to improving nutrition for vulnerable populations in low- and middle-income countries (LMICs), through increasing the availability, quality, comparability, and use of dietary data and metrics. We hope that the availability of valid, concise, and effective diet-related metrics, along with *Intake* technical assistance for collecting, analyzing, and using dietary intake data, can play an important role in helping actors in LMICs to develop evidence-based nutrition and agriculture policies and programs to ensure high-quality diets for all.

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Executive Summary

Poor quality diets are increasingly recognized as major drivers of morbidity and mortality, globally. In many low- and middle-income countries, persistent hunger and food insecurity co-exist with micronutrient deficiencies as well as with overweight, obesity, and diet-related chronic diseases. Diets are changing rapidly, particularly in urban areas, with increased intakes of highly refined carbohydrate, poor quality fats, and processed foods, many high in sodium and sugar.

Though diets are changing rapidly, most dietary metrics developed for use in low- and middle-income countries focus on assessing adequacy of energy or micronutrient intakes. New metrics are required to capture a wider range of dimensions of diet quality, so that diet quality can be assessed and monitored, and so the impacts of policies and programs can be tracked.

This paper aims to provide a basis for new efforts to develop such metrics, with a specific focus on women of reproductive age. Improved nutrition for women of reproductive age, including older adolescents, is an urgent priority and currently receiving much attention.

To provide the context for development of new metrics, the paper presents a narrative review and synthesis of conceptual and operational definitions of diet quality, illustrating how concepts and metrics have evolved. Metrics operationalize but do not define diet quality, though they are often taken to do so. The process of describing and defining a high-quality diet has been an iterative interplay of science, elaboration of guidance, specific operational definitions (metrics) based on the guidance that allow further evidence generation, revision of guidance, and so on.

Most ‘whole of diet’ metrics describing healthy dietary patterns have been developed based on evidence of relationships of dietary patterns to health outcomes in the global north; we survey the nature of the evidence from the global south and discuss considerations in extending evidence from the global north to the south.

Using a set of existing metrics as examples, we describe various defining features of metrics and the many decisions involved in their design, and outline considerations for and possible approaches to development of novel metrics for women of reproductive age in low- and middle-income countries.

Acronyms

AHEI	Alternate Healthy Eating Index
AI	Adequate Intake
AMDR	Acceptable Macronutrient Distribution Ranges
ASF	Animal-source food
BMI	Body-mass index
CVD	Cardiovascular disease
DASH	Dietary Approaches to Stop Hypertension
DGAC	U.S. Dietary Guidelines Advisory Committee
DPMP	Dietary Patterns Methods Project
DQI	Diet Quality Index
DQI-I	Diet Quality Index International
DRI	Dietary Reference Intake
EAR	Estimated Average Requirement
ELANS	Latin American Study of Nutrition and Health
EPIC	European Prospective Investigation into Cancer and Nutrition
FAO	Food and Agriculture Organization
FBDG	Food-based dietary guideline
GBD	Global Burden of Disease
GLOPAN	Global Panel on Agriculture and Food Systems for Nutrition
HDI	Healthy Diet Indicator
HEI	Healthy Eating Index
HFD	Healthy Food Diversity
HIC	High-income countries
ICN2	2nd International Conference on Nutrition
INFORMAS	International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support
LDL	Low-density lipoprotein
LMIC	Low and middle-income county
mAHEI	Modified AHEI
MAR	Mean Adequacy Ratio
MDD-W	Minimum Dietary Diversity for Women of Reproductive Age
MUFA	Monounsaturated fatty acids

NCD	Noncommunicable disease
NHANES	U.S. National Health and Nutrition Examination Survey
NHLBI	U.S. National Heart, Lung and Blood Institute
NIH	U.S. National Institutes of Health
NPNL	Non-pregnant, non-lactating
PDQS	Prime Diet Quality Score
PUFA	Polyunsaturated fatty acids
PURE	Prospective Urban Rural Epidemiology Study
RDA	Recommended Dietary Allowance
RNI	Recommended Nutrient Intake
SDI	Sociodemographic index
SFA	Saturated fatty acids
SSB	Sugar-sweetened beverage
STEPS	STEPwise approach to Surveillance
TDS	Total Diet Studies
UL	Tolerable Upper Intake Level
UPF	Ultra-processed food
USDA	U.S. Department of Agriculture
WHO	World Health Organization
WRA	Women of reproductive age

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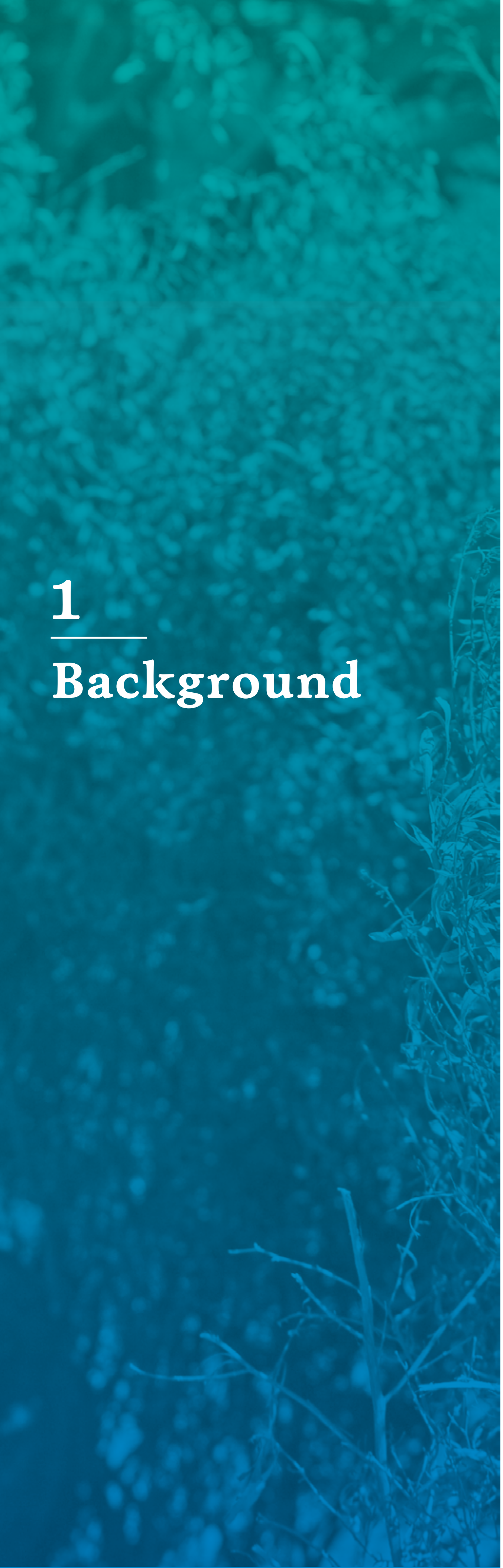


1 Background

Globally, dietary and related metabolic risk factors together with maternal and child malnutrition are the most important drivers of poor health (1). The ranking of dietary risks relative to other environmental and behavioral risks varies by country socioeconomic status, with dietary risks ranked first in middle- and middle-high sociodemographic index (SDI) countries, and third and fifth in low-middle and low SDI countries, respectively. However, if combined with micronutrient deficiencies and with metabolic risks closely related to diets such as high fasting plasma glucose, high systolic blood pressure, and high body-mass index (BMI), this constellation of diet-related factors tops risks for poor health and mortality at all country income levels. Diet quality links all of these, and the Global Burden of Disease (GBD) group (1) concludes:

'… among all forms of malnutrition, poor dietary habits, particularly low intake of healthy foods, is the leading risk factor for mortality' (p. 1410).

For countries undergoing nutrition transitions, hunger, extreme food insecurity, wasting and thinness may decline overall (even if pockets persist), but absolute lack or low quantity of food is often replaced by very low-quality and monotonous diets, high in carbohydrates, sometimes including meat and/or fish (2), but typically low in fruits, vegetables, nuts, legumes and dairy (1, 3). Such poor-quality diets may also be energy-dense, which may in turn contribute to increased overweight and obesity. Poor quality diets reflect the cost of nutrient-dense foods and also the reality that people will meet (and sometimes exceed) their energy needs before they will purchase diverse and expensive nutrient-dense foods (4). Cultural preferences, including for staple foods and certain animal-source foods (ASFs), also play a role, as do convenience and marketing (5).

While rising levels of cardiometabolic risks and associated morbidity and mortality are alarming, many low- and middle-income countries (LMICs)[1] also continue to struggle with undernutrition, including child stunting and wasting; thinness, short stature and poor pregnancy weight gains for

1. The Global Burden of Disease (GBD) collaborative uses a unique classification system for socio-demographic index ("SDI") levels, related to their analytic requirements. However, the World Bank classification (into low-, lower-middle, upper-middle, and high income country status) is much more widely used in general, and will be used throughout this paper except when referring to GBD results (see: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups for the classification) [Accessed Dec 20 2018]. Low-, lower-middle, and upper-middle income countries are referred to collectively as low- and middle-income countries (LMICs).

women; and known and unknown micronutrient deficiencies across demographic groups. Iron, zinc, iodine, and vitamin A have received the largest share of attention, assessment and programmatic action, but diets of women of reproductive age (WRA) are frequently inadequate across a far broader range of micronutrients, including a range of B vitamins, and calcium (6-8). When ASFs are infrequently consumed, as in many poor households, calcium and vitamin B12 requirements of WRA are particularly hard to meet (9). Poor quality diets are only one among numerous causes of undernutrition. But – while not sufficient – good quality, nutrient-dense diets are necessary for healthy pregnancies and for healthy infant and child growth and development.

Thus, many countries are experiencing double burdens of under- and overnutrition. In response, there are increasing calls for 'double-duty' policy and programmatic responses that simultaneously target under- and overnutrition (10).

Poor quality diets impact all ages and both sexes, and many efforts at the food system and policy levels will rightly aim to improve diets for all. At the same time, women, adolescent girls, and infants and young children are often targeted due to their vulnerability and higher needs for nutrient-dense diets (11, 12) and, in the case of WRA due to their roles as mothers, caregivers, and 'gatekeepers' for nutrition for households (13). Consequently, there are a number of recent calls to action to design, target and assess interventions seeking to improve diet quality for WRA (14, 15).

Given rising recognition of the economic and social costs of disease burdens imposed by poor quality diets and given the renewed and rising interest in improving diets for WRA in particular, there is a need for operationalized metrics reflecting diet quality, for assessment and for monitoring and evaluation of policy and programmatic interventions, and for advocacy.

However, despite the primacy and urgency of dietary risk factors, to date there is no clear and actionable global guidance on what constitutes a healthy or high-quality diet. But there is growing consensus on common elements of a healthy diet pattern, particularly for cardiometabolic risk reduction (16-18). The action plan following from the 2014 Second International Conference on Nutrition (ICN2) includes a call for international guidelines on healthy diets (19), and this was echoed by the Global Panel on Agriculture and Food Systems for Nutrition (GLOPAN) (17).

Further, in addition to lack of clarity on a global definition of a high-quality diet, to date we lack metrics (indicators and more complex multidimensional indices) that capture the full range of characteristics of diets relevant to both under- and overnutrition and validated for use in LMICs. Without such metrics, governments and other stakeholders in LMICs cannot assess diet quality nationally, regionally or locally, have a limited evidence base on which to design and target policy and programmatic actions to improve diets, and cannot monitor changes in response to such actions.

1.1

Objective of the paper

In this paper, we seek to provide the basis for an effort to develop novel population-level metrics reflecting multiple dimensions of diet quality for non-pregnant, non-lactating (NPNL) WRA in LMICs.

Pregnant and lactating women (as well as young children and adolescents) are also high priority groups for developing novel population-level metrics of diet quality, but here we focus our efforts on catalyzing the development of metrics for NPNL WRA for the following reasons:

- NPNL WRA are increasingly becoming a focal group for nutrition interventions, with growing recognition of the importance of addressing women's nutritional status and diet quality before as well as during pregnancy to allow for the greatest potential for optimal growth and development for the child in utero;
- Most population-level surveys will include a much higher proportion of NPNL WRA than pregnant or lactating women, thereby providing a greater opportunity for diet quality measurement among this demographic group;
- We focus on NPNL WRA rather than all WRA because NPNL women have lower energy and nutrient requirements than pregnant and lactating women. Therefore, depending on what aspect of diet quality is measured, there could be justification and need for different metrics to be developed for pregnant and lactating women; and
- The nutrition of WRA is important, regardless of a woman's status as a pregnant or lactating mother.

Ideally, any diet quality metric developed for NPNL WRA would also be appropriate and meaningful for pregnant and lactating women, and/or adolescents and/or men, but in the absence of knowing if all of these demographic groups can be addressed by the same set of diet quality metrics, as a first step, we are prioritizing advancing the development of metrics for NPNL WRA.[2]

WRA are defined as girls and women 15-49 years of age, and the aim is to provide a basis for development of metrics that are relevant across that age-span (i.e., not to develop separate metrics for adolescent girls). We do not seek to catalyze development of metrics to assess diet quality for individuals (e.g. for screening or counseling) as diet quality metrics for individuals would have higher data requirements and are not necessary for many population-level uses.

We do aim to catalyze development of metrics that will be suitable for:

- Population-level assessment of diet quality for WRA;
- Tracking of change across time;
- Assessment of change relative to population targets;
- Tracking of change in response to policy and programmatic interventions;
- Geographic targeting, when used within a broader suite of metrics; and
- Communication and advocacy.

Although we seek metrics for use at population level, since we seek metrics for a specific demographic group (WRA), it is likely that data collection for the metrics will need to be on an individual- as opposed to household- or higher level.

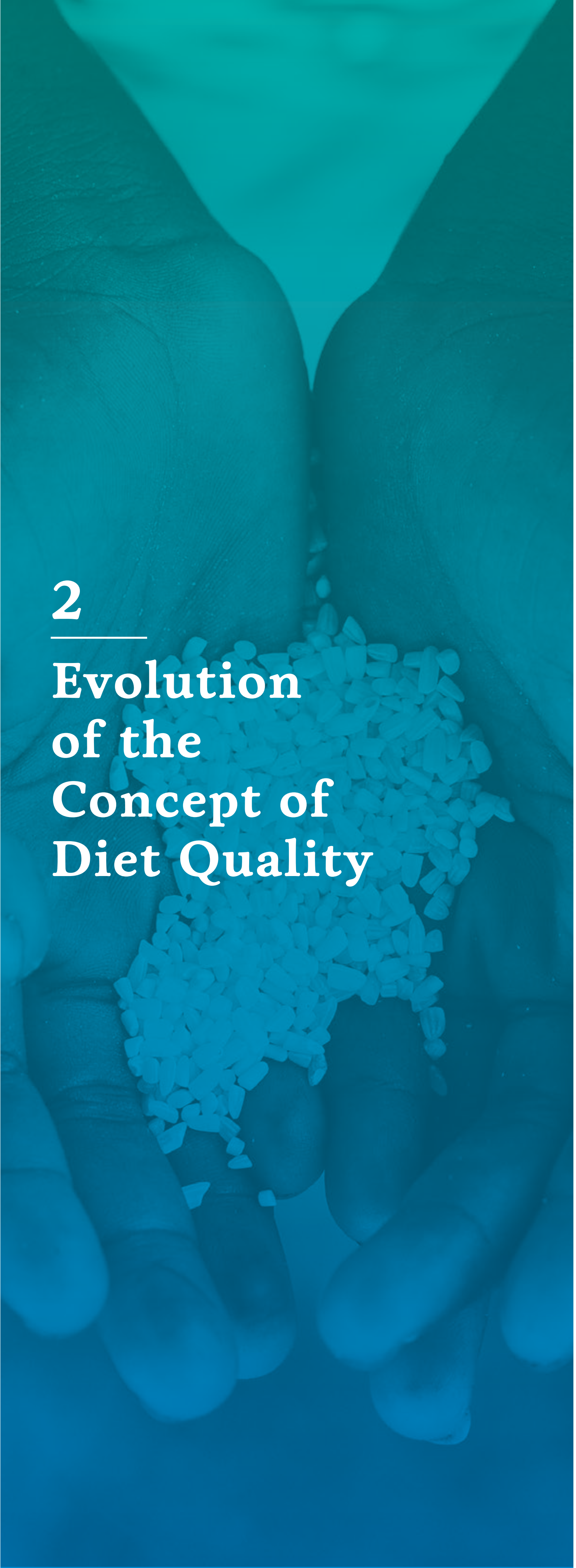
2. While we prioritize metric development for NPNL WRA because of the technical and other issues just noted, we nevertheless will refer to WRA throughout this document, for simplicity and because ideally, the metrics would be useful with all WRA, not only those who are NPNL.

This is because use of household-, community-, or national-level dietary data requires a series of strong assumptions regarding distribution of food (across and within communities and households) as well as about food losses due to processing and waste.

While numerous diet quality indicators and indices exist, most have been developed for use in high-income countries (HICs).

In the following sections, we describe a variety of conceptual and operational definitions of diet quality, with attention to how the definitions evolved and for what purposes and populations. We first provide an overview of the evolution of concepts regarding diet quality, and then provide detail on several diet quality concepts and healthy dietary patterns, with the objective of illustrating how evidence for these accumulated. Through these examples we also describe and illustrate the interplay between conceptual and operational definitions and metrics. We then focus on the nature of the evidence base from the global south and discuss considerations in extending evidence from the global north to the south.[3] We describe existing definitions as well as underlying dimensions of diet quality, which may (or may not) be reflected in metrics, to illustrate the choices that must be made regarding the breadth of metrics. The last sections describe characteristics of metrics by way of detailed examples, and outline considerations for and possible approaches to development of novel metrics for WRA in LMICs.

3. There are many ways to group countries, and all have limitations. In this paper, we use the 'global north' to mean countries that are mostly high-income, mostly rank high on the Human Development Index, and are mostly in the north, but also include, for example Australia and New Zealand. We use the 'global south' to mean countries that are mostly low- or lower-middle income and are almost exclusively in the southern hemisphere. Both the 'global north' and the 'global south' include middle-income countries. In this narrative review, different sources cited have used different groupings of countries. We use these more generic terms at certain points, as appropriate, to reflect the general situations just described. These are not intended as technical terms with very specific meaning.



2 Evolution of the Concept of Diet Quality

Descriptions and definitions of diet quality and of high-quality dietary patterns are numerous; we do not aim to provide an exhaustive review but rather to use selected examples to describe how diet quality concepts and high-quality dietary patterns have been developed, described, and defined.

Overall, the process of describing and defining a high-quality diet has been an iterative interplay of science, elaboration of guidance, operational definitions (metrics) based on the guidance that allow further evidence generation, revision of guidance, and so on.

The earliest advice on dietary intakes based on nutrition science concerned only energy and protein (nitrogen) intakes and aimed to *'prevent starvation and the diseases associated with it'* during an economic depression in the UK in the 1860's (20, p 511). And several other late-19th century recommendations similarly focused on energy and protein (nitrogen), as these were the first for which requirements were determined. As will be described, concepts of diet quality evolved rapidly in the 20th century in the global north, but in conditions of poverty and particularly in the global south, the priority long remained on ensuring sufficient quantities of food, with a focus that evolved through protein, protein-energy malnutrition, and access to sufficient energy. These are still salient today, with the most recent estimate from 2016 indicating that approximately one in ten people, globally, lack sufficient food to meet energy needs (21). It is only very recently, in the 21st century, that concerns with a nutrition transition and diet quality issues have received attention in the global south.

However, in Europe and North America some of the earliest 20th century conceptions of diet quality, and earliest guidance, incorporated the idea of 'protective foods', including fruits, vegetables and (for children) milk (UK population standards adopted after World War I) or leafy vegetables, milk, eggs, fish, and organ meats (League of Nations Health Organization, during the economic depression of the 1930's) (22). These reflected early 20th knowledge of classical nutrient deficiency diseases and emerging knowledge on vitamins. Implicitly, a high-quality diet was defined as one that prevented clinical deficiency. Later, the central motivation for development of the first U.S. Recommended Dietary Allowances (RDAs, first published in 1941) was to *'develop a dietary standard for evaluating the nutritional quality of U.S. military and civilian diets'* (22, p.3700).

Similar motivations originally guided development of other national recommendations, and of global recommendations (e.g. World Health Organization/Food and Agriculture Organization (WHO/FAO) Recommended Nutrient Intakes (RNIs)). Thus, a high-quality diet was one that met all defined nutrient requirements. Diets could be designed, and their quality evaluated based on the RDAs or RNIs.

While nutrient adequacy is still recognized as a core dimension of diet quality, with the emergence of knowledge of dietary risk factors for chronic disease and later the role of dietary patterns as a whole, new approaches to defining and describing diet quality emerged. These included descriptions and definitions based on nutrient density, nutrient profiling and level of food processing, as well as descriptions and definitions of healthy diets based on results of randomized controlled trials (such as the Dietary Approaches to Stop Hypertension (DASH) diet), prospective cohort studies (the Mediterranean diet), and evidence syntheses (considering all relevant evidence as, for example, underlying food-based dietary guidelines (FBDGs)).[4]

In the following sections, we first describe diet quality concepts that apply to individual foods as well as to diets, including nutrient density, profiling and level of food processing. We then describe diet quality concepts at the 'whole of diet' level, including the DASH diet, the Mediterranean diet, and food-based dietary guidance based on broad syntheses of available evidence. The DASH diet and the Mediterranean diet have often been operationalized in diet quality metrics, which are further discussed later in the paper. In this section, we include them as 'case studies' of different pathways for the evolution of thinking on diet quality and healthy dietary patterns. This section on diet quality concepts is followed by a summary of evidence for LMICs.

2.1

Nutrient density and nutrient profiling

Nutrient density is generally defined as the amount or relative proportion of nutrient(s) per weight, per unit energy (often, 100 kcal) or per serving. In the context of overconsumption of energy, the concept of nutrient density provides a general approach for evaluating foods, meals or diets with the aim of providing more nutrients per kilocalorie. The concept has also been employed in evaluating diets of infants and young children, as their diets must be both energy-dense and nutrient-dense due to small gastric capacity and high needs relative to quantities consumed (23, 24).

4. In addition to these, dietary patterns have also been defined using data-driven methods such as cluster analysis, factor analysis, or reduced rank regression. These approaches to defining dietary patterns will not be further considered as they are non-generalizable.

The concept of nutrient density has been incorporated in numerous nutrient-profiling systems which provide algorithms originally aimed at classifying individual food items based on their density of both nutrients to consume ('beneficial nutrients') and/or nutrients or food substances[5] to limit (for example, saturated fat, added sugar, sodium) (26-28). Nutrient profiling frequently aims to simultaneously reflect several health-related attributes of the individual food item (27).

Nutrient profiling has several public health applications at the food-item level related, for example, for guiding consumer choice and regulation of marketing and of allowable health claims (29). Nutrient profiling schemes are sometimes validated against 'whole of diet' measures of diet quality (see e.g. Arambepola et al. (30); Darmon et al. (26); Fulgoni et al. (31)) and, less frequently, against health outcomes (32). More recently, the approach has been extended to develop nutrient profiling algorithms to evaluate meals and entire diets (33) and commercial food product categories (34). Cooper et al. (35) provide a systematic review of construct and criterion-related validation of nutrient profiling systems.

This literature has developed separately from research around dietary patterns (below) but is not unrelated, and the concept of nutrient density is present in most discussions of high-quality diets and healthy dietary patterns.

2.2

Level of food processing

Recently, Monteiro and colleagues (36) proposed a classification scheme for foods based on level of processing. The original scheme classified foods as being: 1) unprocessed or minimally processed; 2) processed culinary and food industry ingredients; or 3) ultra-processed food products. This was later amended to a 4-category scheme (1) unprocessed or minimally processed foods; 2) processed culinary ingredients; 3) processed foods; 4) ultra-processed food and drink products) and the scheme is now called the 'NOVA' classification (37). Rising trends in consumption of ultra-processed food (UPF) have been described for Brazil (38); Canada (39); Sweden (40); the U.S. (41); and globally (42).

Similar to concepts of nutrient-density and to nutrient profiling, this scheme begins with classification of individual food items but can also be used to describe diets (e.g. the proportion of energy consumed from UPF at individual and population levels).

Following the original article, the same authors and others have characterized the energy density[6] (high) and nutrient density or nutrient profile (poor) of UPF (or similar classifications) (43-48) and contributions of UPF to intake of added sugars specifically (49, 50). Others have documented concurrent and unfavorable associations between higher intake of highly processed or UPF and:

- Overall diet quality (51);
- Meeting WHO or U.S. diet quality recommendations for fat, sugar and sodium (41, 48);
- Obesity (52-54);
- Satiety (55); and
- Chronic disease risk factors (56, 57).

5. Food substances are nutrients that are essential or conditionally essential, energy nutrients, or other naturally occurring bioactive food components (25, p.253S).
6. Energy density is the amount of energy per unit volume or mass, but in nutrition is usually expressed as kilocalories or kilojoules per gram, or 100 grams.

A small number of cohort studies have documented prospective associations of UPF consumption with obesity and hypertension (58, 59) and lipid profiles in children (60).

Studies of concurrent associations of the level of food processing with nutrient intakes have shown somewhat mixed results, and most negative associations are with UPF and not with other 'less-processed' foods. A scientific statement from the American Society for Nutrition (61) affirmed that processed foods[7] (considered more broadly) provide both nutrients to encourage and food substances to limit, and highlighted the importance of selecting nutrient-dense foods, whether processed or not.

Concerning UPF, Louzada et al. (54) showed negative associations between increased consumption of UPF and micronutrient intakes for 11 of 17 micronutrients studied in Brazil, but the reverse (higher micronutrient intake with higher of UPF consumption) for 3 micronutrients (calcium, thiamin and riboflavin). Batal et al. (62) showed evidence of decreased diet quality with higher intake of UPF among First Nations people in Canada (e.g. higher intakes of free sugar, saturated fat, and sodium, and lower intakes of several micronutrients) but also showed calcium and vitamin C intakes increasing with increased UPF. In a study from Colombia, Cornwell et al. (63) combined processed and UPF, and similarly observed increased calcium intake with an increase in processed and UPF consumption, but, as in the other studies, lower intakes of other micronutrients and fiber, and higher intakes of sugar, saturated fat, and sodium. Finally, using national survey data from Canada, Moubarac et al. (47) showed intakes of all micronutrients decreasing with increasing share of UPF in the diet.

The NOVA classification scheme is quite new, and evidence from prospective studies of its relation to health outcomes is still very limited, notably compared to several dietary patterns described below. For example, a simple PubMed search of 'ultra-processed' returned 119 results, 80 of which were published in 2016 or 2017, whereas a simple search of 'Mediterranean diet' returns nearly 4000 results, starting in the mid-1980's.[8] The INFORMAS Network (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support), which includes many individuals involved in research employing the NOVA classification, recently reviewed approaches to monitoring diet quality and noted that the classification is promising, but acknowledged that more evidence is needed (64).

Others take a negative view of the NOVA classification and have challenged its usefulness (61, 65). In a recent comprehensive narrative review of dietary priorities for reduction in cardiometabolic risks and disease, Mozaffarian (18) discusses risks associated with specific UPF but also notes that in terms of cardiometabolic health, the classification may be overly simple, as some unprocessed foods are associated with higher risks and some processed foods with lower risks. He proposes a more nuanced approach to the issue, including additional work to define optimal processing.

In contrast to the concepts of nutrient density, nutrient profiling, and classification based on level of processing – all of which operate first at the level of individual foods and beverages, but which can be aggregated to the level of a meal or diet – the remaining approaches to defining high quality diets are 'whole of diet' approaches and either explicitly or implicitly embody the idea that the whole may be more than the sum of its parts.

7. 'Processed foods' in this case includes all 'processed foods'. Note that Weaver et al. use a classification scheme for processing proposed by the International Food Information Council, which is a food-industry supported educational foundation (see http://www.foodinsight.org/sites/default/files/Partners-and-Supporters.pdf [Accessed Dec 20 2018].
8. Searched on October 13, 2017.

2.3

The Dietary Approaches to Stop Hypertension diet

The DASH diet was developed for a randomized multi-center feeding trial in the U.S., designed to determine the impact of entire dietary patterns on blood pressure. The original DASH trial first enrolled participants in 1994. The rationale for the trial is provided by Sacks et al. (66) and Vogt et al. (67). Previous work had investigated effects of vegetarian diets and of experimental manipulation of intakes of potassium, calcium and magnesium. In contrast to both observational studies related to these minerals and to trials of vegetarian diets, trials with single nutrients had generally negative (null) results. There was also suggestive epidemiological evidence of a beneficial effect of increased protein intake, but no well-controlled and sufficiently large trials.

The three-arm DASH trial was designed to test two hypotheses: 1) that high intake of fruits and vegetables would lower blood pressure ('fruits and vegetables' trial diet), and 2) that a dietary pattern high in fruits, vegetables, and low-fat dairy products, that emphasized fish and chicken rather than red meat, and was low in saturated fat, cholesterol, sugar, and refined carbohydrate ('ideal' or 'combination' trial diet) would lower blood pressure. The control diet was designed to reflect then-typical U.S. intakes of macronutrients, refined grains, dairy fat, fruits, nuts, legumes, vegetables, fiber, and the targeted nutrients noted above for manipulation (potassium, calcium and magnesium) (66). The trial demonstrated positive impacts of both trial diets relative to the control diet, with stronger impacts of the 'ideal' or 'combination' diet (68, 69).

The trial diets were designed to have the blood-pressure lowering effects of vegetarian diets, but with enough ASFs to be acceptable for non-vegetarians. Levels of sodium were held constant across all three arms and energy intakes were also adjusted for needs identically across arms. The diets, by design, varied in macronutrients (as a percent of energy), fiber, potassium, magnesium and calcium (66). However, since the nutrients were delivered in foods, in addition to varying in these target nutrients, the diets also varied across a range of other micronutrients, complicating attribution of effects. Therefore, conclusions could be drawn about the entire dietary patterns, as intended, but with no attribution to specific dietary factors (68).

Although originally designed to address one chronic condition (hypertension), subsequent meta-analyses and multi-cohort analyses have shown associations of adherence to the DASH diet with reductions in other cardiovascular risk factors (70), inflammatory markers (71, 72), incident type 2 diabetes (73) and mortality (due to all causes, cardiovascular disease (CVD) and cancer)(74).

Subsequent trials examined impact of variations on the DASH diet. In the DASH-Sodium trial, researchers tested DASH diets with varying levels of sodium. The trial confirmed the benefits of the DASH diet for reducing blood pressure and low-density lipoprotein (LDL) cholesterol and showed progressively larger impacts on blood pressure with lower sodium intakes (75, 76). The OmniHeart Trial showed that replacing some carbohydrate in the DASH diet with either protein or unsaturated fats had added benefits for blood pressure and LDL-cholesterol levels, beyond the benefits of the original DASH diet (77). This indicated that a DASH diet with flexibility in macronutrient profile could be beneficial (78).

We were unable to find studies reporting on the micronutrient adequacy of the DASH diet, so we compared the original DASH trial diets (68) to the current U.S. RDA and the WHO/FAO RNIs for NPNL WRA. At the 1600 kilocalorie level the two trial diets meet, or nearly meet, the RDAs/RNIs for all micronutrients, and at the 2100 kilocalorie level they meet all recommendations.

Box 1 provides an overview of the current DASH diet, now called the DASH eating plan, as described by the U.S. National Heart, Lung, and Blood Institute website.

The DASH diet is rare in having originated from a randomized feeding trial, and has come to be viewed as providing a framework for consuming a higher-quality diet for the general population. However, the evidence base for the DASH diet has been developed primarily in the global north and benefits demonstrated for the diet are thus in contrast to prevailing dietary patterns in this context. One randomized trial in Brazil among hypertensive patients treated in a primary care setting reported positive impacts of an adapted DASH diet (also low in sodium and with a low glycemic index) on blood pressure and on glycemic and lipid biomarkers (79, 80). None of the studies included in the multi-cohort and meta-analyses cited above (70-74) were from Africa[9], South or Southeast Asia, or Latin America. However, to the extent that 'Western' dietary patterns are developing in the global south, and in the absence of much-needed evidence from these regions (see below, Section 3.4), the same contrasts might nevertheless apply.

Box 1. Dietary Approaches to Stop Hypertension Eating Plan

The Dietary Approaches to Stop Hypertension (DASH) eating plan is described as follows at the website of the U.S. National Heart, Lung and Blood Institute (NHLBI).[a]

'The DASH eating plan requires no special foods and instead provides daily and weekly nutritional goals. This plan recommends:

- *Eating vegetables, fruits, and whole grains*
- *Including fat-free or low-fat dairy products, fish, poultry, beans, nuts, and vegetable oils*
- *Limiting foods that are high in saturated fat, such as fatty meats, full-fat dairy products, and tropical oils such as coconut, palm kernel, and palm oils*
- *Limiting sugar-sweetened beverages and sweets.'*

Based on these recommendations, the NHLBI provides tables showing daily and weekly servings that meet DASH eating plan targets for diets at 7 calorie levels, for the following: 1) Grains; 2) Meats, poultry, and fish; 3) Vegetables; 4) Fruit; 5) Low-fat or fat-free dairy products; 6) Nuts, seeds, dry beans, and peas; 7) Fats and oils; 8) Sodium; and 9) Sweets. Whole grains and lean meats are emphasized.

a. See: https://www.nhlbi.nih.gov/health-topics/dash-eating-plan [Accessed Dec 20 2018].

9. Neale et al. (71) included one study (out of 17) from North Africa (Algeria).

2.4

Mediterranean diet

Evidence for the healthfulness of the Mediterranean diet may have first emerged from the Seven Countries Study, as described in Menotti and Puddu (81).[10] Begun in the late 1950's, this was the first large prospective study to investigate diet and other risk factors for CVD across cultures, including sites in Finland, Greece, Italy, Japan, the Netherlands, the U.S. and (then) Yugoslavia, and to demonstrate associations between diets and coronary heart disease. But the early papers from that study did not identify a Mediterranean diet as a general concept; the concept emerged more fully and definitively when the original ecological study was complemented by prospective cohorts. An influential early study of the Greek version of the Mediterranean diet, initiated in 1988, followed a small cohort of elderly people and demonstrated, prospectively, a protective effect against mortality of higher adherence to the Mediterranean diet (82).

Several features of this early study are worth noting. First, as the aim of the study (like many others) was to make comparisons within the population and to relate better adherence to outcomes, cut-offs for scoring elements (food groups, alcohol, and the ratio of monounsaturated to saturated fat) were relative, based on sex-specific medians in the study sample. Those consuming above the median received a point. This contrasts with *a priori* absolute cut-offs, where the study subject must consume quantities defined as sufficient (and/or not excessive) for each food, food substance, food group or nutrient to receive point(s) for that element.

Relative cut-offs are a common feature of a number of diet quality indices, particularly those developed for the purpose of illuminating associations of diet patterns to disease risk factors and outcomes. Because context-specific relative cut-offs do not allow comparisons across studies, several research groups have addressed this issue and have identified quantities associated with reduced risks for food groups or for each element within a score (1, 74, 83, 84).

Secondly, though the index was designed to capture key elements of the Greek traditional diet, the authors also noted that it was in harmony with the U.S. National Research Council's then-recent 1989 *Diet and Health: Implications for Reducing Chronic Disease Risk* (85). Thus, one of the earliest Mediterranean diet papers previewed current thinking about common elements of healthy dietary patterns.

Subsequently, many variations of the Mediterranean diet have been defined and studied in relation to a wide variety of chronic disease risk factors and health outcomes, frequently though not universally demonstrating protective or positive effects, but few studies report on nutrient adequacy. Alkerwi et al. (86) reported positive associations with intake of most vitamins and minerals, except for vitamin A and calcium (no association), but do not comment on adequacy.

Alkerwi et al. also documented inverse concurrent associations with a range of biomarkers indicative of chronic disease risks. A recent umbrella review of meta-analyses documented associations between greater adherence to the Mediterranean diet and reduced risk of overall mortality, CVD, coronary heart disease, myocardial infarction, overall cancer incidence, neurodegenerative diseases and diabetes (87). Jannasch et al. (73) also documented reduced risk of incident type 2 diabetes in a recent meta-analysis of prospective cohorts. Another recent meta-analysis of prospective studies and randomized controlled trials focused on CVD and concluded that reductions in risk were most strongly associated with the olive oil, fruit, vegetable and legume components of the adherence scores (88).

10. See also: https://www.sevencountriesstudy.com/ [Accessed Dec 20 2018].

And another recently updated meta-analysis also documented associations between increased adherence to a Mediterranean diet and reductions in a range of cancers and cancer mortality; these authors associated cancer risk reductions primarily with protective effects of fruits, vegetables and whole grains (89).

The Mediterranean diet concept also provides an example of the iterative process for defining a healthy dietary pattern. Since the original study based on the Greek diet, the evidence base has been built by a large body of research on diverse versions of the diet, followed by reviews and meta-analyses that have helped to define the core common elements in protective diets. See **Box 2** for a description of general characteristics of the Mediterranean diet.

Note that although numerous studies have documented benefits outside of the Mediterranean region, particularly from elsewhere in Europe and from the U.S., as for the DASH diet there is far less evidence from the global south. For example, in the recent meta-analyses cited above (88, 89) none of the studies included in the reviews were from Africa or Latin America and only two studies, one each from Singapore and China, were from Asia.

Box 2. Mediterranean Diet

There is no single definition or operational definition of the Mediterranean diet; however, most definitions have a number of elements in common. Sofi et al.[a] provided a useful summary of elements from a set of prospective cohort studies published between 2010 and 2013.

Studies presented by Sofi were primarily from Europe and included the multi-country EPIC[b] study as well as additional studies from some of the EPIC study countries (Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and the UK). Several studies were from the U.S., and no studies were from Asia, Africa, or Latin America.

There was high consistency in terms of components of the adherence score across studies, but high variability in the amounts per food or ingredient that defined higher vs. lower intake. Across most studies, components included:

- High intake of legumes (rarely: grouped with vegetables or nuts)
- High intake of cereals (rarely: grouped with potatoes, or specified as pasta, or as whole-grain)
- High intake of fruit and nuts, or of fruit only
- High intake of vegetables (rarely: grouped with legumes or with potatoes)
- High intake of fish
- Low intake of meat and meat products (rarely: specifying processed meat or poultry as well; rarely, including eggs in addition to meat and meat products)
- Low intake of dairy products (rarely: low butter only)
- High ratio of MUFAs : SFAs (rarely: high PUFAs : SFAs; or MUFAs + PUFAs : SFAs; or high olive oil and low butter)[c]
- Moderate intake of alcohol
- Rarely included: low intake of soft drinks; low intake of potatoes

a. Sofi F, Macchi C, Abbate R, Gensini GF, Casini A. Mediterranean diet and health status: an updated meta-analysis and a proposal for a literature-based adherence score. Public Health Nutr. 2014;17(12):2769-82. (84)

b. EPIC = European Prospective Investigation into Cancer and Nutrition

c. MUFAs = monounsaturated fatty acids; PUFAs = polyunsaturated fatty acids; SFAs = saturated fatty acids

2.5

Evidence synthesis: Food-based dietary guidelines

The DASH diet study and the Mediterranean diet literature illustrate two approaches to developing the concept of a healthy dietary pattern that emerged in specific contexts. The third and most common approach involves synthesizing evidence from a wide range of all relevant clinical and epidemiological evidence. This is the approach taken in development of many national FBDGs.

Dietary guidelines – along with associated “consumer-facing” food guides, graphics, etc. – aim to translate available science into behavioral advice for populations. During the process of developing FBDGs, national committees consider available evidence on nutrient intakes, gaps between intakes and requirements, and overconsumption. In addition, evidence relating food and food substances to clinical outcomes of public health importance is considered. More recently, evidence for healthy dietary patterns has been considered and incorporated into some guidance. Guidelines have been developed at national level, and in addition there is some limited global guidance, described below. In both national and global contexts, metrics have been developed to reflect the guidance; these metrics are further discussed in Section 6.

The U.S. Dietary Guidelines provide an example of the evidence synthesis process. The U.S. 2015 Dietary Guidelines Advisory Committee (DGAC) considered ‘portfolios of evidence’ for sugars and: body weight, dental caries, and type 2 diabetes; sodium and blood pressure; and saturated fat and CVD. They also considered evidence portfolios for several defined dietary patterns and body weight, CVD, and type 2 diabetes, among other outcomes ((16); see Appendix 2).

Of particular value, the Dietary Patterns Methods Project (DPMP)[11] was conceived to contribute to the U.S. Dietary Guidelines process with harmonized analyses comparing scores for four major operationalized dietary patterns (Mediterranean Diet Score, the Healthy Eating Index (HEI-2010, an index operationalizing the previous U.S. Dietary Guidelines; see **Box 3**), Alternate Healthy Eating Index (AHEI (90); see **Box 4**), and DASH) across three large cohorts. Notably, the DPMP included one of the largest and most ethnically diverse cohorts currently under study, globally.[12] The operationalized dietary patterns, including the HEI, the AHEI, and operationalized versions of the DASH and Mediterranean diet, will be further discussed in Section 6.

In the synthesis paper of the DPMP the authors assessed whether higher dietary quality, as characterized by four indices, was consistently associated with lower all cause, CVD, and cancer mortality in all cohorts. They reported notable similarities across indices in ranking individuals and in the strength of associations to health outcomes and conclude that multiple indices capture the same core dimensions of healthy diets (74).

11. See: https://epi.grants.cancer.gov/dietary-patterns/ [Accessed Dec 20 2018].
12. The Multiethnic Cohort ‘was established to examine lifestyle risk factors, especially diet and nutrition, as well as genetic susceptibility (an inherited tendency to react more strongly to particular exposures) in relation to the causation of cancer....The cohort is comprised of more than 215,000 men and women primarily of African American, Japanese, Latino, Native Hawaiian and Caucasian origin.’ See: http://www.uhcancercenter.org/research/the-multiethnic-cohort-study-mec [Accessed Dec 20 2018].

Box 3. Healthy Eating Index

The Healthy Eating Index (HEI) is a measure of diet quality used to assess adherence to key recommendations in the U.S. Dietary Guidelines. The HEI was first developed in 1995 and has been updated several times, to align with updates to the Guidelines. The current version of the HEI is described at the website of the U.S. Department of Agriculture Center for Nutrition Policy and Promotion:[a]

> *The HEI uses a scoring system to evaluate a set of foods. The scores range from 0 to 100. An ideal overall HEI score of 100 reflects that the set of foods aligns with key dietary recommendations….*
>
> *The HEI-2015 includes 13 components that reflect the key recommendations in the 2015-2020 Dietary Guidelines for Americans. There are two groupings:*
>
> - *Adequacy components* represent the food groups, subgroups, and dietary elements that are encouraged. For these components, *higher* scores reflect higher intakes, because *higher* intakes are desirable.
> - *Moderation components* represent the food groups and dietary elements for which there are recommended limits to consumption. For moderation components, *higher* scores reflect *lower* intakes, because lower intakes are more desirable.
>
> *Overall, a higher total HEI score indicates a diet that aligns better with dietary recommendations.*

a. See: https://www.cnpp.usda.gov/healthyeatingindex [Accessed Dec 20 2018].

Box 4. Alternate Healthy Eating Index

The Alternate Healthy Eating Index (AHEI) was originally developed in 2002 and updated to AHEI-2010 in a 2012 publication.[a] AHEI is based on a synthesis of evidence for foods and nutrients predictive of chronic disease risk. Most elements in the index are scored based on absolute a priori cut-offs except for sodium, where the scoring is based on observed deciles of consumption.[b] As with the DASH and Mediterranean diets, AHEI scores have been associated with differential risk for a range of chronic illnesses, and mortality.[a,c]

The AHEI illustrates the iterative role indices can play in evidence-generation and in informing revision of guidance. Both versions of the AHEI, as the name implies, were explicitly developed as an alternative to the Healthy Eating Index (HEI) based on the U.S. Dietary Guidelines. The AHEI was based on an alternative synthesis of evidence.

The updated AHEI-2010 sought to incorporate additional distinctions with associations to disease outcomes; specifically, the AHEI-2010 *'explicitly emphasizes high intakes of whole grains, polyunsaturated fatty acids, nuts, and fish and reductions in red and processed meats, refined grains, and sugar-sweetened beverages'* (Chiuve et al., p. 8).

In an analysis of two prospective cohorts comparing the older HEI-2005 and the AHEI-2010, the authors demonstrated stronger associations to chronic disease outcomes for the AHEI-2010. They concluded that:

> *'…future revisions of Dietary Guidelines may consider special emphasis on selecting the healthiest choices within each food group, specifically high-quality grains (whole vs. refined grains) and protein sources (nuts/beans/fish vs. red/processed meats), and encouraging greater intake of PUFA and reducing intake of sugar-sweetened beverages' (Chiuve et al., p. 8).*

a. Chiuve SE, Fung TT, Rimm EB, Hu FB, McCullough ML, Wang M, et al. Alternative dietary indices both strongly predict risk of chronic disease. J Nutr. 2012;142(6):1009-18. (90)

b. This was due to a lack of brand-specificity in the food-frequency questionnaire, which therefore did not allow accurate estimates of absolute intakes of sodium (Chiuve et al., p. 2).

c. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, et al. The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr. 2015;145(3):393-402. (74)

The evidence portfolios considered by the DGAC were the result of systematic reviews of evidence related to the selected food substances or dietary patterns and the outcomes. Based on these reviews, the 2015 Dietary Guidelines incorporated an even stronger emphasis on overall dietary patterns in recognition that health benefits, including chronic disease risk reduction, accrued not to individual dietary components but to the entire pattern. In sum, the scientific report of the 2015 DGAC (16) (which precedes and is an input to the Guidelines development process) concluded that:

'the U.S. population should be encouraged and guided to consume dietary patterns that are rich in vegetables, fruit, whole grains, seafood, legumes, and nuts; moderate in low- and non-fat dairy products and alcohol (among adults); lower in red and processed meat; and low in sugar-sweetened foods and beverages and refined grains' (p. 4).

However, the scientific report generated some controversy and contrasting input from food industry and other stakeholders, particularly in relation to advice to consume a dietary pattern 'lower in red and processed meat' and the inclusion of sustainability as a consideration.[13] The recommendation to reduce consumption of red meat is not found in the 2015 U.S. Dietary Guidelines.

Globally, FBDGs have now been developed by 90 countries. Several reviews have described commonalities among national FBDGs summarized at regional or global level (WHO (91) for Europe; FAO (92) for Latin America; Fuster (93) for the Caribbean; Tee et al. (94) for Southeast Asia; Fischer and Garnett (95) on sustainability in FBDGs, and Albert (96) and Herforth et al. (97), for global overviews).

The most recent review of FBDGs across the 90 countries (Herforth et al. (97)) identifies consistent themes and messages across countries but also many differences, including in how foods are grouped, the emphasis given to messages on moderation as compared to 'encouraged' food groups, and the level of specificity in guidance, for example in relation to quantities to consume. Consistent themes include encouraging consumption of diverse diets and of fruits and vegetables, and encouraging moderation in consumption of sodium or salt, fats or specific fats, and sugar or sweets. Consistency likely reflects global guidance, particularly from WHO (see below).

At the global level, WHO and FAO have provided very limited food-based dietary guidance; this was in recognition of the wide variety of dietary patterns globally, and the need to engage in national processes to elaborate guidelines as described in WHO 1998; global guidelines were considered *'neither feasible nor practical'* (98, p. 1146).

However, the WHO 'Healthy Diet Fact Sheet' (see **Box 5**) has provided some advice for consumers and a partial framework for evaluating diet quality. The Fact Sheet reflects a synthesis and practical application of several guidelines and systematic reviews, and the landmark report of the WHO/FAO Expert Consultation on diet, nutrition and the prevention of chronic diseases (99). As with the U.S. Dietary Guidelines, several metrics operationalize this guidance, and are further discussed in Section 6.

13. See for example a timeline with links to stakeholder inputs at: http://civileats.com/2016/01/08/shaping-the-2015-dietary-guidelines-a-timeline/ [Accessed Dec 20 2018].

The key points in the WHO description of a healthy diet are reflected in many national FBDGs. The WHO also developed the '3 Fives' materials *(Five Keys to safer food, Five Keys to a healthy diet, Five Keys to appropriate physical activity)* launched at the time of the Beijing Olympics in 2008, and the brochure was subsequently adapted for a campaign around the football World Cup in South Africa in 2010.[14] *The 'Five keys to a healthy diet'* (**Box 6**) provides consumer guidance similar to many national FBDGs.

Except for a target amount of fruits and vegetables, the WHO guidance in **Boxes 5 and 6** is qualitative with respect to foods, with consumers advised to 'eat', 'choose' or 'limit' various types of food, but without guidance on quantitative limits or advisable portions per day or week. Lack of quantitative guidance may present a challenge in interpretation by and for consumers, and certainly presents a challenge in measuring adherence. In contrast, many (but not all) national FBDGs translate guidance into concrete recommendations on the number of portions per day or week to consume per food group, and on portion sizes.

Note that the *Fact Sheet* provides only one quantitative food-based criterion, for fruits and vegetables. Legumes, nuts and whole grains are indicated as part of the healthy diet, but with no recommendations for quantity or frequency of consumption.

Other recommendations are for 'food substances' including free sugars and *trans* fat. Several food and beverage items that may include free sugars or *trans* fat are noted, but no specific guidance is provided on avoidance of beverages or foods. The salt recommendation is expressed in a household unit and as consumed, but in contrast to many national FBDGs, no mention is made of processed foods that are typically high in sodium.

The *Fact Sheet* is currently silent on consumption of ASFs (dairy, meat, fish and eggs), which are all sources of highly bioavailable nutrients, but which are consumed in excess of needs by many in middle- and high-income countries.

As noted, recently the *Framework for Action to guide the implementation of the commitments of the Rome Declaration on Nutrition adopted by the Second International Conference on Nutrition* (19) called on WHO and FAO to develop international guidelines on healthy diets, and work is underway (*personal communication from Dr. F. Branca*). A growing evidence base around the common elements in healthy dietary patterns (16, 74, 86) as well as the prominent place of dietary and related metabolic risk factors in the global burden of disease (1, 104) may further motivate demand for global food-based guidance.

In line with this and recognizing the lack of global guidance, the GLOPAN provided a 'picture of a high-quality diet' to inform food systems policies ((17), p. 41). GLOPAN considered diverse needs related to all forms of malnutrition as well as requirements for food safety and sustainability and articulated the elements of a high-quality diet (**Box 7**). While the purpose of the GLOPAN description was to inform policy, and not to provide dietary guidance for individuals, we include it in this section on dietary guidelines because in fact their description draws from and is articulated similarly to many national FBDGs. As in the WHO healthy diet statements, there are no quantitative criteria for intake of foods or food groups.

In addition to the efforts reflected above, there is an on-going effort undertaken by the EAT-Lancet Commission for Food, Planet and Health. This Commission has committed to address the question of 'What is a healthy diet?' (among others) at the global level, with publication of results expected in January 2019.[15]

14. The brochure and briefing materials can be downloaded from: http://www.who.int/foodsafety/areas_work/food-hygiene/3_fives/en/ [Accessed Dec 20 2018].
15. See: https://eatforum.org/initiatives/eat-lancet/ [Accessed Dec 20 2018].

Box 5. World Health Organization 'Healthy Diet'

Fact sheet N°394, Updated September 2015[a]

'Overview

Consuming a healthy diet throughout the lifecourse helps prevent malnutrition in all its forms as well as a range of noncommunicable diseases and conditions. But the increased production of processed food, rapid urbanization and changing lifestyles have led to a shift in dietary patterns. People are now consuming more foods high in energy, fats, free sugars or salt/sodium, and many do not eat enough fruit, vegetables and dietary fibre such as whole grains.

The exact make-up of a diversified, balanced and healthy diet will vary depending on individual needs (e.g. age, gender, lifestyle, degree of physical activity), cultural context, locally available foods and dietary customs. But basic principles of what constitute a healthy diet remain the same.

For adults

A healthy diet contains:

- *Fruits, vegetables, legumes (e.g. lentils, beans), nuts and whole grains (e.g. unprocessed maize, millet, oats, wheat, brown rice).*
- *At least 400 g (5 portions) of fruits and vegetables a day (2). Potatoes, sweet potatoes, cassava and other starchy roots are not classified as fruits or vegetables.*
- *Less than 10% of total energy intake from free sugars (2, 5) which is equivalent to 50 g (or around 12 level teaspoons) for a person of healthy body weight consuming approximately 2000 calories per day, but ideally less than 5% of total energy intake for additional health benefits (5). Most free sugars are added to foods or drinks by the manufacturer, cook or consumer, and can also be found in sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates (4).*
- *Less than 30% of total energy intake from fats (1, 2, 3). Unsaturated fats (e.g. found in fish, avocado, nuts, sunflower, canola and olive oils) are preferable to saturated fats (e.g. found in fatty meat, butter, palm and coconut oil, cream, cheese, ghee and lard) (3). Industrial trans fats (found in processed food, fast food, snack food, fried food, frozen pizza, pies, cookies, margarines and spreads) are not part of a healthy diet (4).*
- *Less than 5 g of salt (equivalent to approximately 1 teaspoon) per day (6) and use iodized salt....'*

1. Hooper L, Abdelhamid A, Moore HJ, Douthwaite W, Skeaff CM, Summerbell CD. Effect of reducing total fat intake on body weight: systematic review and meta-analysis of randomised controlled trials and cohort studies. BMJ. 2012; 345: e7666. (100)
2. Diet, nutrition and the prevention of chronic diseases: report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series, No. 916. Geneva: World Health Organization; 2003. (99)
3. Fats and fatty acids in human nutrition: report of an expert consultation. FAO Food and Nutrition Paper 91. Rome: Food and Agriculture Organization of the United Nations; 2010.
4. Nishida C, Uauy R. WHO scientific update on health consequences of trans fatty acids: introduction. Eur J Clin Nutr. 2009; 63 Suppl 2:S1–4. (101)
5. Guideline: Sugars intake for adults and children. Geneva: World Health Organization; 2015.(102)
6. Guideline: Sodium intake for adults and children. Geneva: World Health Organization; 2012. (103)

a. http://www.who.int/mediacentre/factsheets/fs394/en/ [Accessed Dec 20 2018].

Box 6. World Health Organization 'Five keys to a healthy diet'[a]

'1. Give your baby only breast milk for the first 6 months of life

From birth to 6 months of age your baby should receive only breast milk, day and night

Breast feed your baby whenever the baby feels hungry

2. Eat a variety of foods

Eat a combination of different foods: staple foods, legumes, vegetables, fruits and foods from animals

3. Eat plenty of vegetables and fruits

Consume a wide variety of vegetables and fruits (more than 400 g per day)

Eat raw vegetables and fruits as snacks instead of snacks that are high in sugars or fat

When cooking vegetables and fruits, avoid overcooking as this can lead to loss of important vitamins

Canned or dried vegetables and fruits may be used, but choose varieties without added salt or sugars

4. Eat moderate amounts of fats and oils

Choose unsaturated vegetable oils (e.g. olive, soy, sunflower, corn) rather than animal fats or oils high in saturated fats (e.g. coconut and palm oil)

Choose white meat (e.g. poultry) and fish that are generally low in fats rather than red meat

Limit consumption of processed meats and luncheon meats that are high in fat and salts

Use low- or reduced-fat milk and dairy products, where possible

Avoid processed, baked, and fried foods that contain industrial trans fatty acids

5. Eat less salt and sugars

Cook and prepare foods with as little salt as possible

Avoid foods with high salt content

Limit the intake of soft drinks and fruit drinks sweetened with sugars

Choose fresh fruits for snacks instead of sweet foods and confectionery (e.g. cookies and cakes)'

a. http://www.who.int/foodsafety/areas_work/food-hygiene/3Fives_poster.pdf?ua=1 [Accessed Dec 20 2018].

Box 7. Global Panel on Agriculture and Food Systems for Nutrition: Elements of high-quality diet[a]

'Drawing the evidence together with an emphasis on adequacy, diversity and balance, current recommendations from UN agencies, governments and scientific bodies point towards the following choices for ensuring a high-quality diet for all people over two years of age:

- *Eat a diverse diet drawing on as many food groups as possible.*
- *Consume diets that contain plenty of wholegrains, fruits and vegetables, fibre and nuts and seeds.*
- *Unless a vegetarian or intolerant to dairy, consume eggs, moderate amounts of dairy (mainly milk), fish and small amounts of meat.*
- *Avoid, or consume low levels of, added sugars, sugary snacks and beverages.*
- *Avoid, or consume low levels of, processed meat.*
- *Replace saturated and industrial trans fats with unsaturated fats.*
- *Eat low levels of salt and ensure that all salt that is consumed is iodized.*

Babies under six months of age should consume only breast milk; infants and young children 6–23 months of age should continue to consume breast milk but consume complementary foods that are sufficiently diverse and nutrient dense to promote optimal child growth.

The food consumed needs to be free of foodborne disease agents and toxins. There is a tension here since many fresh, perishable foods, which can contribute to a high-quality diet – e.g. fruits and vegetables, dairy and fish – are also the leading sources of foodborne disease.

Food processing can be beneficial for the promotion of high-quality diets; it can make more food more available as well as making food safer. Some forms of processing can lead to very high densities of salt, added sugar and saturated fats and these products, when not consumed in low amounts, will undermine diet quality.

To be accessible to future generations, high-quality diets need to be produced, processed, distributed and prepared in ways that use natural resources sustainably and mitigate the generation of greenhouse gases.'

a. Global Panel on Agriculture and Food Systems for Nutrition. 2016. Food systems and diets: Facing the challenges of the 21st century. London, UK, ssp. 41. (17)

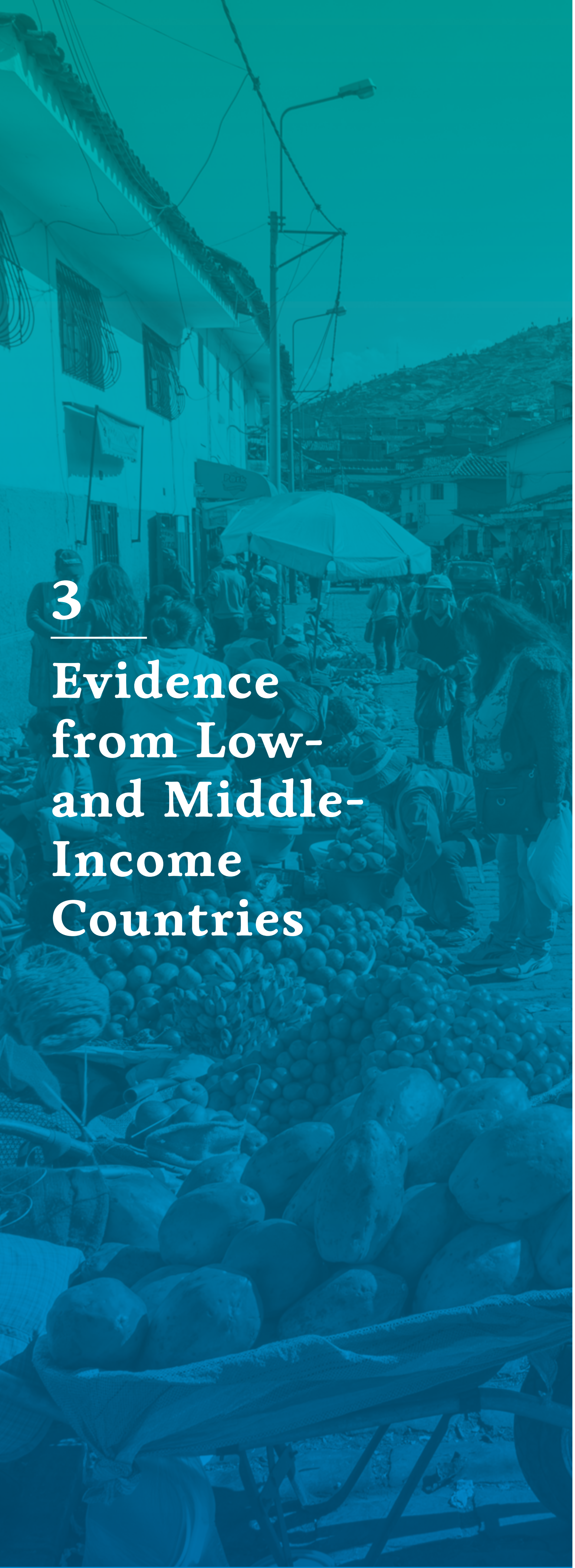
2.6

Evidence synthesis: Cardioprotective diets

Mozaffarian (18) synthesized a very wide range of evidence relevant to cardiometabolic health and have proposed dietary priorities that are articulated similarly to FBDGs (i.e., in terms of food groups and servings per day or week; see **Table 1** below in Section 6.1.3). These are summarized as:

'Evidence-informed dietary priorities include increased fruits, nonstarchy vegetables, nuts, legumes, fish, vegetable oils, yogurt, and minimally processed whole grains; and fewer red meats, processed (e.g., sodium-preserved) meats, and foods rich in refined grains, starch, added sugars, salt, and trans fat. More investigation is needed on the cardiometabolic effects of phenolics, dairy fat, probiotics, fermentation, coffee, tea, cocoa, eggs, specific vegetable and tropical oils, vitamin D, individual fatty acids, and diet- microbiome interactions' (p. 187).

He notes that the historical focus on meeting nutrient requirements has not resulted in cardioprotective diets, and underscores the importance of the dietary patterns approach, given the complex array of pathways through which dietary patterns exert physiological effects and influence weight homeostasis.



3 Evidence from Low- and Middle-Income Countries

3.1

Rationale for examining evidence separately for low- and middle-income countries

In theory, relationships between dietary patterns and outcomes could vary between high-income and lower-income settings for at least three reasons.

First, defined dietary patterns – although recently becoming more comprehensive – still describe only certain elements of diets and generally in broad terms (e.g. food groups). This leaves open the possibility that diets that meet the criteria of a particular healthy dietary pattern could still differ by context – either in the specific constellation and balance of foods selected (e.g. within food groups) and their health effects, and/or in unmeasured aspects of the diet. This will be illustrated below with the case of vegetarian diets.

Second, and analogously, other unmeasured aspects of health and lifestyle that also affect the same health risk factors and outcomes could differ between settings, resulting in a different relationship between diets, risks and outcomes. Level of physical activity is a clear example. However, in the context of urbanization in the global south, lifestyles are transitioning along with diets.

Third, biological differences could require different definitions for healthy diets. For example, several diet patterns developed in the global north include substantial quantities of dairy, but lactose intolerance is widespread in the global south.

For these reasons, we undertook to consider whether evidence relating dietary patterns to health has been consolidated specifically for LMICs in the global south. Before describing that evidence, we first consider issues related to vegetarian diet patterns, and the challenge of defining optimal intakes of ASFs.

3.2

Vegetarian dietary patterns in south Asia

Many in the global south consume primarily vegetarian diets because they cannot afford any other. Among people who *choose* to consume vegetarian diets, there is wide variation in foods consumed, including vegan, lacto-, ovo-, and lacto-ovo diets. Some consider diets including fish (with or without eggs and/or dairy but excluding poultry and mammal meat) to be 'pescovegetarian' (see e.g. Singh et al. (105)). Similarly, diverse definitions are found in studies relating vegetarianism to health outcomes. Increasingly, the term 'plant-based diet' is used to describe a diet dominated by plant foods, but which may include small amounts of various ASFs (e.g. Satija et al. (106)).

Given that in general vegetarian and plant-based diets have been considered to be healthy (107), several recent studies have examined the apparent paradox of high prevalence of vegetarianism and high prevalence of chronic disease risks and morbidity in South Asia (105, 108).

In examining whether health risks vary when using a consistent definition of vegetarianism that allowed any of the versions above, Jaacks et al. (108) compared cardiometabolic risk factors among urban South Asians in three cities to a national sample of U.S. vegetarians. Urban South Asian vegetarians were nearly as likely as non-vegetarians to be overweight or obese (49% vs. 53% among non-vegetarians) whereas in the U.S., vegetarians were substantially less likely to be overweight or obese (48% vs. 68%). U.S. vegetarians were also less likely than non-vegetarians to be centrally obese, but there was no difference between South Asian vegetarians and non-vegetarians.

Diet quality contrasts between vegetarians and non-vegetarians also differed between South Asian and U.S. vegetarians, with South Asian vegetarians more likely, and U.S. vegetarians less likely, to consume dairy, fried food and desserts as compared to non-vegetarians in the respective samples. Singh et al. (105) also examined this paradox and proposed several explanations related to a nutrition transition among vegetarians in India, including: substitution of white rice for brown rice; overconsumption of other refined carbohydrate (among which they include potato); changes in the amounts and types of cooking fats and oils; and increased consumption of fast foods/processed foods.

Consistent with these studies from India – the country with the largest number of vegetarians globally – and based on current knowledge of healthy diets, it is clear that vegetarian or plant-based diets may or may not be healthy diets depending on, among others, quality of carbohydrates and fats consumed (106). Similarly, Mozaffarian (18) concludes that *'vegetarianism per se is neither necessary nor sufficient for a good diet'* (p. 191).

This illustrates how unmeasured aspects of diets may mean that a dietary pattern understood to confer health benefits in one context, may not in another. Because of the limitations illustrated above, we do not recommend development of diet quality metrics based on the concept of vegetarianism *per se*, but recognize the value of the concept of plant-based diets and the need to define minimum and maximum levels of ASF intake (and of various types of ASFs) consistent with both nutrient adequacy and other health benefits. Plant-based diets may also deliver environmental benefits (see Section 5.7 below).

3.3

Animal-source foods

Excessive consumption of ASFs is a concern in many high- and middle-income countries, and among upper-income consumers in low-income countries as well. Concerns with sustainability of ASFs consumption are discussed below, in Section 5.7. However, among WRA in many resource-poor settings intakes of ASFs remain very low, particularly in many rural areas. In one analysis of intakes in 8 urban and rural sites in Africa and South Asia, intakes of ASFs as a percent of energy ranged from 2-5% in rural or mixed urban/rural samples and were 7-12% in two urban West African sites (109). In the context of developing indicators and indices for LMICs, where many people cannot afford much or any ASFs and where WRA require nutrient-dense diets to meet needs, defining a minimum required amount of ASFs is necessary.

ASFs deliver a range of micronutrients in highly bioavailable forms. In the absence of supplements or fortified products, vitamin B12 is only delivered by ASFs. Vitamin B12 deficiencies, including sub-clinical deficiencies, have been widely documented among vegetarians and vegans (110). Even assuming they would want to purchase fortified foods or supplements, many WRA in LMICs do not have access, or consistent access (including economic access) to supplements or products fortified with B12. In many cases, WRA would prefer to purchase ASFs if affordable.

In addition to vitamin B12, calcium needs of WRA are very difficult to meet without ASFs. There is controversy over appropriate calcium intake recommendations for populations in the global south (111). But even when considering a lower target level of intake set by WHO/FAO for environments with lower animal protein intakes, it is challenging to meet calcium needs for WRA without dairy foods (9).[16] Small fish eaten whole, with bones – another ASF – can also contribute. The challenge of meeting calcium requirements without dairy foods is also reflected in the near universal inclusion of dairy foods in FBDGs (97).

At the same time, as noted, lactose intolerance is widespread though far from universal in the global south (114, 115). Some populations without lactase persistence nevertheless consume dairy, and there are various hypotheses concerning tolerance, but reasons are not fully known. Some have suggested that fermentation may play a role (114, 115).

In considering whether and how dairy foods might be reflected in healthy dietary patterns in LMICs, it should be noted that dairy is not only a source for calcium. There is currently lack of consensus on health effects of diverse dairy foods, but benefits may go beyond their role in delivering specific micronutrients, and fermented products may be beneficial (18, 116-118). Based on knowledge to date the GBD study group has characterized both low calcium intake and, separately, low milk intake as dietary risk factors, in relation to certain cancers (1). Recently, researchers from a multi-country cohort including LMICs have reported associations of higher dairy intake with lower risks of mortality and major cardiovascular events (119); see further details of the Prospective Urban Rural Epidemiology (PURE) Study in the next section.

16. Of note, in the Cochrane review (112) undergirding the current WHO recommendation for calcium supplementation during pregnancy among women with low intakes (113), "low intakes" were defined as less than 900 mg/d, which is intermediate between the RDAs/RNIs and the WHO/FAO suggestion of 750 mg (800 mg, last trimester) for environments with lower animal protein intakes.

3.4

Reviews and studies from low- and middle-income countries

Knowledge relating healthy dietary patterns to cardiometabolic risk factors and/or health outcomes has not been consolidated and synthesized for LMICs, and it was beyond our scope to perform a systematic review of all available individual studies. The systematic reviews performed for the U.S. Dietary Guidelines process, which are among the most comprehensive available,[17] nevertheless by design included only studies from countries scoring high or very high on the Human Development Index (120). As noted above there were few or no studies from Sub-Saharan Africa, South or Southeast Asia, or Latin America in the systematic reviews relating the DASH and Mediterranean diets to cardiometabolic risks and health outcomes.

We searched for reviews and meta-analyses of prospective studies of *a priori* dietary patterns and health outcomes in LMICs, and for multi-country studies that included LMICs. In addition, although we could not aim to review and filter all individual studies from the global south, it was feasible to do so for Sub-Saharan Africa due to the relatively small number of studies identified with broad search terms.

We found one systematic review and meta-analysis from Latin America examining impacts on blood pressure from randomized controlled trials that included a dietary intervention (121). The authors identified 6 small trials (range for sample size of 42-142) with diverse behavioral interventions, including versions of the DASH diet and adapted Mediterranean diets; two trials also included physical activity in the intervention and one was among HIV+ individuals. Four of the six were from Brazil. The meta-analysis demonstrated a small favorable impact on diastolic blood pressure.

We could find no other systematic reviews of *a priori* dietary patterns studies for LMICs. Four recent or ongoing multi-country studies include measurement and characterization of diet quality, and also include LMICs: the INTERHEART Study, the INTERSTROKE Study, the PURE Study, and the Latin American Study of Nutrition and Health (ELANS).

The INTERHEART Study[18] used a case-control design to explore the association of a range of potentially modifiable risk factors with acute myocardial infarction. The study included 262 sites in 52 countries, including countries in all regions of the world. Dietary intakes were assessed using a 19-item food frequency questionnaire that assessed frequency, but not quantity of consumption. Lack of daily consumption of fruits and vegetables was identified as a consistent risk factor for myocardial infarction across all regions, globally (122). No *a priori* dietary patterns were evaluated, but a study-specific dietary risk score was calculated based on relative consumption of foods considered (*a priori*) to be predictive of risk (meat, salty snacks, and fried foods) or protective (fruits, green leafy vegetables, other cooked vegetables, and other raw vegetables) (123).[19] The dietary risk score was associated with risk of myocardial infarction in most regions, but not in Africa.

17. The reviews for the U.S. dietary guidelines process incorporated evidence on a wide range of outcomes. Concerning cancers only, the World Cancer Research Fund International's Continuous Update Project (CUP, http://www.wcrf.org/int/research-we-fund/continuous-update-project-cup [Accessed Dec 20 2018]) provides comprehensive evidence syntheses by body location/system. We did not review the material across these to determine to what extent the evidence includes studies from LMICs. There are CUP synthesis reports available for cancers in twelve body locations/systems and, for example, for colorectal cancer alone, CUP findings were published in ten peer-reviewed systematic reviews/meta-analyses. The synthesis report for colorectal cancer (the most recent CUP report) did not comment on applicability of evidence to LMICs specifically.
18. The INTERHEART Study was a global study of risk factors for acute myocardial infarction. See: http://www.phri.ca/research/population-health/interheart/ [Accessed Dec 20 2018].
19. Three dietary patterns were also derived using factor analysis, but are not described here as we have excluded this approach from our review.

The INTERSTROKE study[20] also used a case-control design, and examined potentially modifiable risk factors for stroke in 32 countries, including 5 in Africa, 2 in South Asia, 3 in Southeast Asia, and 6 in South America (124). A modified AHEI (mAHEI) was used to characterize diet quality. Results for the association between diet quality and stroke were heterogeneous; higher diet quality as measured by the mAHEI was associated with lower risk in most regions but was non-significant in Africa, and in South Asia a higher (better) mAHEI was associated with higher risk. Based on this, the authors raise a caution about the global application of dietary risk scores developed in the U.S. and Europe.

The PURE study[21] was designed to fill knowledge gaps related to the impact of urbanization on the development on a broad range of risk factors for CVD, including in LMICs. The cohort includes over 100,000 adults aged 35 to 70 years from 18 low-, middle-, and high-income countries in seven geographical regions: North America and Europe, South America, the Middle East, south Asia, China, southeast Asia, and Africa (3). Diet quality was characterized using the AHEI (125). To date, prospective associations of the AHEI with outcomes have not been published; however, recently the consortium published results related to prospective associations of consumption of fruits, vegetables, and legumes (3) and macronutrients (126) to CVD and mortality. While the inferences drawn have sparked controversy[22] the results generally support the healthfulness of diets rich in fruits, vegetables and legumes, and with levels of fat and carbohydrate intake consistent with the Mediterranean diet and some other healthy dietary patterns.

The ongoing ELANS aims to provide comparable data on nutrition and physical activity for representative samples of urban populations in eight countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru and Venezuela) (127). In the published study protocol there is no mention of proposed analysis of specific defined *a priori* dietary patterns, but the study was designed explicitly to provide information on nutrition transitions in the region and the dietary data collected will be sufficient to characterize diet quality in a variety of ways. Results are not yet available.

Considering single studies from Sub-Saharan Africa, the Benin Study (128) assessed diet quality with two measures: a 14-point summary measure for micronutrient adequacy (scored yes/no across 14 micronutrients), and an 8-point preventive diet score reflecting adherence to WHO guidelines for the prevention of chronic diseases (99). In this cross-sectional study, Delisle et al. report that the micronutrient adequacy indicator, but not the preventive diet score, was positively associated with high-density lipoprotein (HDL) cholesterol (128). This difference highlights the potential usefulness, in the context of nutrition transitions, of either separate indices or indices that can be separated into their component parts.

20. INTERSTROKE is a study of the importance of conventional and emerging risk factors of stroke in different regions and ethnic groups of the world; see http://www.phri.ca/research-study/interstroke/ [Accessed Dec 20 2018].
21. See http://www.phri.ca/pure/ [Accessed Dec 20 2018].
22. See: [Accessed Dec 20 2018].
https://www.hsph.harvard.edu/nutritionsource/2017/09/08/pure-study-makes-headlines-but-the-conclusions-are-misleading/;
http://www.pcrm.org/media/news/pure-study-killer-carbs-or-poor-living-conditions;
https://foodrevolution.org/blog/food-and-health/pure-study-reporting/;
https://www.theatlantic.com/health/archive/2017/09/moderate-intake-of-things-linked-to-health/538428/;
https://www.acsh.org/news/2017/09/01/fruit-and-veggies-beneficial-heart-health-carbs-arent-what-11765;
https://oldwayspt.org/blog/pure-study-actually-no-carbs-dont-kill.

In another study, Delisle (129) summarized results across several studies of African populations or those of African descent. In these cross-sectional studies, cluster analysis was used to derive dietary patterns, but in addition the author reports elements of consistency in derived patterns and notes that:

'It appears that a limited number of foods predict diet quality and health outcomes in various population groups; in particular, fruit and vegetables, fish, whole-grain cereal, and legumes do so on the protective side, and sweets, processed meats, fried foods, fats and oils, and salty snacks do so on the negative side' (abstract, p. 224).

This author also notes the need for additional studies relating dietary patterns to outcomes, in diverse food cultures.

3.5

Extending evidence from the global north to the global south

In the absence of a consolidated evidence base from LMICs for associations of a priori dietary patterns to health outcomes, a judgment must be made on whether it is legitimate to assume that the contrasts that established associations to outcomes in the global north can be applied. The INTERSTROKE study provides a cautionary note and a call for additional research on the question of applicability.

Further, in both the South Africa PURE site (130) and in the Benin study (128), the problem of low micronutrient intakes was noted. In the context of 'double burdens', diet quality scores designed to capture both nutrient adequacy and excess consumption in the same metric may result in higher (better) overall scores in urban areas and/or among income subgroups that also have higher chronic disease risk, as was the case in South Africa (130), highlighting the need for careful construction and interpretation.

Adaptation of dietary patterns defined in the global north would require care. For example, in the DASH trial diets decisions on quantities of ASFs and 'alternative' protein foods (e.g. legumes) for all three diets were influenced by U.S. dietary patterns, with an aim of acceptability (66). Types of foods within groups were also influenced by U.S. food choices, and the sample menus conformed to typical U.S. meal patterns, for example with juice, cereal or muffins, and dairy for breakfast, and sandwiches for lunch (68, 131). Many Mediterranean dietary patterns emphasize olive oil or mono-unsaturated fats not commonly available to many low- and middle-income consumers in the global south.

However, arguably, to the extent that dietary patterns in LMICs in the global south (especially in urban areas) begin to approximate those in higher-income settings, the evidence base from the global north may be relevant. In support of this, Anand et al. (132), reporting on a Consensus Conference convened by the World Heart Federation, summarized evidence for food groups, food substances, and dietary patterns and risk of CVD, and included a focus on LMICs. They concluded that evidence for LMICs is low, weak, or absent but – while they call for additional trials and prospective studies in the global south – they also consider the evidence base for the Mediterranean diet to be sufficiently consolidated, and they provide suggestions for its adaptation with foods from other regions.

4

Defining a High-Quality Diet

The DASH diet, the Mediterranean Diet and its variations, and FBDGs all provide examples of healthy dietary patterns, but do not provide a concise definition. The operationalized metrics reflecting these patterns are themselves sometimes viewed as defining diet quality, but these are generally not universal and are operational rather than conceptual definitions. There is currently no consensus on a concise conceptual definition of diet quality adopted for global use, though several have recently been offered and have many common features.

Overall, the process of describing and defining a high-quality diet has been an iterative interplay of science, elaboration of guidance, operational definitions (metrics) based on the guidance that allow further evidence generation, revision of guidance, and so on.

As previously noted, for the U.S. context the DGAC (16) has provided a useful and concise description of a high-quality diet as being:

'rich in vegetables, fruit, whole grains, seafood, legumes, and nuts; moderate in low- and non-fat dairy products and alcohol (among adults); lower in red and processed meat; and low in sugar-sweetened foods and beverages and refined grains' (p. 4).

And this is similar to Mozaffarian's (18) dietary priorities for cardiometabolic health described above:

'increased fruits, nonstarchy vegetables, nuts, legumes, fish, vegetable oils, yogurt, and minimally processed whole grains; and fewer red meats, processed (e.g., sodium-preserved) meats, and foods rich in refined grains, starch, added sugars, salt, and trans fat' (p. 187).

However, Mozaffarian's synthesis rejects the relevance of the distinction between low- and higher-fat dairy products in favor of attention to other characteristics (e.g. fermentation).

The two syntheses above define a high-quality diet by describing what it does and does not include (abundantly, in moderation, etc.). Two other definitions focus on what a high-quality diet should deliver.

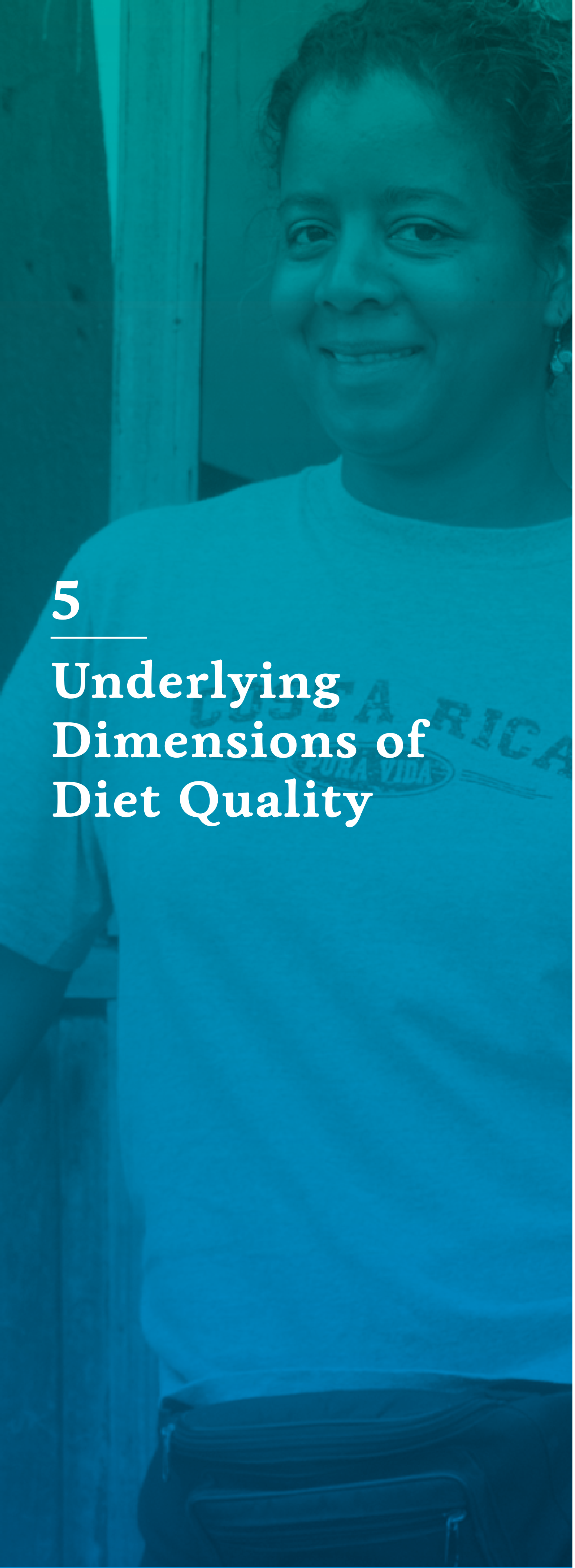
At global level, the ICN2 2014 Rome Declaration describes (19) 'healthy, balanced, diversified diets' as

'meeting nutrient requirements of all age groups and all groups with special nutrition needs, while avoiding the excessive intake of saturated fat, sugars and salt/sodium, and virtually eliminating trans fats, among others' (p. 5).

Elsewhere in the Declaration, issues of food security, safety, sustainability, and cultural acceptability are all addressed, but there is no unified, concise definition of 'diet quality'.

The GLOPAN (17) has suggested a broad but concise definition:

'High-quality diets are those that eliminate hunger, are safe, reduce all forms of malnutrition, promote health and are produced sustainably i.e. without undermining the environmental basis to generate high-quality diets for future generations' (p. 32).



5

Underlying Dimensions of Diet Quality

All definitions of diet quality – both conceptual and operational – explicitly or implicitly reflect selection of one or more dimensions or characteristics of quality and exclude other dimensions. Before moving on to measurement issues in the next section, this section outlines some commonly included dimensions.

While this section lists dimensions or attributes singly, this is not a rejection of the possibility of synergistic effects of positive attributes. The high-quality dietary patterns detailed earlier incorporate many of the key dimensions below – adequacy, nutrient density, macronutrient balance, diversity and proportionality, and moderation. It is worth noting again that these individual dimensions – just like individual nutrient-dense foods or food groups – may be necessary but not sufficient to deliver health benefits such as chronic disease risk reduction.

As in the definitions above, these dimensions and characteristics represent a mix of what we may want diets to deliver (e.g. adequacy, safety, sustainability) and other measurable characteristics that are thought to play a role in delivering high-quality diets. For example, nutrient density is a characteristic or dimension of diets that we associate with an increased likelihood of delivering nutrient adequacy, while avoiding excess energy intake or maintaining energy balance. Some dimensions are more closely related to nutrient intake recommendations (adequacy, macronutrient balance) whereas others are expressed in dietary guidelines (diversity, proportionality). Thus, the dimensions described below are not all on the same level or of the same type – but all have been included in various conceptual or operational definitions of diet quality.

Conceptions and operationalized definitions of high-quality diets differ in breadth. Some national dietary guidelines as well as the GLOPAN definition cited above include consideration of food safety and sustainability. The concept of sustainability alters the time frame for evaluating quality and requires consideration not just of current, but also of future consumers. 'Dietary' guidelines may also give guidance on physical activity. Some guidelines include advice on intake of water and/or alcohol and others do not. Some authors have proposed even broader sets of characteristics for diet quality, including organoleptic and sociocultural dimensions (133). But many descriptions of healthy dietary patterns, and all of the food-item based concepts (nutrient density, nutrient profile, processing level) exclude these broader considerations. In developing indices (or sets of indicators) choices must be made about which dimensions to include and reflect.

5.1

Adequacy

Adequacy is a core dimension of diet quality. Late 19th century conceptions of diet quality focused entirely on adequacy of energy and protein; 20th century conceptions incorporated adequacy of micronutrient and essential fatty acid intakes (22, 134). The concept of adequacy is featured in the ICN2 description of a healthy diet; in the GLOPAN definition, adequacy is reflected in the call to eliminate hunger, and to reduce all forms of malnutrition (implicitly including macro- and micronutrient deficiencies). Adequacy is defined by nutrient intake relative to requirements and is reflected in FBDGs development processes. FBDGs speak to adequacy both in messages to consume diverse food groups and specific food groups, and in some cases in quantitative guidance on portions and frequency of consumption for different food groups. FBDGs also often invoke the concept of nutrient density and encourage nutrient-dense foods to help ensure micronutrient adequacy within an energy-balanced diet. Healthy dietary patterns are also assumed to be – but have not always been explicitly demonstrated to be – adequate in providing sufficient quantities of macro- and micronutrients.[23] Diet quality indices incorporate the concept of adequacy through inclusion of either nutrient-based criteria and/or criteria related to sufficient consumption of a range of healthy food items/food groups, providing diverse nutrients.

5.2

Nutrient density

As described (see above, Section 2.1), nutrient density – usually, unit of nutrient per 100 kilocalories – is a concept that may originate at the food level but can be applied at many levels – food, diet or dietary pattern, food supply, etc. As just noted it is closely related to the concept of nutrient adequacy and is present in many FBDGs and reflected in many diet quality indicators and indices. We note it as a separate dimension because in measuring diet quality, nutrient density may be assessed instead of or in addition to adequacy. This may be either for conceptual reasons and/or to address measurement issues when estimated dietary intake data are used to construct indicators/indices (discussed below in Section 6.1).

23. See Alkerwi et al.(86) for a comparison of associations of five diet quality indices to micronutrient intake in the population-based ORISCAV-LUX (Observation of Cardiovascular Risk Factors in Luxembourg). With the exception of B12, associations with intakes of water-soluble vitamins were generally positive but several indices were negatively correlated with intakes of vitamins A and E, as well as vitamin B-12. However, there was no analysis of associations to adequacy.

5.3

Macronutrient balance

The concept of macronutrient balance evolved in the late 20th century in relation to chronic disease risk. The North American Acceptable Macronutrient Distribution Ranges (AMDR) and the WHO Ranges of Population Nutrient Intake Goals are described in **Box 8**. The WHO Healthy Diet Fact sheet incorporates the upper end of the range for fat intake (30% of energy) but does not incorporate the lower end, or the protein or carbohydrate ranges of the WHO Goals. Healthy dietary patterns and diet quality indices have often included criteria related to total fat and/or specific types of fat as a percent of energy, or ratios of mono- and/or polyunsaturated fat to saturated fat. More rarely, protein is a target nutrient. There is currently controversy over health effects of higher total fat in diets and risks of high carbohydrate diets, rising emphasis on quality of both fats and carbohydrates (rather than total intake), and consensus on avoidance of trans- fatty acids (18).

Recently, WHO's Department of Nutrition for Health and Development has released updated draft guidelines on intake of saturated fatty acids (SFAs) and *trans*- fatty acids, for adults and children. These guidelines were open for public comments in mid-2018 and remain under development.[24]

But, for the moment, the concept of macronutrient balance, expressed by broad AMDR or WHO ranges described in **Box 8** remains in global guidance. And at a certain, extreme point, excessive intake of one or two macronutrients would result in inadequate intake of the other. And this may in fact be evident for WRA in some resource-poor settings; for example, in one secondary analysis of five dietary data sets reflecting urban, peri-urban, and rural settings, women in the two rural sites (in Mozambique and Bangladesh) exceeded both the AMDR and the WHO range for percent of energy from carbohydrate, and fat intake as percent of energy fell substantially below the lower end of the AMDR and WHO ranges (135).

24. See: https://www.who.int/nutrition/topics/sfa-tfa-public-consultation-4may2018/en/ [Accessed Dec 20 2018].

Box 8. Macronutrient Ranges for Adults, as Percent of Energy

Both the North American Acceptable Macronutrient Distribution Ranges (AMDR)[a] and the globally applicable World Health Organization (WHO) Ranges of Population Nutrient Intake Goals[b] provide ranges for macronutrients as a percent of total energy intake.

The AMDR were set for carbohydrate, fat, n-6 and n-3 polyunsaturated fatty acids, and protein based on evidence that suggested their role in the prevention or increased risk of chronic diseases and based on ensuring sufficient intakes of essential nutrients. The AMDR for fat is 20-35% and the AMDR for carbohydrate is 45-65%. Key considerations included evidence for increased risk of cardiovascular disease from diets high in carbohydrate, and increased risks of excessive energy intakes and resulting weight gain when diets are high in fat. In addition, in the U.S. context diets exceeding 35% of energy from fat are high in saturated fat, and this was associated with cardiovascular risk. Trade-offs between the proportion of intake from fats and from carbohydrates were highlighted since these two macronutrients provide the majority of energy in most diets, and thus diets high in fat tend to be low in carbohydrate, and the reverse. Concerning protein, the IOM concluded that the lower end of the range could be set at 10%, which is approximately equivalent to the RDA, and that there were insufficient data to define the upper end of the range. This was therefore taken as 100% minus the sum of the lower values for fat and carbohydrate, resulting in an AMDR for protein of 10-35%.

The WHO ranges were aimed at preventing diet-related chronic diseases. The range for fat is set at 15-30% of energy, based on the following:

> *'Total fat energy of at least 20% is consistent with good health. Highly active groups with diets rich in vegetables, legumes, fruits and wholegrain cereals may, however, sustain a total fat intake of up to 35% without the risk of unhealthy weight gain. For countries where the usual fat intake is between 15% and 20% of energy, there is no direct evidence for men that raising fat intake to 20% will be beneficial… For women of reproductive age at least 20% has been recommended by the Joint FAO/WHO Expert Consultation on Fats and Oils in Human Nutrition that met in 1993.' (WHO 2003, p. 56).*

For protein (10-15% of energy) and carbohydrate (55%-75% of energy) no justification is articulated, except for the lower end of the range for protein: *'The suggested range should be seen in the light of the Joint WHO/ FAO/UNU Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition, held in Geneva from 9 to 16 April 2002.' (WHO 2003, p. 56).*

The conclusions of that consultation in 2002 provided a range of protein: energy ratios (both means and safe' levels for populations) for adults, depending on age, sex, body weight and physical activity level. Values for 'safe' levels range from ~7% for smaller young men with heavy physical activity to ~13% for heavy, older sedentary women (WHO/FAO/UNU 2007, p. 87).[c] The carbohydrate range could be taken by subtraction of the fat and protein ranges from 100%.

a. Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, D.C.: National Academies Press; 2002/2005. Available from: https://www.nal.usda.gov/sites/default/files/fnic_uploads/energy_full_report.pdf [Accessed Dec 20 2018]. (136)

b. World Health Organization. Diet, nutrition, and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation. World Health Organization; 2003. Report No.: 924120916X. Available from: http://www.who.int/dietphysicalactivity/publications/trs916/en/[Accessed Dec 20 2018]. (99)

c. WHO, FAO, UNU. Protein and amino acid requirements in human nutrition: report of a joint FAO/WHO/UNU expert consultation. Geneva; 2007. Report No.: 0512-3054 Contract No.: 935. Available from: http://www.who.int/nutrition/publications/nutrientrequirements/WHO_TRS_935/en/ [Accessed Dec 20 2018]. (137)

5.4

Diversity and proportionality

Unlike macro- and micronutrient adequacy and macronutrient balance, the closely linked concepts of diversity and proportionality are food- and food group-level concepts that have been expressed primarily in food-based guidance, and not in nutrient intake recommendations. However, the role of diversity in meeting known and unknown needs has been noted in relation to recommendations, as in the 1989 RDA book (85):

'The recommended allowances for nutrients are amounts intended to be consumed as part of a normal diet. If the RDAs are met through diets composed of a variety of foods derived from diverse food groups rather than by supplementation or fortification, such diets will likely be adequate in all other nutrients for which RDAs cannot currently be established' (p. 8).

The *Nordic Nutrition Recommendations* (138) also echo this in noting that diets rich in diverse plant foods – vegetables, pulses, fruits, nuts and seeds, and vegetable oils – also provide bioactive components such as antioxidants, phenolic compounds, and phytoestrogens for which requirements are not set, but which may be positively associated with health outcomes. Recently, biodiverse diets have been emphasized as potentially providing additional benefits beyond food-group diversity (139-141). In short, diversity is at the heart of 'protective diets', as in the earliest recommendations and up to now.

The concepts of diversity and proportionality have been employed in translating nutrient intake recommendations (and, later, science on diet-chronic disease relationships) into guidance for consumers. Globally, a majority of FBDGs and accompanying graphics provide visual, qualitative, or quantitative messages on food-group diversity and proportionality (that is, relative quantities of various food groups to consume) (97). Diversity within food groups, particularly within fruits and vegetables, is also often advocated. Messages and images illustrating proportionality (e.g. small quantities of fats in relation to other food groups; smaller quantities of 'protein foods' relative to staples, fruits and vegetables) are also meant to help achieve macronutrient balance and healthy 'proportionality' in the diet. Indices of diet quality that include quantification of a set of recommended or 'encouraged' food groups also incorporate and operationalize both these concepts.

5.5

Avoiding excess, moderation, and total avoidance

Nutrient intake recommendations often also provide values defining excessive intakes of certain micronutrients. In the North American Dietary Reference Intakes (DRIs) as well as in the current WHO/FAO micronutrient requirements document, these are termed Tolerable Upper Intake Levels (ULs) and are defined as the maximum daily intake level that is likely to pose no risk of adverse effect. The WHO/FAO (111) state that for most micronutrients, no adverse effects are likely when consumed from foods, because of regulation of absorption and/or excretion; excessive intakes for some micronutrients are possible with consumption of supplements. Avoiding excessive consumption of micronutrients has not usually been reflected in dietary guidelines nor reflected in diet quality indices.

In contrast, most FBDGs and many diet quality indices include the concepts of moderation and avoidance. Moderation is frequently advised for ASFs or for specific ASFs (red and processed meat), total fat or saturated fat (and, historically, cholesterol), added sugars, salt or sodium, and alcohol. Visually, fats, sweets and processed snacks are often grouped in or near the 'tip of the pyramid', providing a visual moderation message.[25] Other visual images exclude fats and sweets entirely (e.g. 'healthy plates' as in the U.S. 'MyPlate'). For most of these foods/ingredients, the message – while not strict avoidance – is to minimize to the extent possible. Some guidance now urges complete avoidance of trans- fats, and a few countries now urge moderation or avoidance in consumption of UPF.[26] Similarly, many diet quality indices include components (foods, nutrients, food substances) that must be moderated to score high on the index component.

In summary, while it is uncommon to reflect ULs in dietary guidelines or in diet quality indices, the concept of moderation in certain foods or food substances is present in most.

5.6

Safety

Safe food is food that is free of microbial pathogens, food-borne macro-parasites (e.g. tapeworms, flukes, roundworms), toxins and chemicals (17). Toxins include fungal toxins (mycotoxins) such as aflatoxin and fuminosin, and marine toxins. Chemical contaminants can include metals (e.g. mercury), dioxins, and pesticides. Some harmful chemicals can be formed during cooking.

Global health authorities indicate a slightly broader definition, to incorporate the concept of excessive micronutrient intakes, when estimating population-level dietary exposures, as for example in Total Diet Studies (TDS) (142):

'Potentially harmful chemical substances include e.g. pesticide or veterinary drug residues, heavy metals, environmental or process contaminants, naturally occurring toxins, but can also include micronutrients, that can be present in food at levels that might adversely affect the health of consumers' (p. 11).

TDS are based on known consumption patterns, and involve sampling, pooling and chemical analysis of foods. TDS are usually not integrated with dietary intake or other food consumption surveys but instead are based on knowledge generated in such surveys.

Consideration of food safety is often included in conceptual discussions of diet quality and also in FBDGs messaging. However, diet quality metrics have typically not included considerations of food safety. Given the additional data that would be required to estimate various exposures to risks, it is difficult to see how this dimension could be fully incorporated into diet quality metrics for WRA in LMICs.

25. See, for example, food guide graphics for Austria, Belgium, or Israel at http://www.fao.org/nutrition/nutrition-education/food-dietary-guidelines/en/ [Accessed Dec 20 2018].
26. See, for example, Brazil's dietary guidelines at http://www.fao.org/nutrition/education/food-dietary-guidelines/regions/countries/brazil/en/ [Accessed Dec 20 2018].

5.7

Sustainability

The concept of sustainable diets first emerged in the late 20th century but did not gain traction until more recently. In 2010, FAO and Bioversity International convened a Symposium where the following definition was affirmed (139):

'Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources' (p. 7).

Studies assessing the relative sustainability of consumption of particular food groups, and of dietary patterns, are currently proliferating rapidly. A recent review by Nelson et al. (143) updated an earlier systematic review performed as part of the U.S. 2015 Dietary Guidelines development process. Both the original and the updated review affirmed that the healthy dietary patterns identified by the DGAC – higher in healthy plant foods (vegetables, fruits, legumes, seeds, nuts, whole grains) and lower in ASFs (particularly beef) – have lower environmental impacts.

However – beyond apparent consensus on the negative land use and greenhouse gas impacts of beef production – science in this area is very young, food systems are complex and vary by locale, and multiple metrics are required to fully assess impacts of specific dietary patterns and dietary shifts on differing aspects of sustainability. Addressing this challenge, the *EAT-Lancet Commission for Food, Planet and Health* (noted in Section 2.5 above for addressing the question of *'What is a healthy diet?'*) is also tackling key questions related to sustainability, specifically: *'What is a sustainable food system?'* and *'Can we achieve healthy diets from sustainable food systems? How?'* with publication of results planned for early 2019.[27] At present, given that the sustainability issue itself is multidimensional, and that metrics for sustainability are evolving rapidly and have contextual dimensions, it is not clear how this dimension could be fully incorporated into diet quality metrics for WRA in LMICs.

27. See: https://eatforum.org/initiatives/eat-lancet/ [Accessed Dec 20 2018].

6

Measuring Diet Quality: Indicators and Indices[28]

6.1

An overview of existing metrics

Diet quality indicators and indices have been reviewed many times, including recently (see: Kant (147); Ruel (148); Waijers et al. (149); Arviniti et al. (150); Kourlaba et al. (151); Wirt et al. (152); Vandivijvere et al. (64); Alkerwi (133); Gil et al. (153); Mertens et al. (154)). In addition, in the context of a recent systematic review and meta-analysis of dietary patterns and type 2 diabetes, Jannasch et al. (73) provide extensive supplementary tables describing and comparing characteristics of a wide range of 'whole of diet' indices. They describe 8 Mediterranean Diet Scores, 6 DASH diet scores, 9 versions of HEI or AHEI scores, and 7 scores based on various dietary guidelines.

We will not recapitulate these descriptions and refer the reader to the reviews just cited, and particularly to Waijers et al. (149), Wirt et al. (152) and Jannasch et al. ((73); see supplemental material) for useful tables. Instead, this section will provide selected examples of diet quality indicators and indices, to illustrate the range of existing metrics and some of the conceptual and methodological decisions required during their development.

It is useful to preview some key features distinguishing indicators and indices:

- Breadth: Intended to capture one dimension of diet quality? Several? Whole of diet? What is the indicator or index intended to capture or reflect?

28. This section covers only indicators and indices derived from data collected at the individual level, noting that the uses of the indicators may be for population-level assessment and monitoring. For more comprehensive compendia of indicators related to food consumption as measured at individual, household, market and national levels, see: Herforth et al. (144); Herforth and Ballard (145); and Leroy et al. (146). Also see compilation of the International Dietary Data Expansion (INDDEX) Project: https://inddex.nutrition.tufts.edu/data4diets [Accessed Dec 20 2018].

- Basis and criterion-related validity[29]: Derived from a specific study, or set of studies using a single indicator or index, and validated against risk factors or health outcomes? Derived from/validated against nutrient intakes and in relation to nutrient requirements? Derived as an operationalization of national, WHO, or other behavioral guidance? Developed based on an alternative evidence synthesis? What is the geographic scope of the evidence base?
- Intended uses: Developed for use in epidemiological studies associating dietary exposures to surrogate biomarkers or clinical outcomes? For use in assessing and monitoring intakes relative to national dietary guidance? For use in cross-setting or global assessment and monitoring? Other uses?
- Expression: Continuous, count/ordinal, dichotomous?
- Data requirements or constraints: Requires quantitative, semi-quantitative, or qualitative dietary data?

In the following pages, **Boxes 9-20** provide descriptions including each of the above features for a set of example metrics. The selection of examples favors simpler proxy indicators when available (that is, those indicators having lower data requirements), and indices with absolute rather than relative (study-specific) cut-points for scoring components. Note also that we exclude metrics that would not be appropriate for WRA, such as those explicitly designed for children. The majority of the metrics in **Boxes 9-20** were designed to be applicable to all adults (not only WRA).

In addition to the features noted above, there are several decisions common to operationalizing many indicators/indices including[30]:

- Choice of the components to include (food groups, nutrients, food substances);
- Assigning foods to food groups;
- Choice of cut-off values for scoring each component;
- Operational definition of each component (how to judge against cut-off); and
- Weighting - decisions on the relative contribution of the individual components to the total score.

These operationalization decisions are also described for each of the metrics that follow in the Boxes below.

Finally, in both construction and analysis of diet quality metrics, decisions must be made regarding how to reflect energy intake. In general, energy intakes, nutrient intakes and food group intakes may all be positively correlated, so it may be important to determine if a novel metric is tracking increase in quantity, quality (e.g. nutrient-density) or both (see e.g. Murphy et al. (155)). Some indices incorporate energy-adjusted elements by design (e.g. indicator components incorporate nutrient density or share of dietary energy provided by a food or food group). Inclusion of nutrient densities rather than absolute intakes can also be a strategy to minimize the impact of error introduced by under- or over-reporting of intakes (156); depending on the data source, this may also be a relevant consideration when individual dietary intake data are used in construction of metrics.

29. We include here: predictive, concurrent, convergent and discriminant validity. These assess whether an operationalized construct behaves as it should, in relation to other operationalized constructs. This excludes face validity and content validity. Validation of field measurement methods is also a separate issue and applies to all measurement methods for all indicators and indices.
30. This list is adapted from: Waijers et al. (149).

6.1.1.

Metrics capturing one or several dimensions or characteristics

Early diet quality metrics were generally simpler and focused on adequacy; these were followed by more complex and 'whole of diet' metrics. **Boxes 9-13** provide details for metrics capturing one or few dimensions of diet quality.

An early and relatively widely used summary indicator was the 'Mean Adequacy Ratio' (MAR, **Box 9**), which summarizes intakes relative to recommendations across a selected set of nutrients (see e.g.: Guthrie et al. (157); Krebs-Smith et al. (158); Hatloy et al. (159); Steyn et al. (160); Maillot et al. (161); Rathnayake et al. (162); M'Kaibi et al. (163)). We note, however, that the original MAR was developed in advance of newer and currently recommended approaches to assessing nutrient adequacy, which use the intake distribution around the Estimated Average Requirement (EAR) in assessing probability (or prevalence) of nutrient adequacy. When assessing adequacy of nutrient intakes at population level, approaches comparing intakes to the RDAs (or RNIs) are no longer recommended.

Indicators of adequacy are still relevant, particularly in resource-poor settings in LMICs where monotonous diets – dominated by staple foods and low in fruits, vegetables and ASFs – are insufficient in many micronutrients. In those same settings, simple food group diversity indicators based on qualitative recalls (i.e., with no estimate of quantity consumed) have been proposed as proxy indicators for micronutrient adequacy for WRA, for situations when quantitative dietary data are infeasible to collect. One such indicator is the Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) (**Box 10**, FAO and FHI 360 (164); Martin-Prevel et al. (8)). Recently, Lachat et al. (141) reported that creating a dichotomous indicator that incorporated both food group diversity and dietary biodiversity (characterized by species richness), improved associations to MAR for women (compared to MDD-W alone) in analyses of seven data sets from rural Africa (4 sites), Asia (2 sites) and Latin America (1 site).

Globally, a wide range of dietary variety or diversity indicators have been proposed for various uses, with varying recall periods and with some counting food items and others counting varying numbers of food groups (147, 148, 165). Some include while others exclude fats, oils and sweets. Even when fats and sweets are excluded, diversity indicators are generally positively associated with energy intakes in low-income countries (e.g. Torheim et al. (166); Arimond et al. (135)); however, overconsumption was not assessed in these resource-poor settings.

Several recent global reviews have shown mixed associations of dietary diversity indicators to obesity or adiposity (167-170); however, indicators that only counted recommended foods/groups were either inversely associated, or not associated (167, 168). Drescher et al. (171) and Vadiveloo et al. (172) have proposed more complex 'healthy food diversity' metrics that incorporate proportionality as well as diversity, and are reflective of country-specific dietary guidelines from Germany and the U.S. (**Box 11**), respectively.

In addition to the MAR and various dietary diversity indicators, other simple indicators reflecting a limited number of dimensions have been generated from a wide variety of diet screeners.[31] Indicators derived from simple diet screeners often aim to capture information on intake of single foods, food groups, or nutrients that are either encouraged or discouraged in dietary guidance, or aim to capture other diet-related behaviors.

31. Dietary screeners are typically designed to capture information about a limited number of foods and beverages consumed, or else specific dietary behaviors, over a period of time (e.g. the past month or year). Screeners are designed to be brief and to impose low burdens on respondents. They are often non-quantitative (do not capture quantities consumed) but may be semi-quantitative. See https://epi.grants.cancer.gov/diet/shortreg/register.php for a compendium of validated screeners, and https://www.dietassessmentprimer.cancer.gov/profiles/screeners/index.html for a general description of screeners, and for additional resources; both Accessed Dec 20 2018.

For example, the WHO STEPwise approach to Surveillance (STEPS) questionnaire captures information on fruit and vegetable intake (**Box 12**) and on other behaviors related to chronic disease risk.[32]

When quantitative dietary data are available, adherence to AMDR or WHO ranges is commonly reported as a descriptor of macronutrient balance, and macronutrient summary indicators based on WHO recommendations related to chronic disease prevention have also been operationalized (e.g. Delisle et al. (128)). To our knowledge, there are no widely used simple proxy indicators for macronutrient balance.

Finally, when quantitative data are available, the INFORMAS Network has proposed that the percent of energy from UPF could also serve as a simple indicator of diet quality (**Box 13**, (64)). This indicator is simple in that it only measures one characteristic and is easy to calculate if foods are coded by processing level, but is conceptually more comprehensive in that it aims to reflect several dimensions of dietary quality, including energy- and nutrient-density, and moderation in consumption of salt, added sugar and trans fats. As for macronutrient balance, we know of no simple proxy indicators for percent of energy from UPF.

Prevalence or frequency of consumption of specific UPF such as sugar-sweetened beverages (SSBs) has been assessed (e.g. Stern et al. (173)), and this may serve as a partial proxy for added sugar from UPF when it is known that SSBs contribute a substantial proportion of added sugar consumption. However, note that in some contexts in LMICs, sugar added by the consumer (for example in tea) may provide the highest proportion of sugar in the diet (e.g. Maunder et al. (174); Keding (175)); i.e., UPF, SSBs, and main sources of free sugar may overlap, but not be equivalent.

32. See http://www.who.int/chp/steps/en/ for information on the STEPS approach, and to download questionnaires [Accessed Dec 20 2018].

Box 9. Features of Mean Adequacy Ratio

Definition: An index of the ratio of intake to recommended intake averaged for X nutrients, with each nutrient ratio capped at 1. Nutrients sometimes include macronutrients but often are restricted to micronutrients. The Recommended Dietary Allowances (RDAs), 2/3rds of the RDA, and the Estimated Average Requirements (EARs) have been used as recommended values for calculation of the ratio.

Breadth: Designed to capture nutrient adequacy.

Basis and criterion-related validation: Originally, RDAs; no validation per se; validity based on the validity of the RDAs. Developed in the U.S. but could be adapted to be calculated based on any set of nutrient intake recommendations.

Intended uses: Multiple. Was first developed and used in an evaluation of the impact of U.S. Government food assistance programs.[a] Previously, the Mean Adequacy Ratio (MAR) was frequently used as a gold standard for nutrient adequacy, against which simpler proxy indicators were compared.[b] Current approaches would substitute assessing probability (or prevalence) of nutrient adequacy using newer analytic methods, as noted in text.

Expression: As an average ratio (averaged across individual nutrient ratios), i.e., ranging from 0-1.

Data requirements or constraints: Requires quantitative dietary data; has been calculated using data from quantitative food frequency questionnaires and from quantitative 24-hr dietary recalls.

Choice of the components to include: Nutrients of interest, public health importance, or all nutrients for which food composition data are available.

Assigning foods to food groups: Not applicable.

Choice of cut-off values for scoring each component: Not applicable, score for each component nutrient is continuous, but capped at 1.

Operational definition of each component: Nutrient intakes as estimated by a quantitative dietary method.

Weighting: Implicit weighting of “1” for all component nutrients.

a. Guthrie HA, Madden JP, Yoder MD, Koontz HP. Effects of USDA commodity distribution program on nutritive intake. J Am Diet Assoc. 1972;61(3):287-92. (157)

b. See, for example:

Krebs-Smith SM, Smiciklas-Wright H, Guthrie HA, Krebs-Smith J. The effects of variety in food choices on dietary quality. J Am Diet Assoc. 1987;87(7):897-903. (158)

Hatloy A, Torheim LE, Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr. 1998;52(12):891-8. (159)

Steyn NP, Nel JH, Nantel G, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Public Health Nutr. 2006;9(5):644-50. (160)

Maillot M, Darmon N, Vieux F, Drewnowski A. Low energy density and high nutritional quality are each associated with higher diet costs in French adults. Am J Clin Nutr. 2007;86(3):690-6. (161)

Rathnayake KM, Madushani P, Silva K. Use of dietary diversity score as a proxy indicator of nutrient adequacy of rural elderly people in Sri Lanka. BMC Res Notes. 2012;5:469. (162)

Box 10. Features of Minimum Dietary Diversity for Women of Reproductive Age

Definition: Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) is the proportion of women 15–49 years of age who consumed food items from at least five out of ten defined food groups the previous day or night.

Breadth: Proxy indicator of micronutrient adequacy.

Basis and criterion-related validation: Concurrent validity was assessed against a summary indicator of probability of adequacy averaged across 11 micronutrients, with each micronutrient capped at 1. Validity is based on the predictive strength of the indicator to identify low vs. high probability of adequacy, and underlying that, on the validity of recommendations (U.S. Dietary Reference Intakes (DRIs) and WHO/FAO recommendations). Data sets for assessing concurrent validity were from resource-poor settings in rural, peri-urban and urban Africa and Asia, and most were from low-income countries.

Intended uses: For population-level assessment and monitoring of change over time, and for advocacy communications. Developed explicitly for situations where quantitative dietary data collection is infeasible, and where a prevalence is preferred to a mean or median for communication purposes.

Expression: Dichotomous. The underlying 10-point score can also be used for some purposes.

Data requirements or constraints: Can be generated from quantitative or qualitative 24-hour recalls but developed for the latter. Standard methodology for simple food group recalls has been published.[a]

Choice of the components to include: Components are food groups. Most food groups are defined in ways that align with common groupings in FBDGs. Fruits and vegetables are more disaggregated. Level of aggregation was decided after testing multiple candidate indicators.

Assigning foods to food groups: Rationale and detailed description of decisions on assigning foods to groups have been published.[a] Assignment generally follows culinary, rather than botanical classification. Minor ingredients are classified as condiments and do not count in the MDD-W food groups.

Choice of cut-off values for scoring each component: Each food group is scored 0/1 – either consumed or not consumed during the recall period.

Operational definition of each component: Food group definitions and extensive examples are provided.[a]

Weighting: Implicit weighting of "1" for all component food groups, but level of aggregation was selected based on prediction of the criterion summary indicator of probability of adequacy averaged across 11 micronutrients.

a. FAO, FHI 360. Minimum Dietary Diversity for Women: A Guide for Measurement. Rome; 2016. Available from: http://www.fao.org/3/a-i5486e.pdf (164)

Box 11. Features of U.S. Healthy Food Diversity Index[a]

Definition: The U.S. Healthy Food Diversity (HFD) index measures dietary variety, dietary quality and proportionality according to the U.S. 2010 dietary guidelines.

Breadth: Dietary variety, dietary quality (concordance with U.S. Dietary Guidelines) and proportionality (the proportional distribution of foods and food groups in the diet).

Basis and criterion-related validation: Concurrent validity was evaluated relative to 1) elements of the U.S. 2010 Dietary Guidelines; and 2) energy-adjusted correlations with probability of adequacy for 15 micronutrients. Discriminant validity was assessed by examining whether the HFD index varied between subpopulations with known differences in dietary quality; convergent validity was assessed by comparison with DASH diet scores. Fundamentally, validity of the HFD index is based on validity of the U.S. Dietary Reference Intakes (DRIs) and 2010 Dietary Guidelines. This index was developed with U.S. data and incorporating U.S. Guidelines; previously, a similar indicator had been developed in Germany,[b] and the approach could be adapted elsewhere.

Intended uses: To evaluate the associations between healthy food diversity and health outcomes.

Expression: Continuous, ranging from 0 to 1.

Data requirements or constraints: Requires quantitative dietary data. Developed using U.S. National Health and Nutrition Examination Survey (NHANES) data from 2003-2006. During development, the HFD was calculated both with and without supplementing 2 quantitative 24-hr recalls with a food frequency questionnaire intended to improve estimates of the proportion consuming infrequently consumed foods.

Choice of the components to include: All foods are included, and the algorithm treats foods differently by applying health factors depending on whether foods were in food groups considered by the authors to be emphasized, included, or limited in the 2010 U.S. dietary guidelines. Groups were defined as in the U.S. Department of Agriculture (USDA) Food Patterns.

Assigning foods to food groups: According to USDA Food Patterns.

Choice of cut-off values for scoring each component: No cut-off values; each food item contributes based on quantity consumed and various factors in the scoring algorithm.

Operational definition of each component: Components are individual food items or groups with a total score summed across all items/groups. Health factors are applied based as subjective values quantifying the qualitative guidance (emphasized, included, or limited groups). A score approaching 1 represents a diet with many foods, and with a higher proportion of emphasized foods.

Weighting: See above.

a. Vadiveloo, M., et al. Development and evaluation of the US Healthy Food Diversity index. Br J Nutr. 2014; 112(9): 1562-1574. (172)
b. Drescher, L. S., et al. A new index to measure healthy food diversity better reflects a healthy diet than traditional measures. J Nutr. 2007; 137(3): 647-651. (171)

Box 12. Features of World Health Organization STEPwise approach to Surveillance fruits and vegetables indicator

Definition: Percentage of adults 18-69 y who ate less than 5 servings of fruit and/or vegetables on average per day.[a]

Breadth: Captures one element in WHO (and other) advice for chronic disease risk reduction.

Basis and criterion-related validation: The basis for the indicator is the recommendation of at least 400 g or 5 portions a day of fruits and vegetables in the WHO 2003 *Diet, nutrition and the prevention of chronic diseases: report of a Joint WHO/FAO Expert Consultation*, and as reflected in the WHO Healthy Diet Fact Sheet. The indicator is intended for global use; note, however, that the evidence base grounding the recommendations came primarily from high income countries.

Intended uses: An 'additional indicator' in the Comprehensive Global Monitoring Framework for prevention and control of noncommunicable diseases. Countries are encouraged to consider assessing and monitoring.

Expression: Dichotomous.

Data requirements or constraints: In STEPS methodology, measured with a simple screener with 4 questions about consumption during a 'typical week' in the last year. The indicator can also be generated from quantitative dietary data.

Choice of the components to include: All fruits and vegetables but excluding potatoes and other starchy tubers.

Assigning foods to food groups: Not applicable.

Choice of cut-off values for scoring each component: Average servings per day are estimated based on respondent recall elicited with 4 questions, asking about fruits and vegetables separately. There is a visual prompt for serving size with local examples, and the cut-off is ≥ 5 servings a day.

Operational definition of each component: See above.

Weighting: Not applicable; single component; implicitly, all fruits and vegetables are equally weighted.

a. Definition taken from the STEPS Survey Fact Sheet Template at: http://www.who.int/chp/steps/resources/en/ [Accessed Dec 20 2018].

Box 13. Features of percent of energy from ultra-processed foods

Definition: Dietary share of energy from ultra-processed food (UPF) products, as a percentage of total energy intake.

Breadth: The indicator is intended to reflect several dimensions of diet quality, including energy- and nutrient-density and nutrient adequacy, and moderation in consumption of a group of foods that includes many items high in sodium, added sugar, and *trans* fat.

Basis and criterion-related validation: The novel classification scheme that yielded this indicator was originally proposed without validation.[a] As previous studies had not assessed or considered processing level, evidence to that point related primarily to particular UPF such as processed sugar-sweetened beverages or processed meats. Subsequently, as described in the text above, studies have related the proportion of energy from UPF to overall nutrient content and energy- and nutrient-density of the diet, and to several risk factors. Studies have primarily been in the global north and in Brazil.

Intended uses: To monitor trends in UPF consumption, and to allow study of the relationship of UPF consumption to health outcomes.

Expression: Continuous percent ranging from 0 to 100.

Data requirements or constraints: Requires quantitative dietary data, and appropriate coding of all UPF and beverage items according to the classification scheme.

Choice of the components to include: All foods and beverages are included in indicator construction. The indicator is unidimensional in the sense that the only dietary characteristic that is coded is the level of processing, but to compute the indicator total energy intake must also be known.

Assigning foods to food groups: The classification has evolved over time and has been applied slightly differently in different studies. The updated classification scheme has been described.[b]

Choice of cut-off values for scoring each component: Not applicable.

Operational definition of each component: Food items and ingredients are coded by level of processing, and percent of energy intake is calculated for UPFs as a group.

Weighting: Not applicable; single component.

a. Monteiro CA, et al. A new classification of foods based on the extent and purpose of their processing. Cad Saude Publica. 2010; 26(11): 2039-2049. (36)
b. Monteiro CA, et al. NOVA. The star shines bright. World Nutrition. 2016; 7(1-3): 28-38. (37)

6.1.2.

Whole of diet metrics operationalizing healthy dietary patterns

The healthy food diversity indicators developed for the U.S. and German contexts (171, 172) were described above as an evolution from simpler dietary diversity indicators, but are in fact more like whole of diet metrics capturing multiple dimensions. Myriad other whole of diet indices can be categorized as operationalizing:

- Variations of the DASH diet;
- Regional dietary patterns, including variations of the Mediterranean, Nordic, and several East Asian dietary patterns[33];
- National or WHO dietary guidance; or
- Alternative syntheses of evidence

Whole of diet indices vary in the extent to which they explicitly aim to capture nutrient adequacy. Those based on national dietary guidelines do aim to capture adequacy, because the dietary guidelines themselves are usually designed to enable consumers to meet nutrient needs.

Since other healthy dietary patterns all include a variety of nutrient-rich foods/groups, these patterns may be positively associated with nutrient adequacy. That is, higher adherence to DASH or Mediterranean or other defined dietary patterns may result in higher intakes of many nutrients, even if scoring is not designed to capture nutrient adequacy.

The case of Mediterranean diet scores and calcium may be an exception as these typically assign positive sub-scores to low dairy intake. For example, Sofi et al. (84) assign the highest score to consumption of < 1 portion of dairy/d and the lowest score to consumption of >1.5 portions/d. Accordingly, calcium intake may not be positively associated with adherence to the Mediterranean diet (e.g. as in Alkerwi et al. (86)). Since calcium intake among WRA in LMICs is often low relative to recommendations (7, 9), as noted, this is an issue worth considering in developing novel metrics for WRA.

Boxes 14-20 describe the features of selected examples for each of the 4 categories of whole of diet indices. To date, most whole of diet indices developed to reflect healthy dietary patterns require quantitative data on dietary intakes.

33. Note however that much of the dietary patterns research from East Asia has not employed *a priori* definitions of dietary patterns, and instead has employed cluster analysis, factor analysis, or reduced rank regression.

Box 14. Features of the Dietary Approaches to Stop Hypertension Diet Score

Definition: Adherence to the defined Dietary Approaches to Stop Hypertension (DASH) dietary pattern.

Breadth: Whole of diet index.

Basis and criterion-related validation: Validated relative to blood pressure outcomes in a randomized controlled trial.[a] Subsequently, has been prospectively associated with reductions in multiple risk factors and disease outcomes, as previously described. Most available evidence is from the global north.

Intended uses: The DASH diet is used and adapted in multiple health care, consumer education, and research settings. The diet score is variously used to measure adherence, monitor change after interventions, and analytically in studies of associations between adherence and healthy outcomes, particularly in prospective studies.

Expression: Typically, an ordinal score, for example ranging from 0-40, with 1-5 points per food group.

Data requirements or constraints: Requires quantitative or semi-quantitative dietary data (usually, food frequency data).

Choice of the components to include: Components reflect the food groups in the DASH diet, and sodium. In one common version of the score,[b] groups include whole grains; vegetables (excluding white potatoes); fruit; the combined group of nuts, seeds, and legumes; low-fat dairy; sodium; sugar-sweetened beverages; and red and processed meat. There is some variability in the elements included.[c]

Assigning foods to food groups: Has been done variously depending on data sources. The DASH food groups are generally well-defined but there are some foods that are classified differently in different versions (for example, potatoes).

Choice of cut-off values for scoring each component: There also has been some variation in scoring; in one common version, scoring for each component is relative, based on sex-specific quintiles of observed intake.[b] So cut-offs for scoring 1, 2, 3, 4, or 5 points per component are based on quintile cut-offs.

Operational definition of each component: Food group consumption is estimated, typically from food frequency data. Food groups are described, with examples, at the website of the U.S. National Heart, Lung and Blood Institute. As noted above, the highest score is given for highest consumption quintile for encouraged food groups, and for lowest consumption quintile for sodium, sugar-sweetened beverages, and red and processed meat.

Weighting: Implicit weight of “1” given to each food group, and sodium.

a. Sacks FM, Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, et al. A dietary approach to prevent hypertension: a review of the Dietary Approaches to Stop Hypertension (DASH) Study. Clin Cardiol. 1999;22(7 Suppl):Iii6-10. (69)

b. Liese AD, et al. The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr. 2015; 145(3): 393-402, online supplemental material. These authors state that the version of the DASH score employed in the DPMP was the one most commonly found in the literature for U.S. populations. (74)

c. See, for example, 6 versions of the operationalized DASH diet detailed in online supporting material for Jannasch F, et al. Dietary Patterns and Type 2 Diabetes: A Systematic Literature Review and Meta-Analysis of Prospective Studies. J Nutr. 2017 Jun;147(6):1174-1182. doi: 10.3945/jn.116.242552. Epub 2017 Apr 19. (73)

Box 15. Features of a Literature-Based Adherence Score for the Mediterranean Diet[a]

Definition: Adherence to the Mediterranean diet.

Breadth: Whole of diet index.

Basis and criterion-related validation: After early ecological studies, cohort studies established associations to mortality and later to a range of chronic disease risk factors, as previously described. Many versions of the diet and associated scores have been proposed. The score described here was developed based on intakes observed in a set of cohorts from Europe and the U.S. (Sofi et al. 2014), and convergent validity was assessed by comparison to another validated Mediterranean diet score (Sofi et al. 2017). Previous to their work, the authors could find no synthesis work to define quantities per food group across available cohorts, since adherence (consumption of components of the Mediterranean) had typically been scored relatively (above/below median intakes).

Intended uses: The literature-based adherence score is intended primarily for clinical use (Sofi et al. 2014; Sofi et al. 2017).

Expression: Ordinal score ranging from 0-18.

Data requirements or constraints: Requires quantitative or semi-quantitative dietary data (usually, food frequency data).

Choice of the components to include: Most components are food groups defined and included in the majority of the prospective studies (as in **Box 2**: fruits, vegetables, legumes, cereals, fish, meat and meat products, dairy, and alcohol); however olive oil was included rather than the MUFA : PUFA ratio [b], which was more common in the cohort studies; while not stated, this choice could relate to the objective of clinical use.

Assigning foods to food groups: Not described.

Choice of cut-off values for scoring each component: With the exception of olive oil, means or medians were calculated (across studies, weighted by sample size) and low, middle and high categories of consumption were defined based on cut-offs at ± 2 SD and expressed as portions per day or per week; for olive oil, scoring was based on respondent's report of occasional, frequent, or regular use. For fruits, vegetables, legumes, cereals, fish, and olive oil low intake is scored a 0, middle as 1 and high as 2. For meat and meat products and dairy, scoring was reversed. For alcohol, low intake scored 1, middle intake scored 2 and high intake scored 0.

Operational definition of each component: In this example, food group consumption is operationalized through use of a brief food frequency questionnaire.

Weighting: Implicit weight of "1" given to each component.

a. Sofi F, et al. Mediterranean diet and health status: an updated meta-analysis and a proposal for a literature-based adherence score. Public Health Nutr. 2014; 17(12): 2769-2782 (84); and Sofi, F., et al. Validation of a literature-based adherence score to Mediterranean diet: the MEDI-LITE score. Int J Food Sci Nutr. 2017; 68(6): 757-762. (176)

b. MUFAs = monounsaturated fatty acids; PUFAs = polyunsaturated fatty acids.

Box 16. Features of the Healthy Diet Indicator[a]

Definition: Adherence to a selected set of components of WHO dietary guidance for prevention of chronic disease.

Breadth: Whole of diet index.

Basis and criterion-related validation: The Healthy Diet Indicator (HDI) was designed to measure adherence to WHO recommendations for the prevention of chronic diseases (WHO 1990).[b] Thus its validity rests in part on the then-current evidence synthesis by WHO. However, in its first use the HDI was validated relative to mortality in three prospective cohorts (Finland, the Netherlands, and Italy) that were part of the Seven Countries Study.

Intended uses: Analytical, for the investigation of the relationships of a dietary pattern to outcomes, including in cross-country studies.

Expression: Ordinal score, ranging from 0-9.

Data requirements or constraints: Requires quantitative dietary data.

Choice of the components to include: Components were based on WHO 1990, but total fat and total carbohydrate were not included to avoid overlap with included components (below); sodium was not included due to lack of data, and mono- and disaccharides were substituted for free sugars for lack of data. Food groups included were fruits and vegetables; and pulses, nuts and seeds. Other components were protein; dietary fiber; saturated fatty acids; polyunsaturated fatty acids; cholesterol; and complex carbohydrates.

Assigning foods to food groups: Not described.

Choice of cut-off values for scoring each component: Cut-offs were based on recommended ranges in WHO 1990; components with intake within the recommended range were scored "1", otherwise "0".

Operational definition of each component: As above.

Weighting: Implicit weight of "1" given to each component.

a. Huijbregts, P, et al. Dietary pattern and 20 year mortality in elderly men in Finland, Italy, and The Netherlands: longitudinal cohort study. BMJ. 1997; 315(7099): 13-17. (177)

b. World Health Organization. Diet, nutrition, and the prevention of chronic diseases. Report of a WHO Study Group. (WHO Technical Report Series 797). Geneva; 1990. Available from: http://www.who.int/nutrition/publications/obesity/WHO_TRS_797/en/ (178)

Box 17. Features of Diet Quality Index International[a]

Definition: A composite measure of diet quality.

Breadth: Whole of diet index. However, the authors also note that the index covers 4 dimensions – variety (overall and within protein sources), adequacy, moderation and overall balance (with the last including proportionality in energy sources and fatty acid composition) – and they highlight that in distinction to some other indices, the construction of this index allows assessment of which of these dimensions are problematic.

Basis and criterion-related validation: The Diet Quality Index International (DQI-I) index is based on an evidence synthesis. The authors cite global and national dietary guidelines as well as several previous indices (the Diet Quality Index (DQI), Diet Quality Index Revised, the Healthy Eating Index, and a DQI adapted for China) as providing the rationale for selection of components and for scoring.

Intended uses: Explicitly developed for cross-country comparisons, to provide a global tool for monitoring diet quality and 'for exploring aspects of diet quality related to the nutrition transition' (Kim et al. 2003, p. 3476).

Expression: Ordinal score, ranging from 0-100, with sub-scores available for each component.

Data requirements or constraints: Requires quantitative dietary data.

Choice of the components to include: Includes food groups, nutrients, and other food substances. Rationale for selection is the evidence synthesis.

Assigning foods to food groups: Not described in detail but groups are well-defined. Legumes and dairy are grouped together in recognition that legumes are major sources of calcium in some contexts where dairy is rarely consumed, and/or consumed in small quantities.

Choice of cut-off values for scoring each component: Complex scoring system with a mix of different approaches to cut-offs across components. Rationale for precise scoring of individual elements within each component is not provided. Overall variety is based on 5 major food groups and variety in protein sources based on 6 protein sources. Servings of fruits, vegetables and grains are scored under adequacy, along with intakes of fiber, protein, iron, calcium and vitamin C. Protein is scored based on percent of energy provided (with >10% scoring highest) and iron, calcium and vitamin C are scored based on the RDAs/RNIs or Adequate Intake (AI). Scoring for moderation component is partly related to cut-offs in WHO but is more stringent for highest scores for total fat and saturated fat. A novel element called 'empty calorie foods' was constructed based on nutrient density relative to individual needs and scored based on the percent of total energy from such foods.

Operational definition of each component: As above.

Weighting: 0-20 points for variety; 0-40 points for adequacy; 0-30 points for moderation; 0-10 points for overall balance. The rationale for this relative weighting is not provided.

a. Kim S, et al. The Diet Quality Index-International (DQI-I) provides an effective tool for cross-national comparison of diet quality as illustrated by China and the United States. J Nutr. 2003; 133(11): 3476-3484.(179)

Box 18. Features of the Healthy Eating Index - 2010 [a, b]

Definition: A diet quality index measuring of adherence to U.S. Dietary Guidelines.

Breadth: Whole of diet index.

Basis and criterion-related validation: The Healthy Eating Index 2010 (HEI-2010) was designed to measure adherence to the 2010 U.S. Dietary Guidelines. Predictive validity rests in part on the evidence synthesis reflected in the guidance. Construct validity (convergent and divergent) and reliability were established (180).[b] Subsequently, higher HEI-2010 scores have been prospectively associated with reduced all-cause, cardiovascular, and cancer mortality (74).[c]

Intended uses: A variety of research, policy and programmatic applications, including *'population monitoring; epidemiologic research; and evaluations of the food environment, food assistance packages, nutrition interventions, and the relation between diet cost and diet quality'* (Guenther et al. 2014, p. 399). Applies to U.S. adults and children aged 2 years and older.

Expression: Continuous score, ranging from 0-100.

Data requirements or constraints: Requires quantitative dietary data.

Choice of the components to include: 12 components with 9 reflecting adequacy (total fruit; whole fruit; total vegetables; greens and beans; whole grains; dairy; total protein foods; seafood and plant proteins; and fatty acids) and 3 reflecting moderation (refined grains; sodium; and energy from 'empty calories' (solid fats, alcohol, and added sugars)).

Assigning foods to food groups: Well defined; as described in the U.S. Department of Agriculture Food Patterns, as updated for the 2010 U.S. Dietary Guidelines.[d]

Choice of cut-off values for scoring each component: Standards for maximum scores reflect the Food Patterns and are based on cup, ounce or gram equivalents per 1000 kcal, except for fatty acids (PUFAs + MUFAs/SFAs)[e] and 'empty calories' (percent of energy). Maximum scores reflect best adherence. Minimum scores for food group adequacy components are for zero consumption and for moderation components are described in Guenther et al. 2013. Maximum score assigned for a fatty acid ratio ≥ 2.5 and minimum for a ratio ≤ 1.2. Intermediate consumption for each component is scored proportionally (prorated relative to minimum and maximum scores).

Operational definition of each component: As above; reverse scoring for moderation components.

Weighting: Each of the 12 components has a total score of 5 (total fruit; whole fruit; total vegetables; greens and beans; total protein foods; seafood and plant proteins), or 10 (whole grains; dairy; fatty acids; refined grains; sodium), or 20 (energy from 'empty calories' (solid fats, alcohol, and added sugars)).

a. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, Kuczynski KJ, Kahle LL, Krebs-Smith SM. Update of the Healthy Eating Index: HEI-2010. J Acad Nutr Diet. 2013 Apr;113(4):569-80. doi: 10.1016/j.jand.2012.12.016. Epub 2013 Feb 13. (181)

b. Guenther PM, Kirkpatrick SI, Reedy J, Krebs-Smith SM, Buckman DW, Dodd KW, Casavale KO, Carroll RJ.The Healthy Eating Index-2010 is a valid and reliable measure of diet quality according to the 2010 Dietary Guidelines for Americans. J Nutr. 2014 Mar;144(3):399-407. doi: 10.3945/jn.113.183079. Epub 2014 Jan 22. (180)

c. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, et al. The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr. 2015;145(3):393-402. (74)

d. Britten P, Cleveland LE, Koegel KL, Kuczynski KJ, Nickols-Richardson SM. Updated US Department of Agriculture Food Patterns meet goals of the 2010 dietary guidelines. J Acad Nutr Diet. 2012 Oct;112(10):1648-55. doi: 10.1016/j.jand.2012.05.021. Epub 2012 Jul 31. (182)

e. MUFAs = monounsaturated fatty acids; PUFAs = polyunsaturated fatty acids; SFAs = saturated fatty acids

Box 19. Features of the Updated Alternate Healthy Eating Index

Definition: Adherence to a dietary pattern associated with reduced risk of chronic disease.

Breadth: Whole of diet index.

Basis and criterion-related validation: The original Alternate Healthy Eating Index (AHEI) was developed based on a synthesis of evidence relating foods and nutrients to chronic disease risk and published in 2002. Subsequently, the index was demonstrated to be strongly associated with reduced risks of cardiovascular disease (CVD), diabetes, several cancers and mortality. As with evidence for other healthy dietary patterns, the evidence base was primarily from the global north. The updated AHEI, called AHEI-2010, incorporated new evidence to refine the index, and Chiuve et al. 2012[a] demonstrated prospective associations to major chronic diseases, including CVD, diabetes and cancer, and to mortality in 2 cohorts of U.S. adults. Subsequently, reduced risk of mortality was demonstrated in 3 additional U.S. cohorts in the Dietary Patterns Methods Project.[b]

Intended uses: Not explicitly stated; implied that its use in analyses of prospective associations with health outcomes could contribute to the evidence base for future revision of U.S. dietary guidance.

Expression: Ordinal score ranging from 0-110.

Data requirements or constraints: Requires quantitative dietary data.

Choice of the components to include: 11 components based on the literature, including: high intake of vegetables, fruit, whole grains, nuts and legumes, long chain n-3 fatty acids, and PUFA; low intake of sugar-sweetened beverages (SSBs) and juice, red and processed meats, trans fatty acids, and sodium; and moderate alcohol intake.

Assigning foods to food groups: Not fully detailed but relevant distinctions are highlighted, such as excluding potatoes from vegetables, and grouping juice with SSBs.

Choice of cut-off values for scoring each component: Clearly explained and justified with relevant literature and noting harmonization with then-current U.S. dietary guidelines for some food groups and food substances.

Operational definition of each component: Highest scores are assigned based on low risk in literature. Concordance with high end of range of U.S. recommended intakes is noted for several food groups with positive scoring. Most scoring is based on absolute criteria but scoring for sodium intake is based on deciles of observed intake in the cohorts. Criteria for maximum and minimum scores are well-described but assignment of intermediate scores is not.

Weighting: Implicit weight of "1" given to each component.

a. Chiuve SE, et al. Alternative dietary indices both strongly predict risk of chronic disease. J Nutr. 2012; 142(6): 1009-1018. (90)
b. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, et al. The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr. 2015;145(3):393-402. (74)

Box 20. Features of the Prime Diet Quality Score[a]

Definition: A composite measure of diet quality.

Breadth: Whole of diet index.

Basis and criterion-related validation: The Prime Diet Quality Score (PDQS) was recently developed (2018) and was shown to be associated with reduced risk of ischemic heart disease in several U.S. cohorts.

Intended uses: To contribute to a search for universal diet quality assessment tools associated with a range of health outcomes in both higher- and lower-income countries. The authors acknowledge that further studies of PDQS performance are needed, in a range of settings and in relation to diverse outcomes.

Expression: Ordinal score ranging from 0-42.

Data requirements or constraints: Based on the Prime Screen questionnaire,[b] which is a simple screener developed for clinical use in the northeast U.S. Future use may require development and testing (reproducibility, validity) of a screener (questionnaire) in other contexts.

Choice of the components to include: 21 food groups components, distinguished as 13 healthy (dark green leafy vegetables, cruciferous vegetables, carrots, other vegetables, whole citrus fruits, other whole fruits, legumes, nuts, poultry, fish, eggs, whole grains, and liquid vegetable oils) and 8 unhealthy food groups (red meat, potatoes, processed meat, whole milk dairy, refined grains and baked goods, sugar-sweetened beverages, fried foods obtained away from home, and desserts and ice cream).

Assigning foods to food groups: Not described.

Choice of cut-off values for scoring each component: Each of the 21 groups are scored from 0-2. For healthy foods, consumption of 0-1 servings/week scores “0”, 2-3 servings/week scores “1” and ≥ 4 servings/week scores “2”. Scoring is reversed for unhealthy foods. Serving sizes were not defined.

Operational definition of each component: As above.

Weighting: Implicit weight of “1” given to each component.

a. Fung TT, Isanaka S, Hu FB, Willett WC. International food group-based diet quality and risk of coronary heart disease in men and women. Am J Clin Nutr. 2018 Jan 1;107(1):120-129. doi: 10.1093/ajcn/nqx015. (183)

b. Rifas-Shiman SL, Willett WC, Lobb R, Kotch J, Dart C, Gillman MW. PrimeScreen, a brief dietary screening tool: reproducibility and comparability with both a longer food frequency questionnaire and biomarkers. Public Health Nutr. 2001 Apr;4(2):249-54. (184)

The Prime Diet Quality Score (PDQS) is unique among the indices described above in that it aims to contribute to fulfilling the objective we have identified; that is, to provide a relatively simple approach to measuring diet quality including in the context of nutrition transitions and double- and triple-burdens. It differs from most other whole of diet indicators in that it was based on a simple screener, to address the need for a less data-intensive metric. Because the PDQS is in harmony with our objectives, we looked closely at the basis for the operationalized indicator.

The basis for selection of healthy and unhealthy food groups is not entirely clear in this first paper reporting on the PDQS. Fung et al. (183) state the PDQS was based on the Prime Screen questionnaire of Rifas-Shiman et al. (184) who in turn cite Willett (185) for the basis for inclusion of elements in the screener. However, since the healthy and unhealthy food groups in the 2018 paper are not identical to the elements in the 2001 paper by Rifas-Shiman et al. (184), describing the screener, more recent evidence may have been considered. Fung et al. note that both literature on associations with noncommunicable diseases (NCDs) and 'nutrient contribution in the world-wide setting' were considered, but it is not explained how (p. 121).

Considering the elements selected, the health impact of full fat dairy (scored negatively in the PDQS) is currently an area of discussion (18), and the 'liquid vegetable oil' category could have different meanings for health in different settings, for example where refined palm oil is the most common liquid oil. It is not clear if carrots are included as a group due to their vitamin A content. If so, in other contexts other vegetables may be more relevant; if not, it is not clear why a single vegetable constitutes a group. Distinguishing whole grains from refined grains may be challenging with simple screeners. It would also be helpful to know why fried foods eaten away from home are included but fried foods prepared at home are not. It may be this element is intended as a proxy for, perhaps, fast food consumption, but this is not explained.

In general, screeners are context-specific and are developed (as was the Prime Screen questionnaire) with careful selection of example foods representing the most frequently consumed foods that constitute the group, in a given setting. This poses a challenge for global indicators. But we note that this is the same challenge faced when adapting any simple food group recall tool (and resulting operationalized indicator) to new contexts. Screeners have potential for global applicability if they are guided by general questions that can be adapted to context, and if they meet the challenge of validly and similarly reflecting diet quality across many types of cultural dietary patterns (186).

6.1.3.

Quantity cut-offs for food group consumption

Since most candidate diet quality indicators or indices are likely to include food groups as components, it is useful to look at some selected examples of food group quantity cut-offs or ranges in scores for existing indices and in evidence syntheses. Again, our aim is not to be comprehensive but to provide selected examples to illustrate the range and to identify areas of convergence and divergence.

In **Table 1** we show values derived from four diverse evidence syntheses: the literature-based Mediterranean diet score developed by Sofi et al. and reflecting a set of recent cohorts (84); the AHEI as described by Chiuve et al. (90); the dietary advice for cardiometabolic health summarized by Mozaffarian (18); and the most recent GBD study paper defining dietary risks (1). While the Mozaffarian paper and the GBD study do not aim to present or contribute to development of a diet quality metric, they nevertheless reflect recent and comprehensive syntheses of evidence relating dietary intakes to health risks and outcomes. We also include current DASH Diet guidance from the U.S. National Institutes of Health (NIH) National Heart Lung and Blood Institute website.[34]

These diverse sources had diverse purposes. The literature-based Mediterranean diet score, the dietary advice for cardiometabolic health, and the DASH diet as presented at the NIH website are clinician- or consumer-facing. The AHEI, as presented by Chiuve et al. aimed to contribute to improving U.S. Dietary Guidelines via demonstrating stronger associations to outcomes than those observed with the HEI.[35] The GBD study has broader aims but concerning dietary risk factors, it aims to identify a range of consumption consistent with minimum risk for specific disease outcomes.

In **Table 1**, quantities are sometimes expressed in grams and sometimes in servings. Where possible, we converted servings to grams, but in the case of food groups where different serving sizes are indicated for different types of foods, and where the original sources gave quantities in servings, this would not be straightforward and serving sizes are presented.

For simplicity, to present a summary across these sources we refer to them hereafter in this section as Med (84), AHEI (90) Cardio (18) GBD (1) and DASH (from NIH website). Looking across these diverse syntheses, it is evident that there is some consistency in quantities (indicating high adherence, recommendations, or association with lowest risk) for fruits and vegetables and for fish. There is great divergence for other flesh foods, dairy, legumes/nuts/seeds, and for alcohol. There is also lack of consistency for grains and SSBs.

Although there is reasonable consistency for fruits and vegetables, the absolute quantities do vary somewhat across these sources. Also, there is inconsistency in whether or not potatoes are counted as vegetables, with the DASH including and AHEI, Cardio, and GBD excluding them. The Med does not specify whether or not potatoes are counted as vegetables, and in the Med cohort studies that were reviewed, potatoes were sometimes positively scored and sometimes negatively scored.

34. See: https://www.nhlbi.nih.gov/health/health-topics/topics/dash/followdash [Accessed Dec 20 2018].
35. However, as noted in Section 2.5, the Dietary Patterns Methods Project included the AHEI as well as a later version of the HEI (HEI-2010), and demonstrated similar associations between both indices and all-cause, CVD, and cancer mortality (74). Note also, an updated HEI 2015-2020 was recently published, after preparation of this paper (187).

Within fruits, one inconsistency is in regard to juice. Again, the Med adherence score paper does not specify whether juice counts, and in the cohorts reviewed this varied. The Cardio and DASH allow juice to count as fruit, and the AHEI and GBD do not allow juice to be counted.

Regarding poultry and eggs, only DASH mentions these, and the other four examples neither encourage nor discourage consumption. In the Cardio paper, the author notes substantial controversy and uncertainty over these foods.

Concerning red meat, while all indicate upper limits rather than targets for red meat consumption, upper limits vary widely, with DASH at the high end because it groups all flesh foods and eggs and allows up to 168 g/d of flesh foods (or up to 300 g/d egg). The Med indicates < 80 g/d 'meat/meat products'. The AHEI indicates < 113 g/d of red or < 43 g/d of processed meat. The Cardio indicates a limit of < 28 g/d red meat, and processed meat no more than once per wk (< 50 g/wk). And the GBD indicates minimum risk at 18-27 g/d red meat and 0-4 g/d processed meat. Thus, there is a very wide allowed range for red meat of 0-168 g/d.

There is also a very wide range for dairy, with most sources indicating positive targets for dairy consumption, but Med indicating an upper limit. The AHEI does not include or score dairy, and thus neither encourages nor discourages. When translated to grams of fluid dairy, the ranges are: Med, < 180 g/d; Cardio, 490 – 735 g/d; GBD, 350-520 g/d milk; DASH, 450-750 g/d.

There is also inconsistency regarding dairy fat. The DASH diet restricts dairy to fat free or low-fat, whereas the Cardio paper explicitly allows full-fat dairy and questions the evidence for discouraging. Similarly, the GBD definition includes non-fat, low-fat, and full-fat milk, with low intake of these considered as the risk. The Cardio paper further emphasizes that knowledge is still emerging about other characteristics of dairy that may have importance for health outcomes (e.g. fermentation and probiotics). But GBD, for example, specifies 'milk' and not, for example, fermented dairy products.

In contrast to recommendations for other ASFs, which are inconsistent, recommendations for fish intake are quite similar across Med (>250 g/wk), AHEI (~225 g/wk), Cardio (≥ 200 g/wk), and GBD (~180-270 g/wk). As noted DASH combines all flesh foods, so it is the only pattern that could be met without fish.

Taking ASFs as a whole, and considering LMICs where insufficient intakes can be a concern, all but DASH indicate a lower limit for fish intake, and all but Med and AHEI indicate a lower limit for dairy intake. Most patterns indicate an upper limit for red meat and processed meat, with a lower limit of 0, except that GBD provides a range for minimum risk of 18-27 g/day (red meat). As noted, poultry and eggs are neither encouraged nor discouraged; these may be more available than other ASFs in some LMIC settings.

For legumes, nuts and seeds, there is great inconsistency in grouping, and some inconsistency in quantities. Legumes are in a separate group in Med and GBD but are grouped with nuts and seeds in AHEI and DASH, and with vegetables in Cardio. There is no mention of nuts and seeds in Med, whereas nuts and seeds are a separate group in Cardio and GBD. Quantities for legumes range from 20-70 g/d, and for nuts and seeds the range is 110-175 g/wk. However, when combined with other groups, the lower end of the range for either is effectively zero. This inconsistency in classification and implied messages about legumes, nuts and seeds is also seen when looking across FBDGs, globally (97).

Concerning grains, the main inconsistency is in whether whole grains are specified. AHEI, Cardio, GBD specify whole grains, with ranges of ~75-150 g/d. The Med and DASH do not specify whole grains, though these are encouraged via examples in the DASH guidance.

Finally, for SSBs most include an upper limit, but these range from zero - total avoidance - to up to 227 g/d. There is no mention of SSBs in Med. The AHEI includes fruit juice with SSBs and allows up to 277 g/d and under DASH up to 160 g/d could be allowed, whereas GBD indicates minimum risk at 0-5 g/d, and Cardio advises none (though as noted, in the case of Cardio fruit juice is allowed under fruit).

It is apparent that although there may be emerging convergence on food groups to encourage and discourage, challenges remain in defining optimal ranges, considering diverse health outcomes and dietary contexts. And for some food groups there are inconsistencies in definitions and groupings.

Note that **Table 1** focuses on foods/beverages and food groups only, and does not include nutrients, fatty acids or 'food substances' such as sodium or fiber. Regarding fats, there was consistency in total or near-total avoidance of *trans*- fatty acids to achieve highest scores, but some lack of consistency in regard to dietary fats more generally, with Med specifying 'regular use' of olive oil for a highest score, Cardio indicating 2-6 teaspoons/day of vegetable oil (≒80-240 kilocalories or 4-12% of a 2000 kilocalorie diet), GBD indicating 9-13% of daily energy from polyunsaturated fatty acids (PUFAs), AHEI indicating ≥10% of energy from PUFA, and DASH indicating 2-3 tsp of oil/day (or equivalent amount of salad dressing or soft margarine) in the 2000 kilocalorie DASH diet.

6.1.4

Summary of existing metrics

In summary, most metrics we have described require quantitative dietary data or semi-quantitative food frequency data with use of standard portion sizes. Some indices include foods or food groups only, while others include both foods/food groups and nutrients and/or other food substances. Those that 'count' foods and/or food groups only can generally be constructed without the use of food composition data.

Most metrics were developed and validated in the global north and reflect prevailing dietary patterns in these contexts as well as the public health priority of chronic disease risk reduction. Indices developed primarily to illuminate associations between intakes and outcomes (whether biomarkers/surrogate endpoints, disease outcomes or mortality) frequently are scored in relative terms (e.g. tertiles, quartiles, etc. of consumption of foods and food substances). Such metrics are not suited for global monitoring and comparisons, which are among the uses proposed herein for novel metrics. In the selected examples, we have therefore favored metrics with absolute cut-offs.

For these same metrics developed to reflect chronic disease risks, nutrient adequacy is not always an explicit concern, and the level/nature of validation with respect to nutrient adequacy varies. We note that this is also a matter of the data source, as the food frequency methods often used to assess adherence to dietary patterns may not have been validated to provide quantitative estimates of all nutrient intakes that might be of interest.

Finally, only the MDD-W and the WHO fruits and vegetables indicator are expressed as a prevalence, which is sometimes a desirable characteristic for communication and advocacy, especially in cross-sectoral work. In the case of the MDD-W, the dichotomous indicator is based on an underlying score, which may also be used, depending on context (164). Scores (and percentiles of scores) are more suited for studies of associations of indices to health outcomes. In some situations, scores may also be more sensitive, and may or may not be more useful than dichotomous indicators for detecting change (across time or after interventions); this depends on distributions, cut-offs, and the degree of change that is feasible and meaningful. **Table 2** summarizes selected characteristics of the indicators and indices selected as examples above.

Table 1. Criteria for Highest Component Score, Lowest Risk, or Recommended Amount[a]

	Mediterranean Diet (84)	AHEI (90)		Dietary Priorities for Cardiometabolic Health (18) based on a 2000 Kcal Diet		GBD Minimum Dietary Risk (1)	DASH 2000 Kcal Diet[b]	
Year of publication	2014	2012		2016		2017	Online resource [Accessed Dec 20 2018]	
	Grams	Servings	Serving size	Servings	Serving size	Grams	Servings	Serving size
Fruits	> 300 / d	≥ 4 / d	1 medium or 0.5 c	3 / d	1 medium, 0.5 c dried, 0.5 c fresh, frozen, or unsweetened canned, 0.5 c unsweetened juice	200-300 / d	4-5 / d	1 medium, 0.25 c dried fruit 0.5 c fresh, frozen, or canned 0.5 c fruit juice
Vegetables	> 250 / d	≥ 5 / d	0.5 c or 1 c leafy	3 /d	0.5 c cut-up raw or cooked 1 c raw leafy 0.5 c vegetable juice	290-430 / d	4-5 / d	0.5 c cut-up raw or cooked 1 c raw leafy 0.5 c vegetable juice
Legumes	> 140 / wk			Included with vegetables		50-70 / d		
Nuts & seeds				4 / wk	28 g	16-25 g / d	4-5 / wk	0.3 c or 43 g nuts 32 g peanut butter 14 g seeds 0.5 c cooked legumes 1 slice bread 28 g dry cereal 0.5 c cooked rice, pasta, or cereal
Nuts, seeds, legumes		≥ 1 / d					6-8 / d	
Cereals, grains	> 195 / d		28 g of nuts or 16 g[c] of peanut butter					
Whole grains		75 g / d		3 / d	1 slice whole-grain bread 1 c whole-grain cereal 0.5 c cooked whole-grain rice, pasta	100-150 / d		
Lean meat, poultry, fish, egg			n/a				≤ 6 / d	28 g cooked meats, poultry, or fish, or 1 egg (~45-50 g raw)
Fish	> 250 / wk	~ 2 / wk		≥ 2 / wk	100 g	~180-270 g /wk		
Meat/meat products	< 80 / d	< 1 / d	113 g					
Red meat			113 g red meat or 43 g processed meat	≤ 1-2 / wk	100 g	18-27 g / d		
Processed meat				≤ 1 / wk	50 g	0-4 g / d		
Dairy	< 180 / d			2-3 / d	1 c milk or yogurt, 28 g cheese			
Fat free or low-fat dairy							2-3 / d	~225-250 g milk or yogurt 43 g cheese
Milk, any fat content						350-520 / d		
Alcohol	12-24 / d	0.5-1.5 / d	113 g wine or 340 g beer or 43 g liquor			No alcohol		
Sweets, added sugar, including SSBs							≤ 5 / wk	1 Tbsp sugar, 0.5 cup sorbet, 1 cup sweetened beverage
SSBs & fruit juice		≤ 1 / d	227 g					
SSBs				0	'Don't drink'	0-5 g / d		

a. AHEI = Alternate Healthy Eating Index; c = cup; d = day; g = gram; GBD = Global burden of disease; SSBs = sugar-sweetened beverages; wk = week. Foods/food groups are included if they are present in at least two of the sources. Ounces are converted to grams. Recommendations are shown for foods/food groups only and not for nutrients or food substances, unless equivalents are given for food sources. For example, the AHEI is scored for long-chain omega-3 fatty acids (DHA + EPA) but the footnote to the table translates this into portion of fish per week. The GBD also specified mg/d of seafood omega-3 fatty acids; this has been converted to ~g fish / wk following the AHEI conversion.

b. https://www.nhlbi.nih.gov/health/health-topics/topics/dash/followdash [Accessed Dec 20 2018].

c. Expressed as 1 tablespoon in Chiuve et al. (90); 1 tablespoon is 16 grams in USDA National Nutrient Database for Standard Reference Release 28, food code 16098.

Table 2. Characteristics of Selected Example Metrics[a]

Indicator or index	Version cited	Components	Cut-offs or criteria for scoring	Score or prevalence
MAR	Krebs-Smith 1987 (158)	Nutrients	Absolute	Score
MDD-W	Martin-Prével 2017 (8)	Food groups	Absolute	Prevalence
HFD	Vandiveloo 2014 (172)	Foods, food groups	Absolute	Score
WHO fruits/vegetables	WHO website[b]	Food groups	Absolute	Prevalence
% UPF	Vandivijvere 2013 (64)	Foods	Absolute	Score
DASH	Liese 2015 (74)	Food groups, sodium	Relative	Score
Mediterranean Diet	Sofi 2014 (84)	Food groups, olive oil and alcohol	Absolute[c]	Score
HDI	Huijbregts 1997 (177)	Food groups, nutrients, food substances	Absolute	Score
DQI-I	Kim 2003 (179)	Food groups, nutrients, food substances	Absolute	Score
HEI	Guenther 2013 (181)	Food groups, nutrients, food substances	Absolute	Score
AHEI	Chiuve 2012 (90)	Food groups, nutrients, food substances, alcohol	Absolute, except for sodium	Score
PDQS	Fung 2018 (183)	Food groups	Absolute	Score

a. AHEI = Alternate Healthy Eating Index; DASH = Dietary Approaches to Stop Hypertension; DQI = Diet Quality Index; DQI-I = Diet Quality Index International; HDI = Healthy Diet Indicator; HEI = Healthy Eating Index; HFD = Healthy Food Diversity (HFD); MAR = Mean Adequacy Ratio; MDD-W = Minimum Dietary Diversity for Women of Reproductive Age; PDQS = Prime Diet Quality Score; PDQS = Prime Diet Quality Score; UPF = Ultra-processed food; WHO = World Health Organization.
b. Definition taken from the STEPS Survey Fact Sheet Template at: http://www.who.int/chp/steps/resources/en/ [Accessed Dec 20 2018].
c. Most Mediterranean diet scores are scored relatively; the effort by Sofi et al. (84) was explicitly designed to provide an alternative, with absolute scoring, and with clinical use in mind.

6.2

Considerations in developing novel diet quality metrics for women of reproductive age in low- and middle-income countries

Desired uses for indicators/indices were identified earlier when describing the objectives for the paper, and include:

- Population level assessment of diet quality for WRA in LMICs;
- Tracking of change across time in populations of WRA in LMICs;
- Assessment of change in diet quality relative to population targets for WRA in LMICs;
- Tracking of changes in diet quality in response to policy and programmatic interventions;
- Geographic targeting, when used in broader suites of indicators; and
- Communication and advocacy.

As noted, meeting these needs may require multiple indicators and/or a composite index that can also be broken into component parts, reflecting different dimensions and potential action points for improving diets. To provide a basis for work on novel metrics, we first describe characteristics of metrics that determine their usefulness, and then propose a set of practical, conceptual, technical and operational issues that should be considered.

6.2.1.

Determining if novel metrics are fit for purpose

In considering whether metrics are fit for purpose, a wide range of criteria or characteristics should be considered (**Box 21**). Some of these cannot be determined *a priori*, but others can be discussed at the outset.

New metric development efforts should address as many as possible of the criteria in **Box 21**. Special efforts should be made to ensure that new metrics are suitable for communicating clearly to a range of policy- and programmatic decision-makers. Composite metrics that can be decomposed may be most flexible for meeting diverse needs, including for programming.

Although many sources [e.g.(188-190)] provide lists of criteria and some sources outline decision-making processes for metric selection, the relative weighting of criteria depends on the proposed use(s) of the metrics, including for communication. In addition, there can be no universal guidance on the issue of ‘how good is good enough’ along the many dimensions, and there may be trade-offs both among characteristics and between ideal characteristics and cost and feasibility of data collection.

Box 21. Criteria for selection of metrics[a]

- Accepted practice and history of use; for novel indicators, justification through identifying gaps
- Applicability in different settings; cross-country and cross-cultural appropriateness and relevance
- Availability of data; for novel indicators, potential platforms for data collection with required frequency for proposed uses
- Cost (data collection, analysis, interpretation and processing into communications)
- Respondent burden
- Technical criteria:
  - Validity (face, content, concurrent, convergent, discriminant, predictive)
  - Reliability (test/re-test, intra- and inter-observer)
  - Sensitivity, specificity, nature/balance of misclassification
- Risk for bias
- Responsivity to change in the underlying dimension of interest, over time interval of practical relevance
- Clarity, simplicity
- Pathways for use of data; if none currently exist, is there a plausible pathway? Potential for integration in existing monitoring frameworks and systems?
- Stakeholder evaluation of strength of evidence or substantive merit; support for use
- Adds value within a set of indicators (e.g. fills an important gap, allows triangulation, aids interpretation)

a. The list presented here was adapted and extended based on MacDonald (188). Many other sources suggest similar or overlapping criteria; see for example: Brown (189); Lennie et al. (190).

MacDonald G. Criteria for Selection of High-Performing Indicators: A Checklist to Inform Monitoring and Evaluation. Available from: https://www.wmich.edu/sites/default/files/attachments/u350/2014/Indicator_checklist.pdf [Accessed Dec 20 2018].

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Lennie J, Tacchi J, Koirala B, Wilmore M, Skuse A. Equal Access Participatory Monitoring and Evaluation Toolkit: Helping communication for development organisations to demonstrate impact, listen and learn, and improve their practices. 2011. Available from: http://www.betterevaluation.org/sites/default/files/EA_PM%26E_toolkit_module_2_objectives%26indicators_for_publication.pdf [Accessed Dec 20 2018].

6.2.2.

Practical considerations

Proxy indicators and indices with lighter data requirements are highly desirable to allow less resource intensive data collection methods and wider uptake of metrics. Development of novel metrics should reflect recognition of likely data sources and survey platforms, so that metrics are feasible, useful and used, including for monitoring over time. While several LMICs (for example, Mexico and the Philippines) have implemented multiple surveys that include nationally-representative individual-level quantitative dietary data, these countries are the exception. Even in many HICs, quantitative dietary data for individuals are not collected with any regularity (191).

Similarly, with few exceptions, food frequency questionnaires validated to estimate intakes of a range of relevant nutrients and foods/food groups are rarely available in LMICs. These same countries often lack comprehensive and current food composition databases, so metrics that do not rely on the use of food composition data are needed. Given the cost and complexity of fully quantitative dietary data collection, novel data collection methods and tools, particularly for estimation of portions consumed, may also need consideration.

This in turn may suggest a research agenda for field validation of novel methods (see below, Section 6.2.5).

While many of the ‘whole of diet’ indices described above require quantitative dietary data, those that include foods or food groups only (vs. nutrients or other food substances) could be operationalized based on dietary data but without requiring a food composition database (as, for example, the version of the Mediterranean diet score developed for clinical use and the PDQS).

6.2.3.

Conceptual considerations and judgments

Several conceptual questions must be answered at the outset and have been raised or suggested above. First, a decision must be taken on whether the existing evidence base for healthy dietary patterns or food group intakes associated with reduced risks (e.g. from the GBD group), developed primarily with data from the global north, can be applied globally, with adaptation. If not, one choice would be to measure (or develop proxies for) only the limited number of elements or dimensions for which there is normative global guidance – e.g. on nutrient intakes (111) and the WHO description of a healthy diet (**Box 5**), which provides very little basis for defining optimal intakes of foods as such.

In Section 3, we aimed to provide a basis for considering the issue of global applicability. We provide a rationale for considering context and provide some evidence that suggests caution. We also highlight that in the context of multiple burdens, it may be important to have multiple metrics or metrics that can be decomposed into various dimensions, as, for example, with sub-metrics for micronutrient adequacy and chronic disease risk reduction. But we also note, as affirmed by Anand et al. (132) that there is substantial convergence in current thinking about healthy diets. Further, it is likely to be decades before there is a comparable evidence base from the global south prospectively linking defined dietary patterns to diverse health outcomes. A judgment and decision must be taken as to whether and how to proceed.

The challenge may come in the level of specificity needed to operationally define (and thus measure) the dietary pattern. It is possible to affirm the general relevance of converging views on healthy dietary patterns (plant-based, rich in fruits, vegetables, whole grains, legumes and nuts, with sufficient but not excessive fish, dairy and other ASFs, and with minimal added sugar or added low-quality fats), while questioning the idea that we can define this – globally – such that a metric is comparable in meaning and relevant across countries at differing income levels. This is the challenge.

If there is a decision that the evidence from the global north is sufficient to proceed with operationalizing target quantities for food groups and/or food substances, for application to the global south, several other concepts need attention and synthesis. Different consumption cut-offs may be optimal for different outcomes, so results for different outcomes – including adequacy – must be synthesized. And for some food groups and food substances the relationship between consumption and risks may be U-shaped (i.e., higher risks at both low and high levels of consumption, as, perhaps, with intakes of total fat, or ASFs). Further, to the extent that evidence for specific quantity cut-offs is derived from studies evaluating one food group at a time, the relevance in the context of differing overall dietary patterns may not be clear. Conversely, depending on the process involved in characterizing dietary patterns, guidance on food group consumption based on existing dietary patterns may not be harmonized, as shown in **Table 1**.

Decisions are also needed on the features described and illustrated by examples above (**Boxes 9-20**) for existing metrics, and some of these are at a conceptual level, particularly related to the breadth and range of dimensions or elements to include. Specific diet quality elements or dimensions that may be of interest for WRA in LMICs could include energy adequacy, macronutrient balance, macronutrient quality, micronutrient adequacy (or possibly adequacy for specific problem nutrients), nutrient density, dietary risk factors for chronic disease, and frequency and quantity of consumption of nutrient-poor foods and/or UPF. For most of these, simpler proxy measures are not currently available and may or may not be feasible. Decisions on breadth will be influenced by feasibility and intended uses and will determine the indicator definition.

6.2.4.

Technical considerations in metric construction and validation

Once the scope and meaning of the novel metric(s) are defined, there will remain a large number of concrete decisions on most of the remaining features illustrated in **Boxes 9-20**, including: how the indicator is expressed (continuous, count/ordinal, dichotomous); data requirements or constraints; assigning foods to food groups; cut-off values for scoring each component; operational definitions of each component; and on weighting of each element in the total score.

Indicator validation can happen at several levels and through several processes. Secondary data analysis can speak to many, but not all, of the technical criteria in **Box 21**, depending on the nature of available data. It should be noted that it is likely that few existing dietary metrics have been evaluated against all desirable criteria, but it is useful to aim to speak to as many as possible.

6.2.5

Operational considerations

For novel metrics to be feasible and used, measurement must be feasible. For inclusion in major survey programs, cognitive interviewing or other field testing approaches may be required. Novel diet quality metric(s) may also require innovative measurement methods (for example in estimation of quantities consumed) that require field validation in a range of contexts.

Development and validation of novel metrics can be viewed as a staged process, with secondary data analysis as a first step. However, practical and operational considerations, as well as the full range of criteria for selecting metrics outlined in **Box 21**, should be considered from the outset.

7 Summary

We have aimed to provide a basis for deciding a path forward on development of novel and multidimensional metrics of diet quality for WRA in LMICs. We have described the evolution of diet quality concepts and illustrated iterative processes by which both concepts and metrics have developed. While there is currently no single global definition of diet quality and no comprehensive food-based dietary guidance from normative global agencies, there is substantial convergence on many elements of diet quality, particularly in the context of diets and public health priorities in the global north. And these same priorities - centered on chronic disease risk reduction - have also now emerged as priorities in much of the global south.

However, there are many evidence gaps in the global south, and several lines of evidence provide cautionary notes related to context. In particular, in countries experiencing nutrition transitions energy adequacy and chronic disease risk may both increase with urbanization; micronutrient adequacy may or may not increase with urbanization, depending on context. This argues for separate metrics, or metrics that can be decomposed.

We have outlined a number of dimensions of diet quality and note that decisions must be taken on whether (and how) certain dimensions could and should be reflected in novel metrics. Although such results are often not reported, metrics for healthy dietary patterns should be reflective of energy and nutrient adequacy and macronutrient balance (within broad limits), as well as chronic disease risk reduction. Undernutrition and imbalanced diets, with excessive carbohydrate and very low fat intakes, remain a problem in some contexts. Some other dimensions (safety, sustainability) are important, but may be difficult to incorporate.

Arguably, composite indicators with too many dimensions may in any case be less useful for policy and programs. It may be more useful to envision suites of indicators and accompanying communication tools.

We also provide detailed examples of existing diet quality indicators, to illustrate the range of issues and decisions involved in indicator design and development. We have also highlighted that although there is broad convergence on food groups to encourage and to discourage, there is less convergence on optimal quantities of consumption, particularly for ASFs. To operationalize indicators based on food groups, the issue of quantities will have to be addressed.

We have identified purposes for which metrics are required and have also outlined a set of criteria for evaluating if metrics are fit for purpose. It is worth noting again that no single metric will suit all purposes, and metrics designed to contribute future evidence on relationships to outcomes would likely be designed differently from metrics for use in policy, programs, and advocacy - the purposes that we propose.

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