Methods and Metrics for Food Security and Nutrition Outcome Indicators

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List of abbreviations and acronyms

BMI	Body Mass Index
DHS	Demographic and Health Survey
ELCSA	Latin American and Caribbean Food Security Scale
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FIES	Food Insecurity Experience Scale
FIVIMS	FAO Food Insecurity and Vulnerability Information and Mapping System
FS	Food Security
GHI	Global Hunger Index
HAZ	Height-for-age Z-scores
HDD	Household Dietary Diversity
HFIAS	Household Food Insecurity Access Scale
HHS	Household Hunger Scale
IDA	Iron Deficiency Anaemia
IFPRI	International Food Policy Research Institute
IYCF	Infant and Young Child Feeding
LBW	Low Birth Weight
LSMS	Living Standards Measurement Study
MAD	Minimum Acceptable Diet
MAR	Mean Adequacy Ratio
MDD	Minimum Dietary Diversity
MDD-W	Minimum Dietary Diversity for Women of Reproductive Age
MFAD	Modified Functional Attributable Diversity
MICS	Multiple Indicator Cluster Survey
MMF	Minimum Meal Frequency

MUAC	Mid-Upper Arm Circumference
NAR	Nutrient Adequacy Ratio
NCD	Non-communicable Disease
PoU	Prevalence of Undernourishment
RDA	Recommended Dietary Allowance
RNI	Reference Nutrient Intake
SDG	Sustainable Development Goals
USAID	United States Agency for International Development
US HFSSM	US Household Food Security Survey Module
UNICEF	United Nations Children’s Fund
WAZ	Weight-for-age Z-scores
WC	Waist Circumference
WDDS	Women’s Dietary Diversity Score
WFP	World Food Programme
WHO	World Health Organization
WHR	Waist-to-hip Ratio
WHtR	Waist-to-height Ratio
WHZ	Weight-for-height Z-score

1. Introduction

Agriculture influences food production, food is a component of diets, and diets influence nutritional status. Agricultural policies and interventions impact nutritional outcomes by   through several pathways that influence the quantity and quality of food consumed by individuals. Nutritional outcomes, usually assessed by physical measurements (anthropometry), are measured at the individual level, as they relate to what an individual consumes and the process of absorbing and utilizing nutrients within the body (Aberman et al., 2015).

A nutrition-sensitive intervention aims to contribute to better nutritional outcomes by addressing the underlying determinants of malnutrition such as access to safe and nutritious foods (quantity and quality/diversity), adequate care and a healthy and hygienic environment. Dietary quality is a key intermediary between agriculture and nutrition. Individual dietary quality is best measured by dietary diversity, which is a measure of nutritional adequacy. This means that agriculture interventions and policies, designed to increase food production, only address one aspect of food security (FS). Thus, the appropriate indicator needs to be selected to determine the impact of agriculture on nutrition. For example, an agricultural intervention that only addresses the availability of food, the lack of which manifests as hunger or acute malnutrition, will most likely be assessing wasting or weight-for-height (a nutritional status indicator) as this is the most appropriate nutritional outcome related to increases in household food availability. However, a different nutritional outcome indicator will be required when the interest of the intervention is to improve diet quality. In this case, a better nutritional outcome is stunting, assessed by height-for-age. For an agricultural intervention, e.g., biofortification, where improvements made in the food system are reflected in the increased micronutrient content of food (e.g., Vitamin A content in orange-flesh sweet potatoes), a biochemical metric of nutritional status rather than anthropometry might be necessary. While nutrition sensitive, consumption data alone are not a nutrition indicator because it does not directly lead to improved nutritional outcomes.

The objective of this paper is to describe existing and current metrics for assessing food security and nutritional status outcomes. This review looks at different metrics, especially ones that are more relevant to developing food security measures, diet quality and nutritional status.

2. History of food security measurements

The concept of FS and its measurement has evolved over the years from emphasizing singular constructs motivated by global economic and food-related concerns to a more complex multi-dimensional, multidisciplinary and multi-level conceptualization. The term emerged in 1970 as a food supply or availability concept to counter concerns with global food shortages during that period (Coates et al., 2007; Jones et al., 2013; Pangaribowo et al., 2013). The concept was broadened in the following decade to capture the concept of food access with the recognition that not all people are able to obtain adequate food even in the presence of sufficient national food supplies or availability (FAO, 2012). Further iterations of the concept over time incorporated the dimension of food utilization into the FS concept to capture factors that influence food consumption and biological utilization of nutrients at the household and individual levels. Currently, the 1996 definition by the Food and Agriculture Organization (FAO, 2012) that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences" is universally accepted and used. This definition captures the three pillars (availability, accessibility and utilization) that have been successively incorporated into the concept, as well as the cross-cutting pillar of stability implied by the phrase "at all times" (Jones et al., 2013).

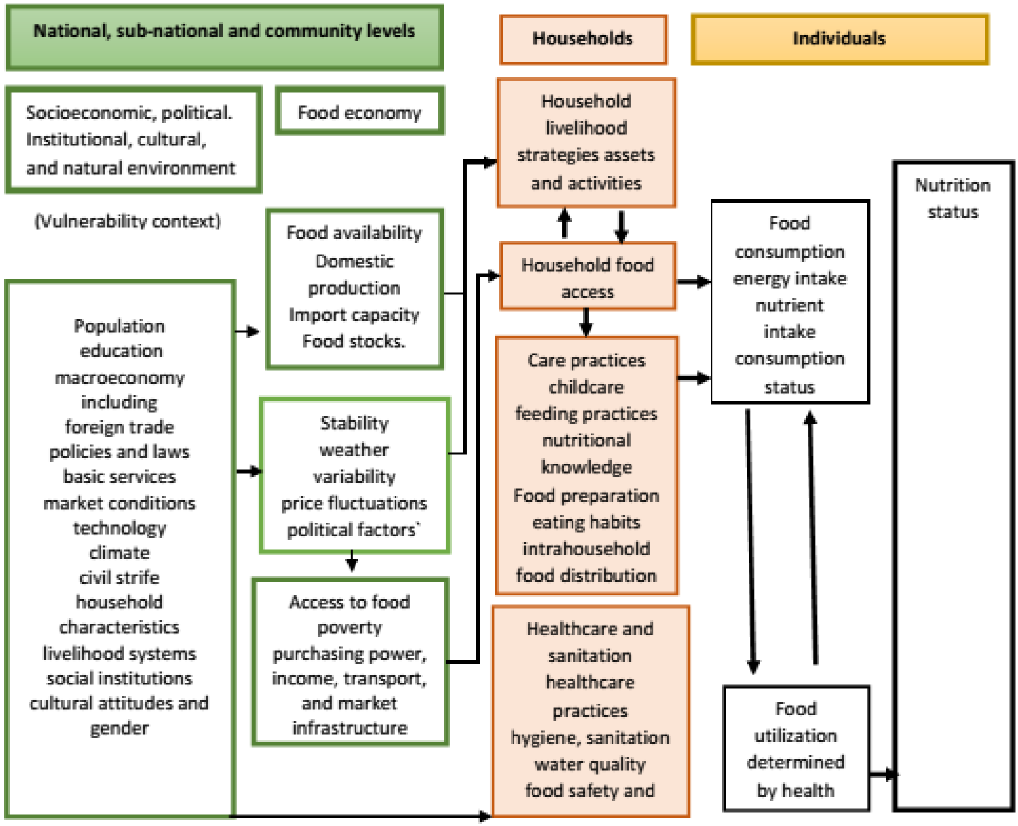
Metrics for measuring FS have similarly evolved with the changing definition of FS. Conventional metrics for measuring FS typically align with one or more of the key pillars organized at various levels of data collection and/or analysis (Carletto et al., 2013; Jones et al., 2013). More recently, further deconstruction of the 1996 definition to enable holistic and functional assessment has been proposed, which broadens FS measurements beyond the well-recognized availability, accessibility and availability pillars to include an exploration of the quality, quantity, preferability, safety, stability and sustainability dimensions of each pillar (Coates, 2013).

3. Conceptual linkages between food security and nutrition

The FAO Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) framework provides a useful model for understanding the nexus between food security and nutrition outcomes, and associated measurement metrics (Figure 1). The framework is an adaptation of the UNICEF framework of the causal links to malnutrition (Black et al., 2008). The framework organizes the four key pillars of food security according to the national/subnational/community, household and individual levels, which correspond to the basic, underlying and immediate causes of malnutrition, respectively. While developing countries are still grappling with persistent undernutrition among children and women, they are also facing an increasing burden of overnutrition, particularly among women. The co-existence of multiple malnutrition burdens manifests as anthropometric deficits (undernutrition) and/or micronutrient deficiencies with overnutrition.

According to the framework, a person's nutritional status is influenced by the food utilization pillar, which at the individual level is a function of food consumption (energy and nutrients), and the person's health status that permits optimal biological utilization of food. Food consumption and utilization are shown to be interdependent, representing the dietary intake and disease link as the immediate cause of malnutrition. Food consumption is shown to be influenced by the food access pillar directly and indirectly through care practices, while health and sanitation influences the food utilization pillar. In turn, household-level influences are a function of national/subnational/community-level factors that determine food availability and food access through markets. In the framework, the stability pillar is captured among the national-level factors but is generally recognized as a cross-cutting issue that pertains to all the FS pillars.

Figure 1: FAO/FIVIMS framework showing linkages between Food Security Pillars and nutrition status



Source: Charlton, 2016

While the framework integrates the food security and nutrition security variables, the two concepts are not the same. Nutrition security is defined as “A situation that exists when secure access to an appropriately nutritious diet is coupled with a sanitary environment, adequate health services and care, in order to ensure a healthy and active life for all household members” (FAO-WFP-IFAD, 2012). Thus, food security is necessary, but not sufficient, to achieve nutrition security.

4. Metrics for measuring food security

The complexity and dynamic nature of the FS concept means it cannot be captured by a single or static metric. Thus, the range of available metrics continue to evolve in response to a changing world with global, national, household and individual-level socioeconomic and health influences and impacts. In this section, some of the most widely used food security metrics are summarized according to analyses at the national, household and individual levels.

National level

National level analyses are based on aggregated national level data on sources of supply and utilization of food, such as food balance sheets (FAO, 2001; Jones et al., 2013). These data cannot be disaggregated to inform on household or individual-level food availability or consumption. National or country-level FS metrics emphasize the FS availability pillar, measuring sufficient availability in terms of quantity and or quality. Examples of national-level FS metrics are provided in Table 1.

Table 1: Selected national-level food security metrics: Measurement and purpose

Metric	Source	How it is measured	Purpose
Prevalence of undernourishment (PoU)	FAO	Based on probability distribution that, based on hypothetical population factors in average amount of energy consumed, variability in usual consumption and threshold representing minimum dietary energy requirement	Estimates proportion of the population with insufficient amount of food (dietary energy) over a 12-month period
Depth of food deficit	FAO	Derived from PoU indicator	Severity of dietary energy inadequacy
Dietary energy supply	FAO	Computed as the sum of quantities of food from various supply sources (e.g., production, import, stock) minus quantities utilized through various avenues (e.g., export, feed, seed, waste) for each commodity, divided by population size and 365 days	Amount of daily calories from food available for human consumption on per capita basis. In absence of individual dietary surveys this metric serves as dietary energy consumption at population level
National energy available from non-staple foods	FAO	Computed as percentage contribution of calories from non-staple food (i.e., all food items excluding tubers and grains) to total food energy supply	Energy available from non-staple foods in the food supply could be proxy for overall quality of national food supply
Global Hunger Index	IFPRI	Composite index constructed from three equally weighted indicators: proportion of undernourishment, prevalence of child underweight and child mortality	Provides awareness on extent of hunger across countries and regions

Prevalence of undernourishment

Produced annually by the FAO, this metric is the indicator for measuring progress towards achieving Target 2.1 (Zero Hunger) of the Sustainable Development Goals (SDG). The metric is derived using dietary energy supply data from national food balance sheets and is used for global monitoring purposes (Cafiero et al., 2014). This indicator only considers dietary energy intake and therefore does not reflect nutrient adequacy or diet quality, which are critical for achieving optimal nutritional status. Furthermore, as an indicator of chronic hunger over a 12-month period, it does not capture short-term experiences of undernourishment associated with seasonality, acute price fluctuations and other food system shocks. Complementary national level metrics contained in the FAOSTAT suite of FS indicators allow an exploration beyond the availability pillar.

Depth of food deficit (kcal/capita)

Dietary energy supply from food balance sheets or food consumption data from household consumption and expenditure surveys can be used to obtain this indicator derived from the prevalence of undernourishment (PoU). It is one of the indicators in the FAOSTAT suite of FS indicators available for nearly all countries, which allows cross-country comparisons.

Dietary energy supply

Also derived from food balance sheets, this metric provides information on whether a nation's food supply contains sufficient energy to meet population needs. The metric does not provide information on accessibility or consumption of dietary energy by different population groups in the country. The indicator also does not ensure dietary energy sufficiency among nutritionally vulnerable groups in a country.

National energy availability from non-staples

Given that staple foods are typically the least expensive, are of low nutrient density and are associated with poor diet quality and micronutrient deficiencies (Arimond et al., 2010), and as non-staples tend to be more nutrient dense this metric, while it does not reflect actual consumption of non-staple foods, gives some indication of the diversity of the national food supply believed to be important for achieving healthy national food systems (Remans et al., 2014). Complementary metrics that reflect national availability of diverse foods (quality) include the modified functional attributable diversity (MFAD), the Shannon entropy diversity metric (Shannon), and national fruit and vegetable availability.

Global hunger index

This metric from the International Food Policy Research Institute (IFPRI) is designed to comprehensively measure and track hunger at global, regional and national levels (Von Grebmer et al., 2016). This index serves as an advocacy tool to highlight successes and gaps in addressing hunger and raise awareness of regional and country differences in hunger, or severe food insecurity. Countries are ranked on a 100-point scale where 0 is the best score (no hunger) and 100 is the worst. Data to construct the Global Hunger Index (GHI) are taken from FAO (undernourishment) UNICEF and the World Health Organization (WHO) based on country Demographic and Health Surveys and the United Nations Inter-agency Group for Child Mortality Estimation (for child mortality).

Household level

These metrics are typically based on data collected at the household level using household surveys. Household-level FS metrics are derived from food acquisition and consumption data and reflect the accessibility pillar. These data can be aggregated to a national level, but cannot be used to draw conclusions about individuals' access to or consumption of sufficient and diverse foods as they do not inform on intra-household food allocation. The most commonly used household-level FS metrics are summarized in Table 2.

Table 2: Selected household level food security metrics

Metric	Source	How it is measured	Purpose	Cut-offs
Food Consumption Score (FCS)	WFP	Index constructed from sum of frequencies of consuming different food groups (8 total) in past 7 days multiplied by standardized food group weight (based on relative nutritional value of different food groups)	Usual household food diet and access to caloric sufficiency and diverse food groups	Household consumption status defined as: Poor (0–21); borderline (21.5–35); acceptable (>35)
Household Dietary Diversity Score (HDDS)	FAO	Number of food groups out of 12 total food groups consumed by household members in past 24 hours	Household access to variety of food groups. Proxy for food access and socioeconomic status	Maximum score = 12 food groups
Household Food Insecurity Access Scale (HFIAS)	USAID/ FANTA II	Based on responses to occurrence (9 Yes/ No responses) and follow-up frequency (3-point scaled responses) questions on inadequate food access over one month period	Experience of insecure food access (FIAS) over one-month period	0 to 27 scoring range used as continuous variable or categorized as: Food secure – mildly FIAS, moderately FIAS, severely FIAS
Household Hunger Scale (HHS)		Based on three hunger-related (occurrence and frequency) questions from the HFIAS over one-month reference period	Most severe experience of food insecurity	Each question scored 0–2: possible score range 0–6. Used as continuous variable or categorized as household with: Little to no hunger; moderate hunger; severe hunger

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Table 2 Continued

Metric	Source	How it is measured	Purpose	Cut-offs
Food Insecurity Experience Scale (FIES)	FAO	Yes/No responses to 8-item questionnaire on experience of food insecurity severity over a reference period of up to 12 months	Food insecurity (hunger) experience, measuring food access over reference period	Mild, moderate, severe
Months of adequate household provisioning (MAHFP)	USAID/ FANTA III	Yes/No response to initial question whether there were months of household food insufficiency in past 12 months with follow-up question on months in which this occurred	Average number of months in past year when households had sufficient food to meet their needs. Proxy measure of household food access	Calculated as 12 months minus months where food insufficiency was experienced. Score range: 0 to 12. No cut-offs

Food consumption score

This metric is a composite score developed by the World Food Programme (WFP) for establishing the prevalence of food insecurity in a country or region. The metric has been shown to be associated with per capita caloric intake as well as socioeconomic variables in African countries (Programme, 2007; Wiesmann et al., 2009). It has not been validated for household diet quality (Leroy et al., 2015).

Household dietary diversity

Developed by the Food and Nutrition Technical Assistance (FANTA) project to monitor changes in access to adequate quantities and quality (diversity) of food (Leroy et al., 2015). Household dietary diversity (HDD) has been shown to be strongly associated with per capita dietary consumption and dietary energy availability, as well as other FS-related indicators (Cafiero et al., 2014; Hoddinott & Yohannes, 2002; Jones et al., 2013; Swindale & Bilinsky, 2006). The metric reflects both quantity and quality FS dimensions. There are no standardized cut-offs for this metric.

Experience-based Metrics

These metrics are modelled after the US Household Food Security Survey Module (US HFSSM), informed by ethnographic studies on how low-income families experience food security. Experience-based metrics attempt to directly measure households' experiences with food security and are derived from responses to questionnaire items reflecting three key cross-cultural domains of food insecurity experience, namely: anxiety about household food supply; insufficient quality relative to variety, preferences and social acceptability; and insufficient food supply and intake (Ballard et al., 2011). The experience-based scales measure the quantity dimension of the food access pillar. There are four experience-based metrics: i) the Household Food Insecurity Access Scale (HFIAS), developed as an indicator for monitoring the impact of USAID Title II food assistance programmes on household food access security (Coates et al., 2007; Swindale & Bilinsky, 2006); ii) the Household Hunger Scale (HHS), an offshoot of the HFIAS, based on more cross-culturally consistent questionnaire items on experiences of severe insufficient food access (Deitchler et al., 2010); iii) the Latin American and Caribbean Food Security Scale (ELCSA), adapted from the US HFSSM and existing scales from Brazil and Columbia (Ballard et al., 2013); and iv) the Food Insecurity Experience Scale (FIES), the most recent of these metrics, developed by the FAO as a global version of an experience-based metric built on experiences with predecessor metrics.

Months of adequate household provisioning

One of the USAID/FANTA FS indicators, this is particularly useful for use with households that rely heavily on their food production. The indicator provides information on the length of the lean season when households experience diminished food sufficiency. Over time, the Months of Adequate Household Provisioning (MAHP) metric can capture changes in household resilience. It is recommended that the metric be used in combination with other FS metrics such as the HHS and HDD. A major advantage of this metric is that it captures the combined effects of a range of intervention strategies, such as improved agricultural production, storage and household purchasing power (Bilinsky & Swindale, 2010).

Individual level

Individual-level FS metrics typically emphasize food consumption and hence address the utilization pillar. Involving the use of dietary intake assessment methods (mainly 24-hour recall and food frequency questionnaires), these metrics measure actual food consumption and can capture both quantity and quality dimensions of the utilization pillar. There are two main categories of individual-level FS metrics: those based on qualitative assessments of the diversity of food groups consumed, and those based on quantitative dietary intake assessments. Quantitative key individual-level FS metrics are summarized in Table 3.

Dietary diversity

This is measured by summing the total number of unique food items or food groups consumed over a reference period (usually 24 hours or 7 days). These include: i) the population-level dichotomous minimum dietary diversity for women of reproductive age (MDD-W) indicator, using a maximum of 10 food groups, which has replaced the

Women's Dietary Diversity Score (WDDS) continuous variable indicator that uses 9 food groups (FAO-FHI, 2016); ii) the minimum dietary diversity (MDD) indicator for children 6–23 months designed by the WHO to assess diet quality as a component of infant and young child feeding (IYCF) practices at population level (WHO, 2008). The MDD-W and MDD have been validated for the micronutrient adequacy of women and children's diets, respectively, and are hence considered as proxies for micronutrient status.

Minimum acceptable diet

This metric is one of the eight core WHO indicators for assessing IYCF. It is a composite indicator that captures both the quantity and quality dimensions of IYCF, however, it does not provide quantitative information on children's food and nutrient intake. Its construction takes into account breastfed and non-breastfed children, and further disaggregation by age group (6–11 months, 12–17 months and 18–23 months) is recommended.

Nutrient adequacy metrics

These comprise the nutrient adequacy ratio (NAR) and the mean adequacy ratio (MAR). The NAR is computed as the ratio of an individual's nutrient intake (derived from quantitative intake assessment and computation of nutrient content using food composition tables) to the estimated average requirement reported on a 0 to 1 or 100% scale. The MAR is computed as an average of all the NAR values. They provide information on the overall nutrient adequacy of a population. Population nutritional status cannot be inferred from this indicator (IOM, 2000).

Table 3: Quantitative key individual-level FS metrics

Metric	Source	How it is measured	What it measures	Cut-offs
Women's Dietary Diversity Score (WDDS)	FAO	Number of food groups out of a total 9 food groups consumed by women of reproductive age in the past day	Quality of women's diet: Proxy for micronutrient adequacy of diet	Continuous variable
Minimum dietary diversity-W (MDD-W)	FAO & FHI	Number of food groups out of a total 9 food groups consumed by women of reproductive age in the past 24 hours	Quality of women's diet: Proxy for micronutrient adequacy of diet; replaced the WDDS	Adequate diet quality (micronutrient) ≥ 5 food groups
Minimum dietary diversity (MDD)	WHO	Number of food groups out of a total 8 food groups (including breastmilk) consumed by children 6–23 months old in the past 24 hours	Diet quality (micronutrient adequacy) of complementary feeding diet of children 6–23 months	Adequate diet quality (micronutrient) ≥ 5 food groups

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Table 3:

Metric	Source	How it is measured	What it measures	Cut-offs
Minimum acceptable diet (MAD)	WHO	Composite indicator based on children 6–23 months achieving the cut-offs for minimum meal frequency (MMF); MDD separately calculated for breastfed and non-breastfed children 6–24 months. MMF cut-offs: 2x: breastfed infants 6–8 months 3x: breastfed infants 9–23 months 4x: non-breastfed infants 6–23 months	Comparison across and within countries of prevalence of children receiving recommended infant and young child feeding practices from their caregivers	NA (population prevalence of children receiving an MAD indicative of extent of practicing recommended IYCF practices)
Nutrient adequacy ratio (NAR)		Compares nutrient intake against nutrient requirements using recommended dietary allowance (RDA) or reference nutrient intake (RNI)	Nutrient adequacy of population's dietary intake	0–1 or 100% scale (possible nutrient adequacy or inadequacy)
Proportion of the diet energy comprised of ultra-processed foods	Proposed by INFORMAS	Proportion of total energy intake provided by ultra-processed food (foods that have undergone industrial processes such as salting, sugaring, frying and curing to increase shelf life and palatability)	Relative contribution of ultra-processed foods to overall individual dietary energy intake	

5. Metrics for measuring nutritional outcomes

In simplified terms, the nutritional status of an individual is characterized by their dietary intake and health status. These are dependent on factors such as food access, care practices and the health and sanitation environment (UNICEF malnutrition framework). The relevant indicators for describing these nutritional outcomes are needed to: identify and prioritize nutritional problems; establish goals; and monitor progress in achieving the set objectives. Although there are several key indicators available for assessing nutritional outcomes, the main challenge is the ability to identify and choose the metrics or data suited to each situation and for different uses. There are limitations to the choice of metrics for assessing nutritional status. There are practical limits to the feasibility, accuracy and precision of all measurements, including for age. The size of the sample and the number of measurements that can be made are constrained by the resources available. Assessing the nutritional status of a person or a population starts with collecting the appropriate metrics, usually at the individual level, such as anthropometric measurements of weight and height or biochemical measurements of haemoglobin concentrations. These metrics are then expressed at the population level, usually in the form of prevalence or percentage of individuals who are malnourished or not with respect to the form of malnutrition being considered, in accordance with cut-off values. The use and interpretation of these indicators of status are presently well-established. For example, for children, the use of two indices, weight-for-height and height-for-age, is recommended for most purposes, but not necessarily for all. These indices can be expressed as the percentage of children under five years of age with a weight-for-age index of <-3 z-scores or <-2 z-scores. The nutrition indicators, especially anthropometric measures and suitable cut-offs for intervention, are normally assigned based on their ability to predict mortality.

The metrics for nutritional status outcomes are usually obtained from nationally representative surveys such as Demographic and Health Surveys (DHS, ORC Macro), household living standards surveys (LSMS/World Bank) and Multiple Indicator Cluster Surveys (MICS/UNICEF).

The indicators included in this section appear to be the most widely used or the most relevant for nutritional outcomes of populations. Table 4 is a list of nutritional indicators designed to assist in the selection of the appropriate nutrition indicators for specific nutritional situations and population groups. The sections have been organized by nutritional outcomes of undernutrition, overnutrition and micronutrient malnutrition to reflect the triple burden of malnutrition.

Malnutrition metrics in children

Low birth weight

At a population level, the proportion of infants with a low birth weight (LBW) is an indicator of long-term poor nutrition, morbidity and poor health of a woman during pregnancy. LBW has been defined as a weight at birth of less than 2.5kg (WHO, 2015). It contributes to a range of poor health outcomes, for example, it is closely associated with foetal and neonatal mortality and morbidity, inhibited growth and cognitive development, and non-communicable diseases (NCDs) later in life. In developing countries, it is often difficult to obtain reliable data on this indicator because a significant number of deliveries occur in homes or health centres where cases of infants with low birth weight often go unreported. As a population indicator, the prevalence of LBW in these settings is often underestimated.

Stunting

Stunting signifies insufficient linear growth relative to age due to a slowing in skeletal growth. Stunting is frequently found to be associated with poor overall economic conditions, especially mild to moderate, chronic or repeated infections, as well as inadequate nutrient intake. Therefore, an indicator based on height-for-age, such as the proportion of stunted children, has been suggested as a measure of overall social deprivation. The percentage of children with low height-for-age (stunting) reflects the cumulative effects of undernutrition and infections since birth, and even before birth. This measure can therefore be interpreted as an indication of poor diet or recurrent infections and may led to the long-term restriction of a child’s growth potential. Stunting is defined as height-for-age <-2 standard deviations (SD) of the WHO Child Growth Standards median.

Wasting

Wasting in children is a symptom of acute undernutrition and indicates a deficit in tissue and fat mass compared with the amount expected in a child of the same height or length, leading to a failure to gain weight or actual weight loss. It may be precipitated by a high incidence of infectious diseases, especially diarrhoea, or some other household crisis, and usually occurs in situations where the family food supply is limited and the food intake of children is low. Wasting is defined as weight-for-height (WHZ) < -2 SD of the WHO Child Growth Standards median. WHZ is an index that is particularly important for the description of current health status.

Underweight

Weight is by far the easiest to measure, making this the indicator for which most data on child undernutrition have been collected in the past. The percentage of children who have low weight-for-age z-scores (WAZ), i.e., underweight, can reflect wasting (WHZ), indicating acute weight loss or stunting, or both. Thus, underweight is a composite indicator that may be difficult to interpret. Underweight is defined as weight-for-age < -2 SD of the WHO Child Growth Standards median.

Overweight

Overweight is defined as weight-for-height > +2 SD of the WHO Child Growth Standards median. Childhood obesity is associated with a higher probability of obesity in adulthood, which can lead to a variety of disabilities and diseases, such as diabetes and cardiovascular diseases.

Mid-upper arm circumference

The measure of mid-upper arm circumference (MUAC), or MUAC for age with simple cut-offs, is comparable to the WHZ as a predictive measure of under-five mortality (Myatt et al., 2006; Rasmussen et al., 2012). MUAC is a popular nutritional indicator because it can be measured easily, quickly and affordably. Values below the cut-offs of 12.5cm and 11.5cm are used to define moderate and severe acute malnutrition, respectively. This index alone may be a sufficient tool for screening for the undernourished in emergencies.

Malnutrition metrics in adolescents

Due to the variable timing of the pubertal growth spurt, the indices of weight and height in relation to age, i.e., the use of a Body Mass Index (BMI), is of little value for the assessment of nutritional status in this age group. The more appropriate indices for assessing nutritional status in adolescents are MUAC, waist circumference (WC) and waist-to-height ratio (WHtR) (Olatunbosun et al., 2018).

Malnutrition metrics in adults

Body mass index

In adults, BMI, computed as the weight of an individual in kilograms divided by the height of the individual in meters squared (kg/m^2), is a more commonly used anthropometric indicator used to detect both under- and overnutrition.

Waist circumference and waist-to-hip ratio

These indicators are used to identify individuals at increased risk of obesity-related morbidity due to the accumulation of abdominal fat (WHO, 2011b). Although BMI, often considered the obesity index, is associated with increased risk of obesity-related morbidity and mortality, the WHR and WC are stronger independent risk factors than BMI. This is because of the importance of abdominal fat mass (referred to as abdominal, central or visceral obesity), which can vary significantly even with small changes in total body fat and BMI.

Micronutrient malnutrition

Iron deficiency anaemia

Iron deficiency anaemia (IDA), which is usually due to inadequate iron intake (about 50% of all IDA), is the most common micronutrient deficiency globally. Although iron deficiency is the most common cause, other vitamin and mineral deficiencies, chronic inflammation, parasitic infections, blood loss and inherited disorders can all cause anaemia. IDA is often defined by the WHO as haemoglobin levels of ≤ 11g/dl (WHO, 2011a). The cut-off values vary by age, sex, altitude, smoking and pregnancy status (WHO, 2015). A preventative strategy to improve iron nutritional status is to increase the consumption of iron-rich foods, including fortified foods. It is also important to advocate the increased intake of enhancers of iron absorption, e.g., vitamin C, while reducing anti-nutritive agents such as polyphenols and phytates. There is clear evidence that the addition of iron fortificants to staple foods is associated with a reduction of anaemia prevalence (Barkley et al., 2015; Gera et al., 2012). Reducing the prevalence of maternal and child anaemia, for example, will improve maternal and health outcomes resulting in reduced undernutrition and stunting in children.

Vitamin A nutritional status

Vitamin A deficiency results from a dietary intake of vitamin A that is inadequate to satisfy physiological needs. It may be exacerbated by high rates of infection, especially diarrhoea and measles. It mostly affects young children and pregnant women. Vitamin A deficiency manifests clinically in the milder stages as night blindness and Bitot's spots, or the potentially more serious blindness. Sub-clinically, serum retinol levels can be used to determine vitamin A deficiency. However, this is an indicator of vitamin A stores in the liver and may not necessarily reflect the adequacy of vitamin A in the diet as blood retinol levels are tightly regulated by the body.

Zinc nutritional status

Zinc deficiency is caused by inadequate levels of zinc in the diet because of the reduced intake of zinc-rich foods from animal sources and/or the intake of plant-based foods that have an abundance of zinc inhibitors (Caulfield & Black, 2004). Plasma or serum zinc concentrations are the most widely used indicators of zinc deficiency at the population level. Zinc deficiency is mostly associated with the low intake of zinc from food, but it is important to note that zinc deficiency can occur even with the adequate intake of food because of poor zinc absorption from the diet due to high levels of inhibitors such as fibre and phytates. Zinc deficiency can also result from excessive loss of zinc during diarrhoea.

Iodine nutritional status

This indicator allows an assessment of iodine deficiency at the population level. Urinary iodine concentration, or median urinary iodine concentration, is the main indicator of iodine status for all age groups due to its ease of assessment. This indicator gives the level of adequacy of iodine in the diet, as most of the iodine absorbed by the body is excreted in the urine. It is thus a sensitive marker of current iodine intake and can reflect recent changes in iodine status (WHO, 2004). The WHO Global Database on Iodine Deficiency provides global data on iodine deficiency.

Table 4: Selected nutritional status indicators

UNDERNUTRITION INDICATORS					
Indicator	**Source**	**How is it measured**	**What is being measured**	**Population**	**Cut-offs**
Low birth weight (LBW)	WHO/ UNICEF-WHO	Birth weight of an infant in kg (or gram)	Abnormal gestational weight gain due to intra-uterine undernutrition related to low maternal food intake; also smoking, alcohol and substance abuse	Neonates	<2.5kg (malnourished); >2.5kg (normal)
Stunting	WHO	Height-for-age z-score (HAZ)	Chronic intake of diet of low quality and quantity, and chronic morbidity	Children under 5	<-2 z-score = cut-off for moderate level; <-3 z-score = cut-off for severe level
Wasting	WHO	Weight-for-height z-score (WHZ)	Acute malnutrition associated with low intake of food	Children under 5	< -2 z-score = cut-off for moderate level; <-3 z-score = cut-off for severe level
Underweight	WHO	Weight-for-age	Undernutrition associated with low intake of food of inadequate quantity and quality	Children under 5	<-2 z-score = cut-off for moderate level; <-3 z-score = cut-off for severe level
Triceps	WHO	Triceps skinfold in mm	Measures nutritional imbalance resulting in undernutrition	Children under 5 years	<5.69 (malnourished); >5.7 (normal)
MUAC	WHO	MUAC-for-age in cm	Measures chronic/acute intake of food of inadequate quantity and quality resulting in undernutrition	Children under 5	<11.5 (malnourished); >11.5 (normal)

continued next page

Table 4 Continued

UNDERNUTRITION INDICATORS					
Indicator	**Source**	**How is it measured**	**What is being measured**	**Population**	**Cut-offs**
MUAC	WHO	MUAC in cm	Measures nutritional imbalance resulting in undernutrition	Adolescents	10–14 years (normal ≥ 18.5cm; moderate 16.0–18.5cm; severe < 16.0cm). 15–17 years (normal ≥ 22.0cm; moderate 18.5–22.0cm; severe < 18.5cm)
MUAC	WHO	MUAC-for-age	Measures nutritional imbalance resulting in undernutrition	Adolescents	Severe z-score < − 3; moderate z-score − 2 < z-score > − 3, normal z-score > − 2
BMI	WHO	BMI-for-age	Measures nutritional imbalance resulting in undernutrition	Adolescents	Normal 1–2 SD; thinness <− 2 SD; severe thinness: <− 3 SD
MUAC	WHO	MUAC-for-age in cm	Measures nutritional imbalance resulting in undernutrition	Adult women	<16.0 (malnourished); >16.1 (normal)
Maternal weight/BMI	WHO	Weight in kg/height in m^2	Measures nutritional imbalance due to chronic energy deficiency because of low food intake	Adult women	Mild 17≤ BMI <18.5; moderate 16 ≤ BMI; severe BMI <16

continued next page

Table 4 Continued

OVERNUTRITION INDICATORS					
Indicator	**Source**	**How is it measured**	**What is being measured**	**Population**	**Cut-offs**
Overweight	WHO	Weight-for-height z-score	Measures nutritional imbalance resulting in overnutrition to identify individuals at increased risk of obesity-related morbidity	Children under 5	Obese: > +3SD; overweight: > +2SD
Waist-to-height ratio (WHtR)	WHO	Waist circumference in cm divided by height in cm	Measures nutritional imbalance resulting in overnutrition to identify individuals at increased risk of obesity-related morbidity	Adolescent	
BMI	WHO	BMI-for-age	To identify overweight/obesity resulting from excessive food intake	Adolescent	Obese: >2SD; overweight: >1SD; normal: 1–2SD
Maternal weight/BMI	WHO	Weight in kg divided by height in m2	To identify overweight/obesity resulting from excessive food intake	Adult women	Overweight 25.0–29.9; obesity: 30–34.9 = mild; 35–39.9 = moderate; >40.0 = severe
Waist circumference (WC)	WHO	Waist circumference in cm	Measures central fat distribution/visceral adiposity to identify individuals at increased risk of obesity-related morbidity	Adult women	Risk of metabolic complications: >80cm = increased; >88 = substantially increased
Waist-to-hip ratio (WHR)	WHO	Waist circumference in cm divided by hip circumference in cm	Measures of obesity, abdominal obesity, cardiovascular disease risk and type 2 diabetes risk	Adult women	Risk of metabolic complications >0.85 substantially increased

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Table 4 Continued

MICRONUTRIENT DEFICIENCY INDICATORS (HIDDEN HUNGER)					
Indicator	**Source**	**How is it measured**	**What is being measured**	**Population**	**Cut-offs**
Iron status	INACG	Haemoglobin level	Undernutrition; measuring whether an individual's body is deficient or replete in iron. Clinical signs: anaemia, fatigue, nail and hair changes	Usually, women or children under 5	U5y Hb >11.0g/dL; 5-12y Hb > 11.5g/dL; 12–15y Hb >12g/dL; pregnant women Hb > 11g/dL; NPNL >15y Hb >12g/dL
Anaemia prevalence	INACG	Anaemia (%) assessed by individual haemoglobin levels	Percentage of individuals with haemoglobin concentrations lower than the norm for sex, age and physiological status	All groups	Mild 5.0–19.9; moderate 20.0–39.9; severe >40.0
Vitamin A status	IVACG	Serum retinol concentrations or breastmilk retinol	Undernutrition; measuring whether an individual's body is deficient or replete in vitamin A. Clinical signs: Bitot's spots, xerophthalmia	Usually, women or children under 5	Low <10-20 µg/100 ml; deficient < 10 µg/100 ml
Zinc status	IZiNCG	Serum zinc concentrations	Undernutrition; measuring whether an individual's body is deficient or replete in zinc. Clinical signs:	Women and children	Zinc deficiency <9.9 µmol/L for children <10 years (morning, non-fasting); WRA, <10.1 µmol/L (morning); severe < 7.65 µmol/L
Iodine status	ICCIDD	Median urinary iodine mg/dL	Undernutrition/overnutrition. Clinical signs: goitre and impaired mental function throughout the life cycle. Impaired physical development in children	Women and children	Severe < 20g/L; moderate 20–49g/L; mild 50–99g/L; normal 100–199g/L; above normal 200–299; excessive >300

6. Impacting nutrition outcomes through agriculture

Agriculture is said to impact nutrition outcomes through six pathways believed to influence mostly the underlying causes of malnutrition (Herforth & Ballard, 2016; Kadiyala et al., 2014). The selection of metrics to determine the nutritional impacts of agricultural policies and interventions should align with objectives and associated activities of agricultural investment to ensure that plausible outcomes are measured (Herforth & Ballard, 2016). Furthermore, having a clear theory of change path that clearly delineates expected outputs and impacts from the agricultural investment to the outcome of interest will inform the choice of metrics for both process and impact assessment (Herforth et al., 2016).

To impact nutritional status, agricultural interventions must ultimately foster improvements to the utilization pillar, which encompasses both food consumption and health status of the individual. Thus, on their own, agricultural interventions are unlikely to have comparable impacts on nutritional status indicators as would be expected for nutrition-specific interventions that directly target the immediate causes of malnutrition. Furthermore, depending on context, other underlying causes of malnutrition may be more relevant to addressing malnutrition in a vulnerable group of interest (Herforth & Ballard, 2016). For example, in certain areas, poor environmental hygiene leading to a high infection burden may pose a stronger limitation to enhancing the anaemia burden than inadequate dietary iron intake (Petry et al., 2016). Thus, improving food access relative to iron rich foods or dietary diversity may not yield the intended improvements in the iron status of the target group. In addition to data limitations and other methodological issues, these factors undermine the research evidence base for agriculture's impact on nutritional outcomes as measured by nutritional status indicators. Herforth and Ballard (2016) suggest that the impact assessment of agricultural interventions should focus on the more proximal outcomes affected by such interventions, such as indicators of food access and diet rather than nutritional status (Herforth & Ballard, 2016). Integrating agricultural interventions into relevant interventions from other sectors (such as water and sanitation and nutrition education through behaviour change communication strategies) will strengthen agriculture's potential to impact nutrition outcomes.

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