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Abstract

The Global Hunger Index (GHI) is a multidimensional measure of hunger that considers three dimensions: (1) inadequate dietary energy supply, (2) child undernutrition, and (3) child mortality. The initial version of the index included the following three, equally weighted, non-standardized (i.e. unscaled) indicators that are expressed in percent: the proportion of the population that is calorie deficient (FAO's prevalence of undernourishment); the prevalence of underweight in children under five; and the under-five mortality rate. Several decisions regarding the original formulation of the GHI are reconsidered in light of recent discussions in the nutrition community and suggestions by other researchers, namely the choice of the prevalence of child underweight for the child undernutrition dimension, the use of the under-five mortality rate from all causes for the child mortality dimension, and the decision not to standardize the component indicators prior to aggregation. Based on an exploration of the literature, data availability and comparability across countries, and correlation analyses with indicators of micronutrient deficiencies, the index is revised as follows: (1) The child underweight indicator is replaced with child stunting and child wasting; (2) The weight of one third for the child undernutrition dimension is shared equally between the two new indicators; and (3) The component indicators of the index are standardized prior to aggregation, using fixed thresholds set above the maximum values observed in the data set. The under-five mortality rate from all causes is retained, because estimating under-five mortality attributable to nutritional deficiencies would be very costly and make the production of the GHI dependent on statistics about cause-specific mortality rates by country and year that are published irregularly, while the expected benefits are limited.

Keywords: Global Hunger Index, composite index, food insecurity, child undernutrition, stunting, wasting, underweight, child mortality, micronutrient deficiencies

JEL codes: I13, J13, O15

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Acknowledgements

This review is part of a process that the International Food Policy Research Institute (IFPRI) initiated eight years after the first Global Hunger Index was published in 2006. The intent is to assess whether the dimensions, indicators and computation methods used for determining the annual Global Hunger Index are state-of-the-art for a composite index of hunger.

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Acronyms and Abbreviations

CM	Proportion of children dying before the age of five years
CST	Prevalence of stunting in children younger than five years
CWA	Prevalence of wasting in children younger than five years
DALY	Disability-Adjusted Life Year
DHS	Demographic and Health Survey
FANTA	Food and Nutrition Technical Assistance Project
FAO	Food and Agriculture Organization of the United Nations
GHI	Global Hunger Index
GNR	Global Nutrition Report
IDS	Institute for Development Studies
IGME	United Nations Inter-agency Group for Child Mortality Estimation
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IRD	Institut de Recherche pour le Développement
MDG	Millennium Development Goal
NIMS	Nutrition Impact Model Study
p4d	partnership for development
PAF	Population attributable fraction
PUN	Proportion of the population that is undernourished
SD	Standard deviation
SDG	Sustainable Development Goal
UN	United Nations
UN ACC/SCN	United Nations Administrative Committee on Coordination/Subcommittee on Nutrition
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNSCN	United Nations Standing Committee on Nutrition
WFP	World Food Programme
WHA	World Health Assembly
WHO	World Health Organization

1 Introduction

The Global Hunger Index (GHI) is a multidimensional measure of hunger that was first released by the International Food Policy Research Institute (IFPRI) and Welthungerhilfe in 2006 (Wiesmann, Weingärtner, and Schöninger 2006).[1] The GHI considers three dimensions: (1) inadequate dietary energy supply, (2) child undernutrition, and (3) child mortality. From the time of its original release in 2006 through the ninth release in 2014, the index has included the following three, equally weighted[2], non-standardized (i.e. unscaled) indicators that are expressed in percent:

1. the proportion of the population that is calorie deficient (FAO's prevalence of undernourishment, reflecting only quantitative deficits according to their definition)
2. the prevalence of underweight in children under five (WHO and other sources)
3. the under-five mortality rate (IGME) (Wiesmann 2006).

While the weighting of the three index components had been supported by empirical findings, i.e. by the results of a factor analysis (Wiesmann 2004; Wiesmann 2006; Wiesmann, von Braun, and Feldbrügge 2000), it is important to note for this methodological review that constructing composite indices is no hard science. There is no commonly accepted best practice to construct international indices, and arbitrary decisions about the choice of indicators, the standardization of the index components or omission of standardization, and the weighting and aggregation function are unavoidable. Therefore, composite indices will always be open to critique and should be revised from time to time to reflect new thinking and the availability of new indicators or additional data.

A set of requirements for international indicators and indices has been postulated in the literature that may guide such revisions. Indicators and indices should be relevant for national and international policy debates, for example (see Wiesmann 2006, Table 3 on p.60, and Wiesmann 2004, Chapter 2.1, for a fuller discussion). In addition, the data should be nationally representative, comparable across countries, based on state-of-the-art measurement methods, and stem from credible sources. Recent data need to be available for a large number of countries, and appropriate estimation techniques have to be developed to fill data gaps.

Certain decisions regarding the calculation of the GHI are reconsidered in the following paper in light of recent discussions in the nutrition community and suggestions by other researchers (Martorell 2008; Masset 2011). This concerns in particular

1. the choice of the prevalence of child underweight for the child undernutrition dimension,
2. the use of the under-five mortality rate from all causes for the child mortality dimension, and
3. the decision not to standardize (or "scale") the component indicators prior to aggregation.

While FAO's measurement approach and data to ascertain chronic calorie deficiency have frequently been criticized, exchanging this indicator in the inadequate dietary energy supply dimension is not discussed due to a lack of suitable alternatives with sufficient data availability that could replace it. While modifying the dimension of inadequate dietary energy supply to also reflect diet quality would be desirable from a conceptual point of view, such an endeavour faces practical challenges with regard to the availability and appropriateness of indicators and data (see also the comments on a dietary diversity indicator for women in Appendix A).

The average percent of dietary energy from starchy staples, for example, which is also based on FAO's Food Balance Sheets, is considered a rough indicator of diet quality, has wide data availability, and shows a closer relationship with child stunting than measures of national dietary energy

1 The GHI is based on research by Wiesmann (2004) and Wiesmann, von Braun, and Feldbrügge (2000).

2 A factor analysis suggested approximately equal weighting (Wiesmann 2004; Wiesmann 2006).

availability. The report on the State of Food Insecurity in the World 2013 finds a much stronger association between percent of energy from starchy staples and stunting in preschool children (R^2 linear=0.46, corresponding to a Pearson's correlation coefficient of 0.68) than between the proportion of undernourished and stunting (R^2 linear=0.28, corresponding to a Pearson's correlation coefficient of 0.53) (FAO, IFAD, and WFP 2013, p.25f). Based on cross-country regressions, Smith and Haddad (2015) estimate that the percent of dietary energy from non-staples (that is, the inverse of dietary energy from starchy staples) has greater potential to reduce child stunting in the future than access to sanitation, women's education, access to safe water, gender equality, and national food availability.

Yet, for the purpose of index construction, the percent of dietary energy from starchy staples is fraught with two disadvantages:

1. In contrast to the other indicators included in the GHI, the percent of energy from starchy staples has an optimum greater than zero and the principle "the less, the better" does not apply throughout. Determining an optimum value up to which reductions of the percent of starchy staples should lead to decreases in GHI scores could prove difficult because the optimum value for good nutrition and health varies with the composition of the local diet; it depends, among other things, on the micronutrient content of the primary starchy staples and the type of animal source foods consumed.
2. Until now, the data have been released with considerable delay: In 2015, the latest available data on dietary energy from starchy staples were from 2009-2011. Thus, they are lagging five years behind the most recent data on undernourishment, which are for 2014-2016 and partly based on extrapolations (FAO 2015; FAO, IFAD, and WFP 2015). The inclusion of these data in the 2015 GHI would affect the currentness of the index.

Nevertheless, the availability of indicators and data that measure or at least proxy diet quality should be closely monitored, and diet quality should be considered for future revisions of the GHI if the data situation improves.

2 The child undernutrition dimension of the Global Hunger Index

The prevalence of underweight in children under five was the only nutrition indicator included with an explicit reduction target in the Millennium Development Goals (MDGs), see United Nations (2008), and has been used for the child undernutrition dimension of the GHI.

Yet, underweight is no longer the preferred indicator for monitoring child undernutrition because of one drawback: It can mask the co-occurrence of normal weight and even overweight with stunting, and thereby give a false impression of progress in reducing child undernutrition (Martorell 2008). In some settings, interventions to improve nutrition can have the undesired side-effect of increasing obesity. If underweight was chosen for monitoring, its reduction would be seen as an indication of success despite the possible increase in overweight, while stunting may remain unchanged (Martorell 2008).

The Lancet series on maternal and child undernutrition uses stunting as an indicator of child nutrition and complements it with measures of weight relative to height, namely wasting and overweight (Black et al. 2008). Stunting was also found to be the best predictor of the long-term consequences of child undernutrition on human capital (Victora et al. 2008).

In 2012, the World Health Assembly (WHA) endorsed six Global Nutrition Targets to be reached by 2025 (WHO 2012). Instead of child underweight, other anthropometric indicators were chosen to monitor progress in the fight against child undernutrition: child stunting, wasting, and low birth weight. All six WHA indicators are among the priority nutrition indicators proposed for the Sustainable Development Goals (SDGs) by the United Nations Standing Committee on Nutrition (UNSCN) (Table 1).

Table 1: Suggested priority nutrition indicators for the post-2015 Sustainable Development Goals

AREA	PRIORITY INDICATOR	SDGs AND TARGETS
GLOBAL NUTRITION TARGETS endorsed by Member States at the 65th World Health Assembly (WHA 2012)	Prevalence of stunting (low height-for-age) in children under 5 years of age	Goal 2, Target 2.2
	Prevalence of wasting (low weight-for-height) in children under 5 years of age	Goal 2, Target 2.2
	Percentage of infants less than 6 months of age who are exclusively breast fed	Goal 2, Target 2.2 and Target 2.1 and Goal 3, Target 3.2
	Percentage of women of reproductive age (15-49 years of age) with anaemia	Goal 2, Target 2.2 and Goal 3, Target 3.1
	Prevalence of overweight (high weight-for-height) in children under 5 years of age	Goal 2, Target 2.2 and Goal 3, Target 3.4
	Percentage of infants born with low birth weight (< 2,500 grams)	Goal 2, Target 2.2 and Goal 3, Target 3.2
DIETARY DIVERSITY	The percentage of women, 15-49 years of age, who consume at least 5 out of 10 defined food groups	Goal 2, Target 2.1
POLICY	Percentage of national budget allocated to nutrition	Goal 2, Target 2.2a

Source: UNSCN 2014

While underweight reflects both acute and chronic undernutrition, stunting indicates only chronic undernutrition, and wasting only acute undernutrition. Table 2 illustrates that underweight has the strongest associations with the other two indicators of child undernutrition in the correlation matrix, but also the highest correlation with overweight as a measure of child overnutrition.

Table 2: Spearman rank correlations for child malnutrition indicators

	Underweight	Stunting	Wasting	Overweight
Underweight	1.00			
Stunting	0.82	1.00		
Wasting	0.83	0.54	1.00	
Overweight	-0.65	-0.35	-0.45	1.00

Nationally representative survey data from the period 2009-2013 retrieved in May 2014 were used. A cutoff of -2SD below the median was used to define underweight, stunting and wasting, and a cutoff of +2SD above the median to define overweight. Correlation coefficients could be calculated for 65 countries with data for the four indicators, and all were significant at p-value < 0.01. If data were used for the 75 countries countries for which data on underweight, stunting and wasting were available, the correlation coefficients among the three child undernutrition indicators would remain virtually identical.

Data sources: UNICEF/WHO/World Bank 2013; WHO 2014a; UNICEF 2014; MEASURE DHS 2014; India, Ministry of Women and Child Development, and UNICEF, India 2014.

The change in thinking about the most suitable indicator(s) of child undernutrition suggests replacing the underweight indicator in the GHI with stunting and wasting. There are several advantages of replacing underweight with both wasting and stunting, as opposed to using only stunting as a substitute:

1. Acute child undernutrition, which can be serious and life-threatening, is not neglected if the focus of the child undernutrition dimension is not exclusively on stunting.
2. Wasting and stunting do not only differ conceptually, they also diverge empirically and show a limited and somewhat variable overlap at the individual level: A recent analysis of stunting and wasting in the same children in five countries with a high burden of undernutrition found that 30 to 65% of wasted children were only wasted and not stunted, and, conversely, that 35 to 70% of wasted children were both wasted and stunted (IFPRI 2015). The two indicators therefore cannot be treated as substitutes for each other.
3. Wasting reacts more quickly to variations in the determinants of child undernutrition than stunting, thereby making the GHI more sensitive to changes over time (whereas stunting can ensure a certain stability in the child undernutrition dimension, since this indicator is not prone to erratic fluctuations).[3]
4. Stunting shows generally lower correlations with indicators of micronutrient deficiencies than underweight—possibly because data which relate these child undernutrition indicators to one or more specific micronutrient deficiencies are lacking[4]—and therefore stunting tends to weaken the association of the GHI with measures of micronutrient deficiencies ("hidden hunger") if it replaces underweight. Yet, this tendency can be counteracted by using a

[3] In other words, wasting can be considered a flow variable, whereas stunting is more a stock variable that shows cumulative effects over time. Other composite indices have also aimed to keep the balance between capturing the effects of past developments and being sensitive to recent changes, and have taken advantage of combining flow and stock variables for that purpose. For example, the education dimension of UNDP's Human Development Index used to include the adult literacy rate (a stock variable that changes slowly over time) together with the combined gross school enrolment rates (flow variables that react quickly to investments in schooling), until these indicators were replaced by the mean years of schooling and expected years of schooling in order to reflect past trends and current conditions (UNDP 2009; UNDP 2010).

[4] It has to be emphasized that the picture presented in this correlation analysis is necessarily incomplete: For most micronutrient deficiencies, data and sometimes even indicators are sorely lacking. For the few indicators of micronutrient deficiencies where nationally representative survey data exist, they are only available for a limited number of countries. Children with less severe subclinical deficiencies show no clinical signs such as xerophthalmia or rickets so that the massive effects of micronutrient deficiencies on the immune system, development and health may remain unnoticed.

combination of stunting and wasting to replace underweight instead of stunting alone (Tables 3 and 4).[5]

5. A revised GHI that includes stunting and wasting is more consistent with the GHI that has been used to date (Spearman rank correlation coefficient: 0.98) than a GHI where underweight was replaced by stunting only (Spearman rank correlation coefficient: 0.94; see also Table 7 in Section 4). When transitioning to the new version of the GHI, a greater consistency with the previous GHI could help to avoid sudden jumps in countries' ranking position that might be difficult to explain.[6]

However, including wasting in addition to stunting also has potential disadvantages related to the particularities of this indicator:

1. Because wasting reflects acute undernutrition, this indicator is more volatile than stunting, and sudden events such as man-made or natural disasters can lead to quick changes in wasting rates (WHO 2014b). The sometimes erratic fluctuations make it very difficult to generate reliable estimates of wasting, and WHO (2014b) abstains from presenting trends at the global level—let alone at the regional or country level—and presents only a snapshot of the global wasting rate for 2012. IFPRI (2014) states that methods to generate reliable data on wasting trends are yet to be developed. For 75 out of 120 countries for which the 2014 GHI was calculated, survey data for wasting were available for the reference period 2009-2013 as of 2014 (using the data sources from which data on underweight were compiled for the 2014 GHI). If data availability is similar for the period 2010-2015, wasting rates may have to be estimated for more than 40 countries to calculate the 2015 GHI, and potentially unreliable estimates would influence the ranking of these countries on the index; this problem cannot be avoided.[7]
2. Wasting responds more strongly to seasonal changes than stunting. It is therefore more important for this indicator that surveys are conducted over an entire year, in a way that is representative for all seasons, especially in countries that show high seasonality such as some in West and Eastern Africa. This is not always done: Surveys that are nationally representative with regard to the sampling often cover only a few months of the year. In addition, limited representativeness over time may make it even more difficult to produce reliable estimates in cross-country regressions.

Regressions using wasting as a dependent variable in the models developed to predict child underweight showed promising results, although the goodness of fit was not as good as for stunting (personal communication with Yisehac Yohannes, IFPRI). Producing reasonable estimates of wasting

[5] This pattern is also reflected in the association of child malnutrition indicators with a dietary diversity measure that was developed as a proxy indicator for the diet quality of complementary child feeding (WHO 2010a). Spearman rank correlation coefficients with low dietary diversity among young children amount to 0.80 for underweight, 0.81 for the combination of stunting and wasting, 0.67 for stunting, 0.65 for wasting, and -0.44 for overweight, and are significant (p-value < 0.01). For this analysis, low dietary diversity was defined as the proportion of children 6-23 months who consume fewer than four out of seven food groups (grains, roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin-A rich fruits and vegetables; other fruits and vegetables); data were taken from WHO (2010b) and Kothari and Abderrahim (2010).

[6] For example, among the 75 countries for which the "old" GHI with underweight (excluding estimates from regression models) as well as several versions of a possible "new" GHI were calculated, India ranked 57 on the "old" GHI, and the same if the component indicators were standardized; 45 out of 75 on a new GHI with stunting instead of underweight, and 44 out of 75 if the component indicators were standardized; and 52 out of 75 on a new GHI with stunting and wasting instead of underweight, with standardized components.

[7] Survey data for stunting were also only available for 75 out of 120 countries for 2009-2013 as of 2014, however, producing reliable estimates for stunting is of less concern than doing so for wasting (WHO 2014b).

for countries with missing data appears to be possible. Based on the weights presented in Section 5, wasting makes up only one sixth of the index if used together with stunting for the child undernutrition dimension. Thus, the effect of estimates with limited reliability cannot be very large.

Consequently, underweight is replaced with a combination of stunting and wasting, although empirical analysis shows that this change has little practical significance for the ranking of countries: Different versions of the GHI, using either underweight or a combination of stunting and wasting for the child undernutrition dimension, and using standardized or non-standardized components, are highly redundant in terms of their rank correlations (Table 7 in Section 4). Thus, the virtue of replacing underweight with wasting and stunting lies mainly in the different message sent to policy-makers about the type of programs that should be implemented to improve child undernutrition.

Further data explorations should be undertaken to examine whether it would be advantageous to use child undernutrition rates for selected age groups, for example, for the age group 0-2 years or the age group 3-5 years, instead of the rate for all under-fives. Child stunting is thought to be partially reversible up to the age of two years, but irreversible after the second year of life, when the full extent of the damage becomes apparent. The results of such explorations could be considered in future revisions of the index.

Table 3: Spearman rank correlations for measures of child malnutrition and indicators of micronutrient status[1]

Prevalence among children under five:	Low urinary iodine concentration among school children (N=54)	Median urinary iodine concentration among school children (N=65)	Night blindness among preschool children (N=24)	Night blindness among pregnant women (N=39)	Low serum retinol among preschool children (N=50)	Anemia among preschool children (N=77)	Anemia among pregnant women (N=55)	Sum of correlation coefficients[4]
Underweight	**0.28** **	-0.19	0.21	**0.50** ***	0.39 ***	**0.54** ***	0.37 ***	2.47
Stunting + wasting, combined[2]	0.27 **	-0.17	**0.35** *	0.44 ***	0.40 ***	0.49 ***	0.39 ***	**2.51**
Stunting	0.23 *	-0.05	0.27	0.28 *	**0.43** ***	0.46 ***	0.26 *	1.98
Wasting	0.25 *	**-0.31** **	0.28	0.43 ***	0.26 *	0.41 ***	**0.41** ***	2.36
	(N=50)	(N=59)	(N=21)	(N=38)	(N=43)	(N=74)	(N=50)	
Overweight[3]	-0.11	0.04	-0.01	-0.48 ***	-0.12	-0.32 ***	-0.18	-1.27

1 Nationally representative survey data were used for indicators of micronutrient status. The latest available data were matched with the child malnutrition indicators using the years of the surveys and the GHI reference periods. N indicates the number of countries for which the correlation coefficients could be computed. The highest correlation coefficient in each column is emboldened.

2 Prior to adding the prevalence rates of stunting and wasting, they were standardized as follows, using thresholds of 70% for stunting and 30% for wasting: stunting (stand.) = stunting/70*100; wasting (stand.) = wasting/30*100. The thresholds were set slightly above the maximum values observed in nationally representative data collected between 1988 and 2013 (26.0% for wasting and 68.2% for stunting, see Section 4 regarding the standardization of indicators).

3 The correlation coefficients for overweight were included as supplementary information, they are not essential for evaluating potential new child undernutrition indicators for the GHI. Data on overweight are not available for all countries with data on underweight, stunting and wasting, which explains the lower sample sizes; the correlation coefficients in the first four rows of the table were only calculated for countries for which data for all three indicators (underweight, stunting, and wasting) were available.

4 The sum of correlation coefficients provides only a rough indication of the strength of the association of anthropometric indicators with the various micronutrient deficiencies, as the number and selection of countries for which the correlation coefficients could be computed are quite variable. The correlation coefficients for the median urinary iodine concentration are negative for indicators of undernutrition and positive for overweight, and were multiplied with -1 before adding them up with the other correlation coefficients. A higher median urinary iodine concentration indicates that the population is less deficient in iodine on average, whereas higher values for the other indicators of micronutrient status indicate that deficiencies are more prevalent.

Definitions and data sources for indicators of micronutrient status: Anemia: Proportion of preschool-age children whose hemoglobin level is less than 110 grams per liter, and proportion of pregnant women whose hemoglobin level is less than 110 grams per liter (World Bank 2014; MEASURE DHS 2014; de Benoist et al. 2008). Iodine: Proportion of school-age children with urinary iodine concentration <100 microgram per liter, and median urinary iodine concentration of school-age children (Andersson, Karumbunathan, and Zimmermann 2012). Vitamin A: Proportion of preschool-age children with night blindness, proportion of pregnant women with night blindness, and proportion of preschool-age children whose serum retinol level is less than 0.70 micromole per liter (WHO 2009a).

* significant at p-value < 0.10, ** significant at p-value < 0.05, *** significant at p-value < 0.01

Table 4: Spearman rank correlations for different versions of the Global Hunger Index and indicators of micronutrient status[1]

Global Hunger Index[2]	Low urinary iodine concentration among school children (N=53)	Median urinary iodine concentration among school children (N=64)	Night blindness among preschool children (N=24)	Night blindness among pregnant women (N=39)	Low serum retinol among preschool children (N=50)	Anemia among preschool children (N=77)	Anemia among pregnant women (N=55)	Sum of correlation coefficients[3]
Components not standardized, including:								
underweight	0.25 *	-0.12	0.56 ***	0.43 ***	0.48 ***	0.55 ***	0.36 ***	2.75
stunting +wasting	0.24 *	-0.10	0.57 ***	0.33 **	0.52 ***	0.54 ***	0.34 **	2.63
stunting	0.24 *	-0.08	0.51 **	0.29 *	0.51 ***	0.53 ***	0.34 **	2.50
Components standardized, including:								
underweight	**0.27** *	-0.14	**0.59** ***	**0.46** ***	0.50 ***	**0.62** ***	**0.44** ***	**3.01**
stunting +wasting	0.26 *	**-0.15**	0.57 ***	0.41 ***	**0.53** ***	0.61 ***	**0.44** ***	2.96
stunting	0.25 *	-0.09	0.55 ***	0.34 **	0.52 ***	0.58 ***	0.42 ***	2.74

1 Nationally representative survey data were used for indicators of micronutrient status. The latest available data were matched with the GHI and its components using the year of the survey and the GHI reference periods. N indicates the number of countries for which the correlation coefficients could be computed. The highest correlation coefficient(s) in each column is/are emboldened.

2 The different versions of the Global Hunger Index include FAO's proportion of undernourished and the under-five mortality rate besides the listed child undernutrition indicators. The three index dimensions are equally weighted, and stunting and wasting are weighted equally within the child undernutrition dimension if used in combination. For the index versions with standardized components, the indicators were standardized using the following estimated maximum values prior to aggregation: 80% for undernourishment, 65% for underweight, 70% for stunting, 30% for wasting, and 35% for under-five mortality (see Section 4 regarding the standardization of indicators). The standardized values X (stand.) for each indicator were calculated as follows: X (stand.) = X/estimated maximum value * 100.

3 The sum of correlation coefficients provides only a rough indication of the strength of the association of the index versions with the various micronutrient deficiencies, as the number and selection of countries for which the correlation coefficients could be computed are quite variable. The correlation coefficients for the median urinary iodine concentration are negative and were multiplied with -1 before adding them up with the other correlation coefficients. A higher median urinary iodine concentration indicates that the population is less deficient in iodine on average, whereas higher values for the other indicators of micronutrient status indicate that deficiencies are more prevalent.

Definitions and data sources for indicators of micronutrient status: See notes to Table 3.

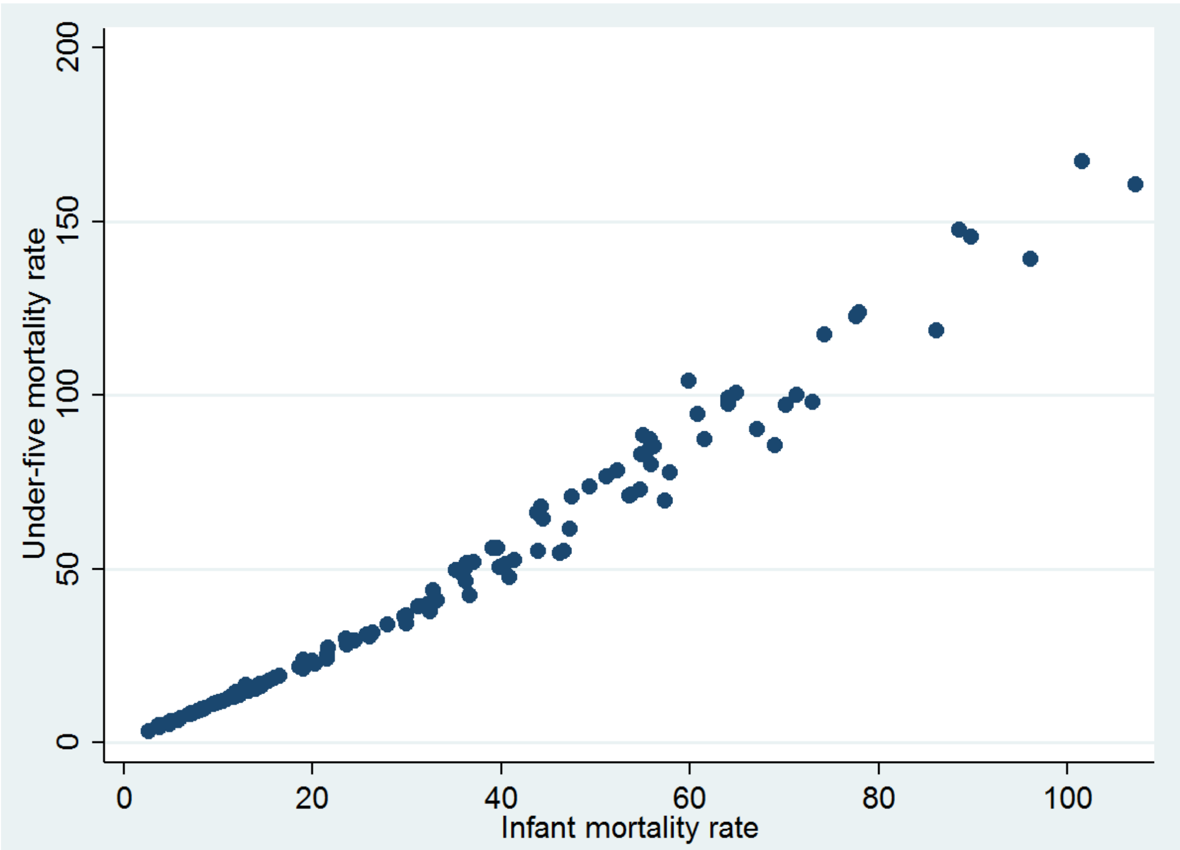
* significant at p-value < 0.10, ** significant at p-value < 0.05, *** significant at p-value < 0.01

3 The child mortality dimension of the Global Hunger Index

It has been suggested to replace the under-five mortality rate with under-two mortality in order to relate the GHI more meaningfully to the nutritionally critical first 1,000 days between conception and the second birthday. Aside from the question of whether the 1,000 days-timeframe that is critical for nutrition outcomes is also pivotal for child survival, implementing this replacement would meet some serious challenges because under-two mortality is not a standard indicator and is not available from official statistics.

It is doubtful whether it would be worthwhile to estimate under-two mortality rates from official data, because the replacement would be of little relevance for the GHI ranking and trends over time. This can be demonstrated from an analysis of under-five mortality and infant mortality rates. The infant mortality rate is a standard indicator available from official statistics and indicates the proportion of children dying before the age of 12 months. Using data for 2013 for 131 countries from IGME (2014),[8] the Spearman rank correlation coefficient for the infant mortality rate and the under-five mortality rate was very close to unity and highly significant, amounting to 0.9965. The close association of the two indicators is also evident from the scatterplot (Figure 1).

Figure 1: Under-five mortality rate plotted against infant mortality rate



The mortality rates are expressed in their original scale, namely deaths per 1000 live births. Data for 2013 from 131 countries were considered.
Source: Authors' own presentation based on data from IGME (2014)

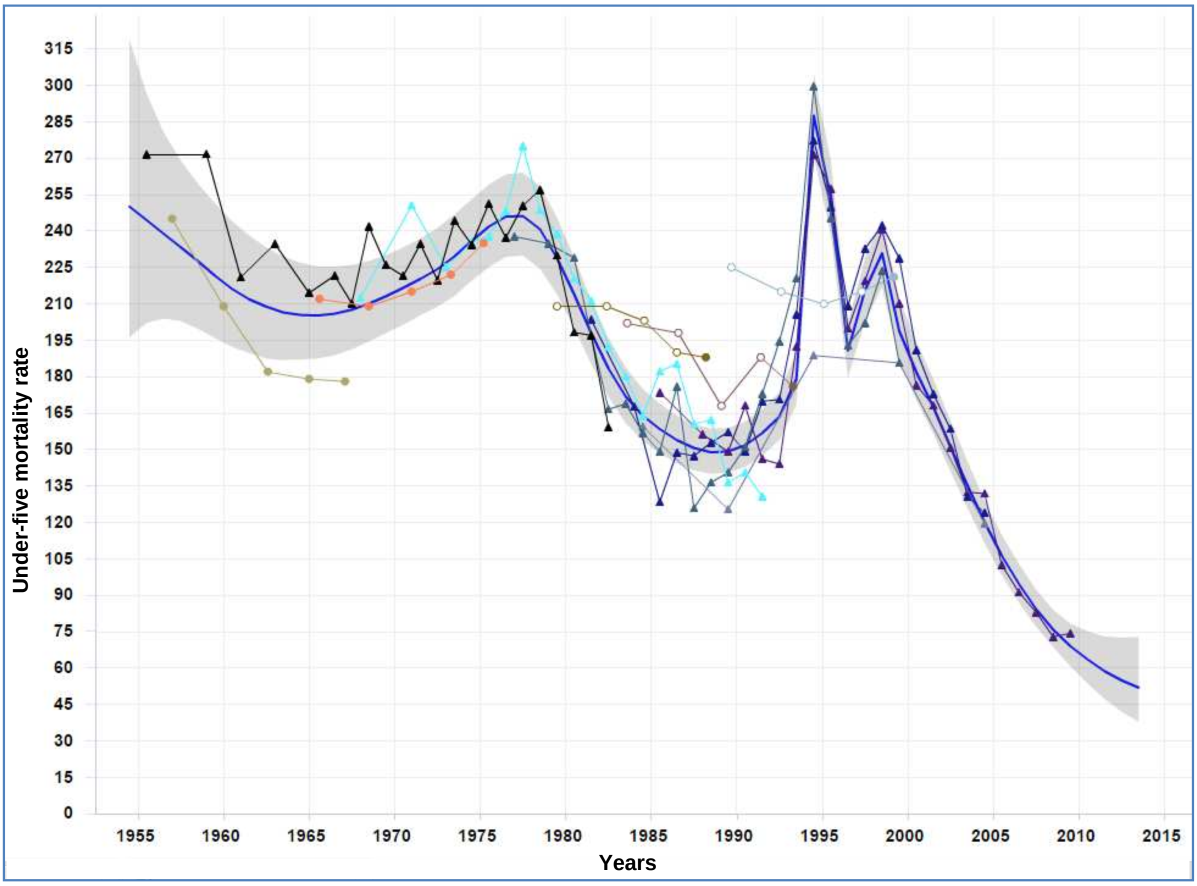
Figure 1 also illustrates that most children who die before their fifth birthday die within the first year. For the 131 countries considered, infant mortality contributes between 57% and 92% of overall

[8] The 130 countries selected for calculating the 2014 GHI (von Grebmer et al. 2014), which include former Sudan, were chosen for this analysis, but Sudan and South Sudan were treated as separate countries.

under-five mortality, with lower shares for countries with higher mortality rates. Liu et al (2015) estimate that 44% of the 6.3 million children who died in their first 5 years of life died in the neonatal period, that is, in the 28 days after birth. Therefore, the differences between under-five mortality and under-two mortality rates can be expected to be fairly small.

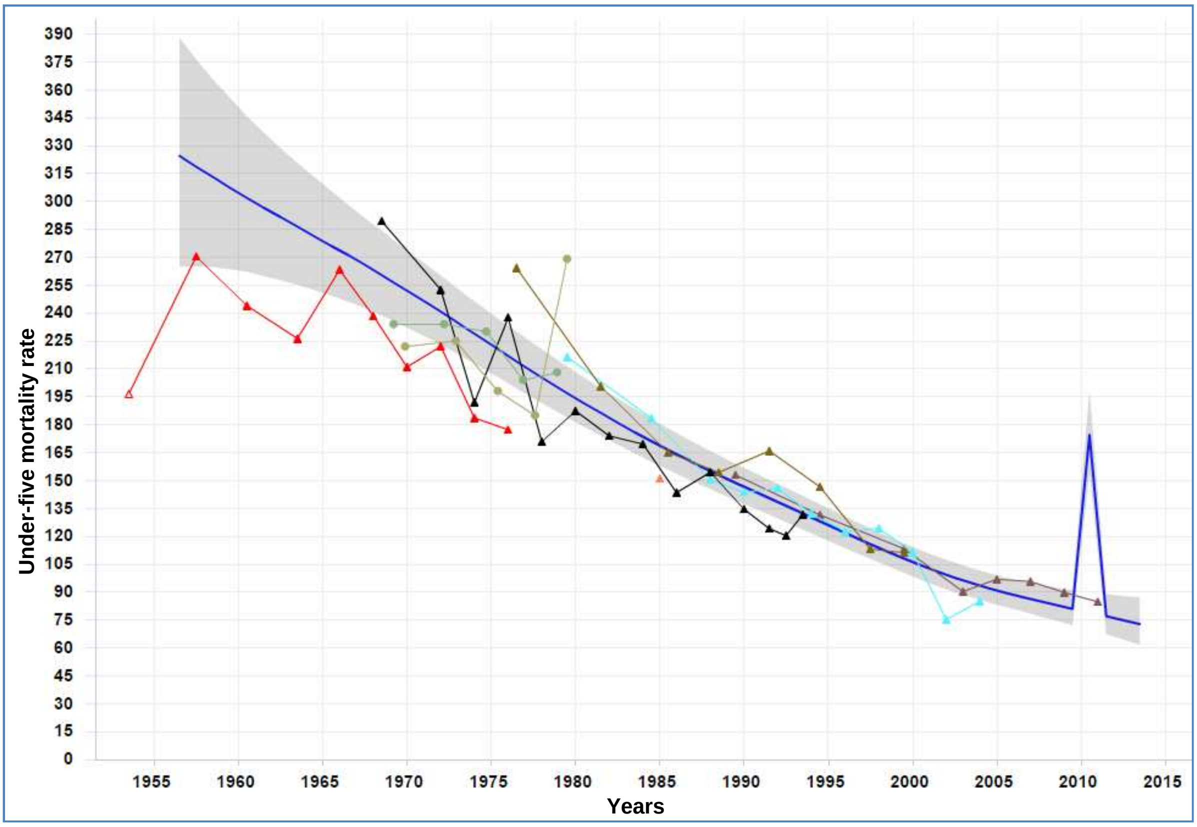
Another suggestion to revise the indicator for the child mortality dimension of the GHI is conceptually very appealing, namely the idea to use estimates of under-five mortality associated with undernutrition instead of under-five mortality from all causes. Deaths from causes not related to undernutrition are not suitable to measure the extent of hunger, or food and nutrition insecurity. This becomes very clear in the event of man-made or natural disasters, such as the genocide in Rwanda in 1994 and the earthquake in Haiti in 2010 (Figures 2 and 3).

Figure 2: Under-five mortality in Rwanda, 1954-2013



The blue line depicts the under-five mortality estimates that are fitted to existing annual data from various surveys and censuses (shown in other colors). Under-five mortality is expressed in deaths per 1000 live births. The grey band indicates the confidence interval of the estimates.
Source: IGME (2014)

Figure 3: Under-five mortality in Haiti, 1956-2013



The blue line depicts the under-five mortality estimates that are fitted to existing annual data from various surveys and censuses (shown in other colors). Under-five mortality is expressed in deaths per 1000 live births. The grey band indicates the confidence interval of the estimates.
Source: IGME (2014)

IGME (2014) estimates that under-five mortality more than doubled in Haiti between 2009 and 2010, soaring from 8% to 17% because of the earthquake and its after-effects.[9] Other things being equal, this sharp rise in child mortality would raise the (non-standardized) GHI by 3 points, and only part of this increase can be thought to reflect rising food and nutrition insecurity in the wake of the disaster. Large-scale disasters such as the genocide in Rwanda and the 2010 earthquake in Haiti tend to worsen food and nutrition insecurity and increase related deaths, but it can be assumed that a large share of the children who died were killed immediately during these events and did not die from undernutrition, or from the effects of the vicious cycle of inadequate food intake, weakened immune systems, infectious diseases, and decreased appetite and nutrient absorption.

Black et al. (2013) estimate that globally, 45% of child deaths among children under five can be attributed to undernutrition, namely to fetal growth restriction, stunting, wasting, underweight, deficiencies of vitamin A and zinc, and suboptimum breastfeeding. While undernutrition is thus deemed to be the direct or indirect cause of a large proportion of child deaths, more than half of all children who died before age five died from causes not related to nutritional deficiencies. To complicate matters, the proportion of child deaths attributable to undernutrition varies and cannot be thought of as constant across countries and regions.

In principle, it should be possible to estimate the contribution of various forms of undernutrition to mortality rates at the country-level. The Disability-Adjusted Life Years (DALYs) published by WHO for

[9] This estimated increase seems to be based on assumptions about the impact of the earthquake and not on actual data. The graph in Figure 3 does not show census or survey data that confirm the projected spike in under-five mortality.

2004 incorporate country-level estimates of age-standardized mortality for all age groups from the following nutritional deficiencies: protein-energy malnutrition, iodine deficiency, vitamin A deficiency, and iron-deficiency anemia (WHO 2009b). Some of the factors considered by Black et al. (2013) for their more recent global estimate of child deaths attributable to undernutrition, such as fetal growth restriction, stunting, zinc deficiency, and suboptimal breastfeeding practices, were not taken into account.

The DALYs from nutritional deficiencies should not be used to replace the under-five mortality rate in the GHI for a variety of reasons,[10] but they exemplify that it is possible to estimate deaths attributable to nutritional deficiencies at the country level. Black et al. (2013) arrive at their global estimate of child deaths attributable to undernutrition by computing child deaths for UN subregions. This involves assessing the fractions of deaths from various causes (diarrhea, measles, pneumonia, and other infections, excluding malaria) that are attributable to stunting, underweight, wasting, and severe wasting—the so-called population attributable fractions (PAFs)—for each subregion. The PAFs are multiplied with corresponding age-specific and cause-specific deaths to estimate the number of deaths attributable to underweight, stunting, wasting and its subset of severe wasting.

More research into the literature and available data would be needed to understand the details of the method and find out if and how it could be applied at the country level, or if PAFs for subregions would be precise enough to derive country-level estimates. The required effort exceeds the scope of this paper, but such a research project might be considered for the future. Before embarking on such an endeavor, the following potential disadvantages of using estimates of child mortality attributable to undernutrition instead of under-five child mortality rates from all causes should be taken into account:

1. The child mortality data for the GHI would solely be based on own estimates and no longer on official statistics; relying on official statistics has the advantage that people who have questions about the data can be referred to the official sources.
2. The reliability of the estimates at the country level may be debatable, considering that multiple assumptions have to be made to obtain them.
3. Data that are published irregularly may be required for the estimation process, such as deaths and death rates from various infectious diseases by country and year.[11]
4. A lot of data work would be needed on an annual basis to arrive at the estimates, whereas using the under-five mortality rates published by IGME is very simple and straightforward. The costs for estimating child mortality from nutritional causes would most likely be considerable, whereas the additional insights and benefits may very well be limited.

Considering the imperfections of the under-five mortality rate as an indicator of hunger and the level of effort required to estimate the contribution of nutritional deficiencies to child mortality for the GHI, it has been proposed to drop the child mortality dimension entirely from the index. Yet, this option is rejected because (1) premature death is the most serious consequence of hunger, and

[10] The value judgments to account for the time lived with disabilities and to aggregate losses from disability with life years lost due to premature mortality are highly questionable (Anand and Hanson 1997). During a presentation at the University of Kiel in the 1990s, Amartya Sen pointed out that minimizing DALYs lost in a cost-effective manner could be equated with “saving the able-bodied”. In addition, some nutritional factors that contribute to mortality have been neglected. It is also considered advisable to remain focussed on child mortality for the GHI, which would not be given if the DALYs, which refer to all age groups, were used. So far, the data for DALYs and death rates by detailed causes have been published irregularly, and it is not clear if and when they will be updated. The data that are available at present are too outdated to be used for the 2015 GHI.

[11] Black et al. (2010) published such estimates for 2008, Liu et al. (2012) provided an updated analysis for 2010 with time trends since 2000. Two years later, Liu et al. (2015) presented annual data for 2000-2013 and projections to inform post-2015 priorities.

children are more vulnerable than adults; (2) the contribution of nutritional disorders to child mortality is only partially captured by stunting and wasting; and (3) child mortality has higher correlations overall with micronutrient deficiencies than the other components of the GHI and thereby strengthens the ability of the index to reflect hidden hunger (see Appendix B for more detailed explanations).

4 Standardization of component indicators

Masset (2011) commented on the GHI: "The choice of adding up the percentage values of each dimension without prior scaling is also questionable as this ends up attributing lower values to changes in mortality rates, whose percentage values are much lower than those of undernutrition and food availability." The standardization or scaling of index components is usually applied to harmonize different measurement units (Szilágyi 2000). Ryten (2000) emphasises that for the purpose of aggregation, the single indicators need to be expressed in a common metric, or need to be standardized. If the component indicators are already expressed in a common metric, standardization is optional and not mandatory. The Hidden Hunger Index for preschool-age children, for example, aggregates the prevalence rates of stunting, anemia due to iron deficiency, and vitamin A deficiency by simple averaging, without prior standardization of the indicators (Muthayya et al. 2013).

However, if the ranges between the maximum and minimum values of the single components differ substantially, aggregation without preceding standardization is questionable. Despite equal weighting, the indicator with the largest variance may dominate the overall index if no standardization is applied, introducing a kind of "unintentional weighting" (Noorbakhsh 1998, p.593; Wiesmann 2004). Such "unintentional weighting" can be avoided by standardizing the index components. The following arguments speak in favor of standardizing the component indicators of the GHI prior to aggregation:

1. The maximum values and standard deviations of the three index components—and of wasting and stunting as suggested replacements for underweight—differ greatly and are lowest for wasting and child mortality (Table 5). Standardization would give greater emphasis to the child mortality dimension relative to the other two index dimensions, balance the contribution of wasting and stunting to the child undernutrition dimension, and diminish the relative impact of the contested undernourishment indicator on the variation of the index.
2. Different methods of standardization are discussed in the literature and were tested for the GHI; the analyses showed that standardization had little effect on the ranking of countries[12], yet, the influence on changes of the GHI over time was non-negligible (Wiesmann 2006). Due to its greater variability, changes in the undernourishment indicator tend to drive changes in the index more than changes in the other two component indicators. This has also become evident from the trend analyses for individual countries performed for Chapter 2 of the Global Hunger Index reports (see the examples of Iraq and Swaziland in von Grebmer et al. 2014, p.17).
3. Because indicators of micronutrient deficiencies and low dietary diversity correlate more strongly with under-five mortality and also—in most cases—more strongly with child underweight than with undernourishment (see Figure B-1 in Appendix B), standardizing the component indicators can be expected to make the GHI better suited to reflect hidden hunger.
4. The lack of standardization of the component indicators of the GHI has frequently been criticized by other researchers as a matter of principle (Masset et al. 2011; personal communication with Shenggen Fan, IFPRI).

[12] The rankings based on index versions with standardized components essentially contained the same information as the ranking of the GHI without standardization. For the total sample, the rank correlation coefficients were above 0.99, and fairly above 0.90 for the three subsamples with low, medium, and high GHI, showing the high redundancy of the index versions with standardized components vis-à-vis the GHI without standardization (Wiesmann 2006).

On the other hand, standardizing the index components involves arbitrary decisions and has several disadvantages. If the actual minimum and maximum values observed in the data set are used, the "goalposts" tend to shift every year due to changes in the data. This would affect the intertemporal comparability of the GHI.[13] To avoid problems with intertemporal comparability due to standardization, estimated maximum values that are safely above the actual past and present maximum values observed in the data set can be used. Yet, this approach has also its downsides:

1. It is not possible to select estimated maximum values without arbitrariness. While it is possible to find estimated maximum values that are unlikely to be exceeded by any country in the near future, they may not be suitable for subpopulations in extreme emergencies when undernourishment, child malnutrition, and child mortality soar, and could pose problems for subnational disaggregation in selected countries.[14]
2. It can be argued that the proportion of undernourished and the prevalence of underweight or of stunting and wasting in children, which are more immediate measures of hunger and undernutrition than under-five mortality, should have a comparatively larger impact on changes in the index. Because the under-five mortality rate is a final outcome with other causal factors than hunger and undernutrition, and only about half of all child deaths are attributable to undernutrition, a smaller impact of this component on the GHI might be considered acceptable (Wiesmann 2006). If it were possible to estimate child mortality from nutritional deficiencies at the country level with sufficient reliability and reasonable effort, this would make standardization more convincing, but this option is at present not within reach.
3. Standardization of any type makes it a bit more complicated to trace back levels and trends in GHI scores to the index components. This is irrelevant for analysts, but might matter for the communication with a lay audience. For example, it is easy to communicate that about 66 percent of children were stunted in 1995 in Bangladesh, and easy to understand how this affects the GHI without standardization. The meaning of the corresponding standardized prevalence of stunting in children of about 94% (which would be included in the GHI based on an estimated maximum value of 70 percent for the data set) is less obvious.

Despite certain drawbacks of standardization, it is considered advisable to standardize the component indicators of the revised GHI to balance the contribution of wasting and stunting to the child undernutrition dimension, decrease the influence of variations in the undernourishment indicator on trends over time, and respond to the frequently voiced critique about the lack of standardization by other researchers.[15]

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[13] Given the case that the maximum value for the prevalence of undernourishment would change from 68 to 75 percent from one time period to the next, a country with a constant prevalence of undernourishment of 50 percent and no changes in the other two index components would have a different GHI score and might be classified differently, although nothing may have changed with regard to its food security and nutrition situation.

[14] The GHI was subnationally disaggregated for Ethiopia, India, and Nepal (Schmidt and Dorosh 2009; Menon, Deolalikar, and Bhaskar 2009; WFP Nepal 2009).

[15] How standardization balances the contribution of stunting and wasting to the child undernutrition dimension of the GHI, and thereby to the overall index, can be nicely illustrated with reference to the cutoffs for public health significance set for these indicators by WHO (1995). At the national level, prevalence rates of 15% or more for child wasting, and of 40% or more for child stunting are regarded as severe public health problems. Although both forms of child undernutrition reached very serious levels according to the WHO definition, stunting would contribute 2.7 times as much to the child undernutrition dimension as wasting if a 40% prevalence was simply lumped together with a 15% prevalence, without prior standardization and with equal weighting. Standardization with the set maximum values of 70% for stunting and 30% for wasting (see below) would largely redress this bias, resulting in standardized scores of 40%/70%=57% for stunting and of

Table 5: Summary statistics for the component indicators of the GHI

Indicator and reference year(s)	N	Mean	Standard deviation	Minimum value	Maximum value
Percentage of undernourished in the population, average for:					
1990-1992	97	24.5	16.8	0.5	70.2
1994-1996	117	22.3	17.2	0.6	72.4
1999-2001	117	20.5	16.1	0.7	**76.5**
2004-2006	118	18.2	15.4	0.1	75.6
2011-2013	120	15.2	14.2	0.4	67.3
Prevalence of underweight in children under five, incl. regression estimates, from:					
1988-1992	104	19.8	13.2	0.9	**61.5**
1993-1997	126	16.8	12.6	0.5	55.2
1998-2002	127	15.7	12.5	0.5	46.3
2003-2007	129	13.9	11.8	0.4	43.5
2009-2013	128	11.8	10.5	0.3	45.3
Prevalence of underweight in children under five[1], from:					
1988-1992	48	19.5	13.7	2.5	**61.5**
1993-1997	82	18.1	12.5	0.5	55.2
1998-2002	91	17.5	11.9	0.7	46.3
2003-2007	100	14.6	11.7	0.6	43.5
2009-2013	75	14.8	10.6	1.1	45.3
Prevalence of stunting in children under five[1], from:					
1988-1992	44	37.4	14.3	10.8	63.4
1993-1997	79	33.4	15.6	1.6	**68.2**
1998-2002	91	32.6	14.9	3.0	63.1
2003-2007	99	28.5	14.8	2.3	57.7
2009-2013	75	27.5	13.5	4.3	57.7
Prevalence of wasting in children under five[1], from:					
1988-1992	43	6.8	4.8	0.6	20.3
1993-1997	77	8.4	5.4	0.5	22.4
1998-2002	91	7.8	4.9	0.5	19.4
2003-2007	97	7.4	5.1	0.3	**26.0**
2009-2013	75	6.9	4.8	0.6	21.5
Under-five mortality rate for:					
1990	107	10.2	7.0	1.3	**32.6**
1995	127	8.6	6.6	1.0	27.9
2000	127	7.6	5.9	0.8	23.4
2005	128	6.3	5.1	0.7	21.6
2012	130	4.7	4.0	0.4	18.2

1 The number of observations is smaller for these data because regression estimates were not included.
N = number of observations. Data sources: See von Grebmer et al. 2014, p.40.

15%/30%=50% for wasting, and resulting in only a 1.1 times higher share of stunting relative to wasting in the child undernutrition dimension.

Moreover, standardization could indeed be shown to increase the correlation coefficients for the GHI and indicators of micronutrient deficiencies, yet, the effects were mostly very small (compare the correlation coefficients for standardized and non-standardized GHI versions in Table 4).

Considering the maximum values of the component indicators observed in the data set for 1988-2013 (Table 5), the following thresholds were used to compute the standardized index versions presented in this document:

Percentage of undernourished:

80%, exceeding the observed maximum of 76.5%, and also the maximum in the provisional, unpublished country-level estimates obtained from FAO

Prevalence of underweight in children under five:

65%, exceeding the observed maximum of 61.5%; this threshold is used to calculate a standardized version of the GHI with its usual component indicators for the sake of comparison

Prevalence of stunting in children under five:

70%, exceeding the observed maximum of 68.2%

Prevalence of wasting in children under five:

30%, exceeding the observed maximum of 26.0%

Under-five mortality rate:

35%, exceeding the observed maximum of 32.6%.

Without a doubt, these thresholds could be set differently. It should be noted, though, that small variations in the thresholds will have no tangible effects on the ranking or the changes of the GHI over time. Two sets of alternative thresholds for standardization were tested: One using the maximum values in the data set as indicated above, and one using thresholds set 10% above the maximum values (that is, 84.15% for undernourishment, 67.65% for underweight, 75.02% for stunting, 28.60% for wasting, and 35.86% for under-five mortality). Using data from 2009-2013, and wasting and stunting for the child undernutrition dimension, the Spearman rank correlation coefficients for the standardized GHI with the selected thresholds (see above), and the standardized GHI versions with (1) the maximum values in the data set, and (2) the maximum values increased by 10%, amounted to 0.9991 each (see also Table 7 for the correlations between standardized and non-standardized index versions).

Relative changes from 1995 to 2005 were calculated for the different GHI versions with stunting and wasting, namely for the non-standardized index and the three standardized versions—the selected thresholds, the actual maximum values, and the maximum values augmented by 10%. Table 6 confirms the very high redundancy of relative changes in the three standardized versions: If they were not shown with four decimals, the Spearman rank correlation coefficients would have to be displayed as 1.000 because they are so close to unity.

Estimated minimum values can also be used for standardization. Yet, this is irrelevant for the data used for the GHI, because the observed minimum values are already close to zero (Table 5). Only stunting has a slightly higher observed minimum value greater than 1%. Using a threshold of 1% as the estimated minimum value for standardizing an indicator with a maximum value of about 70% would be meaningless in terms of its effects on the index. Moreover, the actual minimum values for stunting and other component indicators of the GHI are likely to decrease in the future.

Table 6: Spearman rank correlations for changes in the Global Hunger Index[1] from 1995 to 2005

Changes from 1995 to 2005 (in percent) in the Global Hunger Index with:		non-stand. components	standardized components[2]		
			selected thresholds	maximum values	maximum values + 10%
non-stand. components		1.0000			
stand. components[2]	selected thresholds	0.9460	1.0000		
	maximum values	0.9343	0.9985	1.0000	
	maximum values + 10%	0.9356	0.9985	0.9998	1.0000

1 The different versions of the Global Hunger Index for which the associations of relative changes from 1995 to 2005 were examined include FAO's proportion of undernourished, the prevalence of wasting and stunting, and the under-five mortality rate. Regression estimates were not included for wasting and stunting. Correlation coefficients could be calculated for 66 countries and were highly significant (p-value = 0.000). The three index dimensions are equally weighted, and stunting and wasting are weighted equally within the child undernutrition dimension.

2 For the index versions with standardized components, the indicators were standardized using the following thresholds prior to aggregation: 80% for undernourishment, 65% for underweight, 70% for stunting, 30% for wasting, and 35% for under-five mortality; the actual maximum values in the data set (Table 5); or the actual maximum values increased by 10%. The standardized values X (stand.) for each indicator were calculated as follows: X (stand.) = X/estimated maximum value * 100.

Data sources: See von Grebmer et al. 2014, p.40.

Table 7: Spearman rank correlations for different versions of the Global Hunger Index[1]

Global Hunger Index with		non-stand. components including:			stand. components including:		
		under-weight	stunting	stunting + wasting	under-weight	stunting	stunting + wasting
non-stand. components including:	underweight	1.00					
	stunting	0.95	1.00				
	stunting + wasting	0.97	0.99	1.00			
stand. components including:	underweight	**0.98**	0.93	0.95	1.00		
	stunting	0.94	**0.99**	0.98	0.94	1.00	
	stunting + wasting	0.98	0.96	**0.98**	0.98	0.97	1.00

1 The different versions of the Global Hunger Index include FAO's proportion of undernourished and the under-five mortality rate besides the listed child undernutrition indicators. Nationally representative survey data from the period 2009-2013 retrieved in May 2014 were used for the child undernutrition indicators, regression estimates were not included. Correlation coefficients could be calculated for 75 countries and were highly significant (p-value = 0.000). The three index dimensions are equally weighted, and stunting and wasting are weighted equally within the child undernutrition dimension if used in combination. For the index versions with standardized components, the indicators were standardized using the following estimated maximum values prior to aggregation: 80% for undernourishment, 65% for underweight, 70% for stunting, 30% for wasting, and 35% for under-five mortality. The standardized values X (stand.) for each indicator were calculated as follows: X (stand.) = X/estimated maximum value * 100. Correlation coefficients for standardized and non-standardized indices with the same component indicators are emboldened.

Data sources: See von Grebmer et al. 2014, p.40.

Table 7 shows that different versions of the GHI with data from 2009-2013 (excluding countries for which child underweight had to be estimated for this period, and including only countries for which survey data for stunting and wasting were also available) are highly redundant in terms of their rank correlations. This is particularly true for indices with the same component indicators with and without standardization. Yet, as discussed above, standardization of index components is common practice. In the case of the GHI, standardization can balance the contribution of wasting and stunting to the child undernutrition dimension and decrease the influence of variations in the undernourishment indicator on trends over time.

5 Conclusion

Building on the discussions in previous sections, we come to the conclusion that (1) the child underweight indicator should be replaced with child stunting and child wasting; (2) the weight of one third for the child undernutrition dimension should be shared equally between stunting and wasting; and (3) the component indicators of the index should be standardized prior to aggregation, using fixed thresholds set above the maximum values observed in the data set.

Stunting and wasting are weighted equally within the child undernutrition dimension to place equal emphasis on chronic and acute undernutrition.[16] Both forms of child undernutrition entail human suffering, yet, it is not easy to ascertain which condition has the more serious implications. Stunting at two years was found to be associated with impaired early motor and cognitive development, shorter adult height, lower attained schooling, reduced adult income and—for women—decreased birthweight of their offspring (Victora et al. 2008; Black et al. 2013). In a recent prospective cohort study in Tanzania, McDonald et al. (2013a) found that wasting was associated with deficits in psychomotor and mental development, independently of stunting. Wasting is a stronger determinant of under-five mortality than stunting: The hazard ratio was 11.6 for severe wasting and 5.5 for severe stunting in a pooled analysis of 10 prospective studies in Africa, Asia and South America, and was also higher for moderate wasting than for moderate stunting (Olofin et al. 2013).[17] There is some indication that repeated episodes of wasting lead to stunting, but the mechanisms are still poorly understood (Khara and Dolan 2014). In the absence of conclusive evidence about the relative extent of suffering associated with wasting and stunting, equal weighting of the two indicators is preferred.

Taking into account the thresholds selected for standardization of 80% for undernourishment, 70% for stunting, 30% for wasting, and 35% for under-five mortality, results in the following formula for a revised GHI:

GHI = 1/3*(PUN/80*100) + 1/6*(CST/70*100) + 1/6*(CWA/30*100) + 1/3*(CM/35*100)

with GHI: Global Hunger Index
PUN: proportion of the population that is undernourished (in %)
CST: prevalence of stunting in children younger than five years (in %)
CWA: prevalence of wasting in children younger than five years (in %)
CM: proportion of children dying before the age of five years (in %)

Alternatively, the calculations can be shown in two steps:

Standardization of component indicators:

PUN (stand.) = PUN/80*100
CST (stand.) = CST/70*100
CWA (stand.) = CWA/30*100
CM (stand.) = CM/35*100

[16] Stunting has higher correlations with the undernourishment indicator and the under-five mortality rate than wasting; this may be related to the short-term fluctuations of acute undernutrition and the challenges of obtaining national prevalence estimates that are representative of all seasons, and does not mandate the use of different weights for the two indicators.

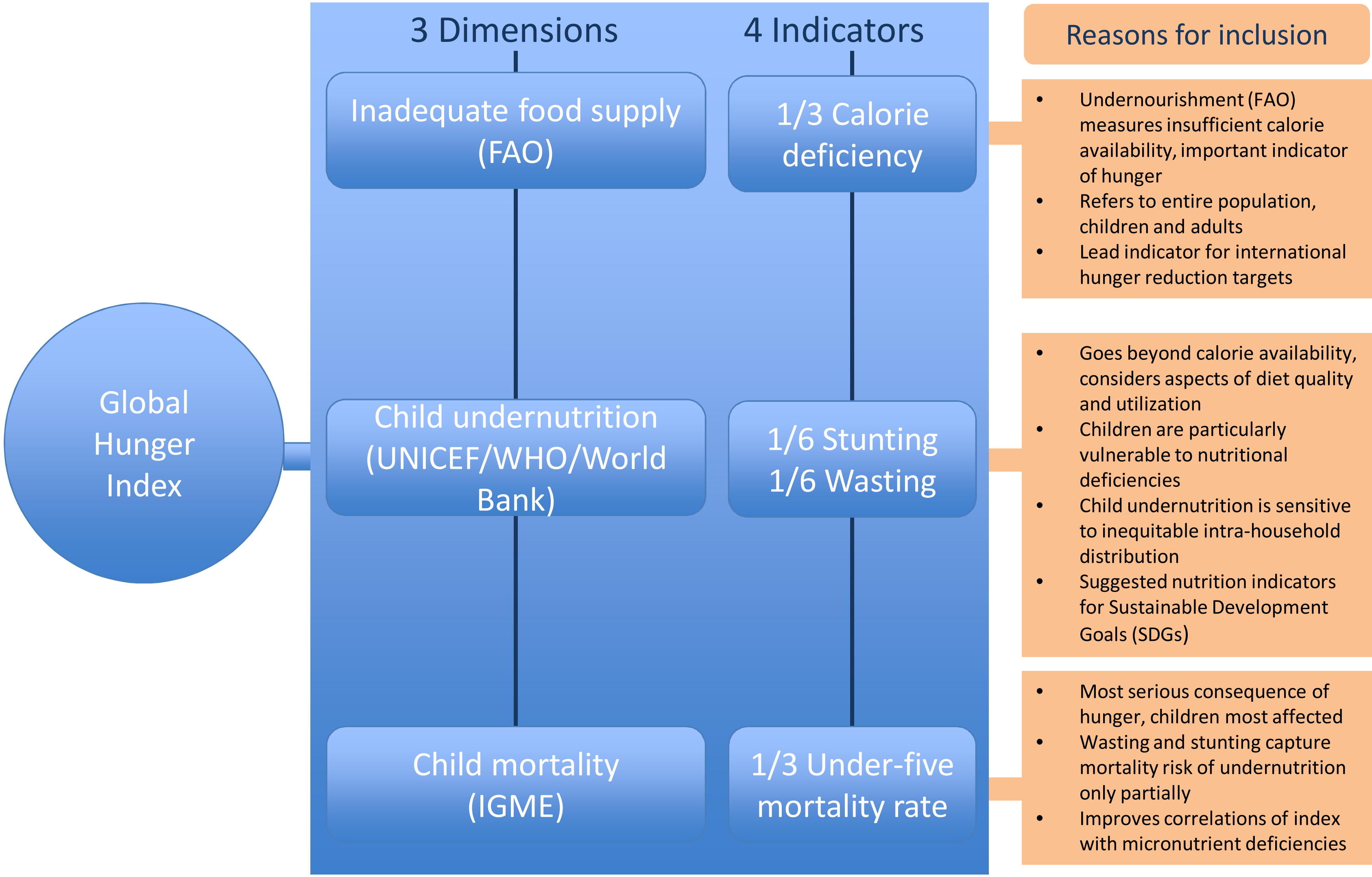
[17] Children who were moderately or severely stunted and moderately or severely wasted (and thereby, almost inevitably, also underweight: only 6 out of 2959 children who were both stunted and wasted in the quoted study were not underweight) had an even higher hazard ratio of 12.3 (McDonald et al. 2013b). This is another argument to include both wasting and stunting in the GHI: High prevalence rates of these two forms of undernutrition in the same population make their co-occurrence in the same individuals more likely, and, if both indicators are considered, they increase the GHI scores compared to countries where only one form is highly prevalent.

Aggregation of component indicators:

GHI = 1/3*PUN (stand.) + 1/6*CST (stand.) + 1/6*CWA (stand.) + 1/3*CM (stand.)

The new GHI formula was utilized to calculate GHI scores for the first time in 2015 (von Grebmer et al. 2015). The cutoffs for classifying countries into categories of low, moderate, serious, alarming and extremely alarming hunger were adapted because the component indicators of the index were standardized as described in this paper, affecting the range of GHI scores relative to years past (see Chapter 1 of the 2015 Global Hunger Index report, von Grebmer et al. 2015). Concluding, Figure 4 illustrates the composition and weighting of the revised GHI, lists the main data sources, and summarizes the reasons for including each dimension and indicator.

Figure 4: Overview of dimensions and indicators of the revised Global Hunger Index



Source: Authors' own presentation

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Appendix A: Nutrition indicators proposed for the Sustainable Development Goals (SDGs) and not recommended for inclusion in the Global Hunger Index

Eight nutrition indicators have been proposed for consideration in the SDGs: the six indicators endorsed by the World Health Assembly, and two additional indicators—one on dietary diversity, and the other one on policy (Table 1). Only two indicators, namely stunting and wasting in children under five, are included in the revised GHI formula.

Two of the eight indicators were not considered for the GHI for conceptual reasons:

The **percentage of national budget allocated to nutrition** should not be included in the GHI because it is an input to and not an outcome of good nutrition. It is recommended to retain the focus of the GHI on outcomes closely related to human well-being (dietary energy deficiency in the population, child undernutrition, and child mortality).

The **prevalence of overweight in children under five** is an important indicator for monitoring nutrition. Yet, it should not become part of the GHI because the index is about capturing deficiencies and deprivation and not excess. If an indicator of overweight or obesity were integrated into the GHI, it could no longer be truthfully called a "hunger index". The correlation coefficients in Table 3 show that child overweight is either not at all or negatively associated with various indicators of micronutrient deficiencies.[18] Indicators of overweight or obesity might better be used to construct a nutrition or overnutrition index.

Four other of the proposed eight indicators have serious data gaps and for some, comparability across countries is also limited:

The **percentage of women of reproductive age with anemia** is a proxy indicator and not a precise measure of iron deficiency because there are many other causes of anemia besides iron deficiency, including other nutritional deficits. The Global Nutrition Report (GNR) assesses that only 5 out of 185 countries are currently on track to meet the WHA target to halve anemia in women of reproductive age by 2025 (IFPRI 2014). Monitoring this indicator and stimulating political will to reduce anemia among women is therefore a high priority.

The percentage of women of reproductive age with anemia would be a great candidate for inclusion into the GHI. The index could be extended to include a fourth dimension for micronutrient deficiencies or hidden hunger in addition to the existing three dimensions, or anemia in women of reproductive age could be integrated into one nutrition dimension together with indicators of child undernutrition.

However, limited data availability is a serious obstacle: Among the 120 countries for which the 2014 GHI could be computed, only 29 have data on anemia in women of reproductive age from nationally representative surveys for 2010 or later, and only 38 countries have such data for 2008 or later (Stevens et al. 2013). If the percentage of women of reproductive age with anemia was included into the GHI, values would have to be estimated by means of regression models for about 90 countries for the 2015 GHI (reference period 2010-2016). The estimation would be especially challenging for the 40 out of 120 countries that never had any survey on anemia in women of reproductive age and

[18] The observed significant negative correlations indicate that night blindness among pregnant women and anemia among preschool children are less prevalent in countries with a higher proportion of overweight children under five. This does not imply causality, but suggests that rising child overweight does not necessarily mean a greater extent of hidden hunger.

would most likely result in shaky estimates for these countries. This would make the ranking based on the 2015 GHI less defensible.[19]

It is recommended to reconsider including an indicator of anemia among women of reproductive age into the GHI after more survey data have become available. The fact that a WHA target has been defined for this indicator will hopefully spur greater efforts to collect data.

The **percentage of women, 15-49 years of age, who consume at least 5 out of 10 defined food groups**, is based on a 10-food group dietary diversity indicator that proxies micronutrient adequacy among women of reproductive age. The new global indicator captures aspects of diet quality and was endorsed by a wide range of stakeholders at a consensus meeting convened by the Food and Nutrition Technical Assistance Project (FANTA) and FAO in July 2014.[20]

So far, data from nationally representative surveys for this indicator are virtually absent. Also, the correlation between the percentage of women consuming at least 5 out of 10 defined food groups and the percentage of women above a 50%, 60% or 70% cutoff for micronutrient adequacy was not very strong for the limited set of cross-sectional data from diverse settings and countries that is available (FAO and IRD 2014). Much greater data availability would be required and the validity of the indicator for cross-country comparisons of diet quality should be further investigated before considering it for the GHI.

The **percentage of infants born with low birth weight** is related to fetal undernutrition and therefore provides information about an important time period within the nutritionally critical 1,000 days after conception, and also about mothers' nutritional status during pregnancy. In principle, it would be worthwhile to examine statistically if this indicator could meaningfully complement other indicators of child undernutrition that have been selected for the GHI.

However, data on low birth weight are sparse and inconsistent. Globally, only about half of all babies are weighed at birth, and the share of weighed babies varies greatly across countries. Estimates of the prevalence of low birth weight are not always comparable across time and across countries, and improved adjustment methods need to be developed (Newby 2014).

At present, both the lack of data and the limited comparability across countries prevent the inclusion of the percentage of infants born with low birth weight into the GHI. If more data become available and reliable adjustment methods can be developed, the potential benefits of including this indicator should be examined.

The **percentage of infants less than 6 months of age who are exclusively breastfed** is an indicator of child feeding. It can be considered an input to child nutrition rather than an outcome measure. Including this indicator into the GHI would be possible, yet, taking into account the type of outcome indicators selected for the GHI, this does not have high priority.

The data collection method for exclusive breastfeeding among infants under 6 months limits the comparability of the indicator across countries. The indicator is calculated as the proportion of infants 0-5 months of age who received only breast milk during the previous day among all infants 0-5 months of age. Because some infants are given other liquids than breast milk irregularly, using the previous day as recall period will lead to an overestimation of exclusively breastfed infants (WHO 2010a). The degree of overestimation will vary across countries because it is more common in some settings to give other liquids than breast milk irregularly than in others.

[19] In a section on data gaps, the GNR states that "More survey-based micronutrient data are required. Anemia data are based on models, and modeled data at the country level may not be considered meaningful or credible" (IFPRI 2014, p.21).

[20] http://www.fantaproject.org/sites/default/files/resources/Introduce-MDD-W-indicator-brief-Sep2014.pdf

Data availability is also still limited: World Bank (2014) presented data from 2010 or later for only 51 out of the 120 countries for which the 2014 GHI could be computed, which means that data for almost 70 countries would have to be estimated.

Appendix B: Reasons to include child mortality in the Global Hunger Index

Three main arguments to include the child mortality dimension in the GHI can be brought forward:

1. **Premature death is the most serious consequence of hunger, and children are more vulnerable than adults.**

Children are particularly vulnerable to nutritional deficiencies because of their fragile immune systems: They are at a higher risk than adults to get caught in a vicious cycle of inadequate food intake, infection, loss of appetite and poor nutrient absorption, often with fatal consequences (UNICEF 1990; Tomkins and Watson 1989). It is true that food insecurity and undernutrition also tend to raise adult mortality rates, especially during famines (Swift 1993). Yet, when comparing across countries, mortality among adults varies to a larger extent according to factors that are not linked to undernutrition, such as other lifestyle aspects, hazardous occupations, or active participation in wars. Chronic diseases that are more strongly associated with unbalanced food intake than with undernutrition, such as cardiovascular diseases and cancer, also play a larger role for adult mortality than for child mortality (WHO 2009b). Therefore, child mortality is preferred as a proxy for premature mortality associated with undernutrition.

2. **The contribution of nutritional disorders to child mortality is only partially captured by stunting and wasting.**

Underweight also contributes to child mortality, and so do zinc deficiency, vitamin A deficiency, fetal growth restriction and suboptimum breastfeeding (Black et al. 2013). At present, indicators of micronutrient deficiencies and fetal growth restriction (that is, low birth weight) cannot be included into the GHI because of limited data availability and/or comparability. It is very likely that the contribution of micronutrient deficiencies to child mortality is underestimated, because data and sometimes also indicators are lacking for most micronutrient deficiencies.

There is an overlap in the contribution of the various nutritional factors to child mortality: If the percentages are added up (Table B-1, numbers based on UN prevalences, second data column,), the result amounts to 76.5%, although all nutritional disorders cause only an estimated 44.7% of all deaths of children under five. Children can be affected by more than one nutritional disorder, and this has to be taken into account. Because fetal growth restriction and suboptimum breastfeeding in neonates (that is, infants <1 month) does not overlap with stunting, wasting, and underweight among children 1-59 months in terms of age group, its joint contribution to 19.4% of all child deaths is independent of the indicated contribution of stunting, wasting, and underweight. This means that fetal growth restriction and suboptimum breastfeeding in neonates jointly cause 43% of all child mortality that is attributable to nutritional disorders (19.4% divided by 44.7%).

3. **Child mortality has higher correlations overall with micronutrient deficiencies than the other components of the GHI.**

Among the indicators included in the GHI up to 2014, child mortality had the highest correlations overall with indicators of micronutrient deficiencies (Figure B-1). This is particularly true for anemia in preschool children and pregnant women and low serum retinol in preschool children. For night blindness among pregnant women, underweight had slightly higher correlations than child mortality, but the difference was not very large.[21] Including child mortality in the GHI therefore improves the correlations of the index with indicators of micronutrient deficiencies. This is a desirable outcome; it would be even better to include indicators of micronutrient deficiencies in the index, yet, this is not possible to date due to the scarcity of data. As long as the availability of data on micronutrient

[21] Low dietary diversity among young children is no measure of micronutrient deficiencies, but only a proxy indicator of diet quality.

deficiencies does not increase significantly, the under-five mortality rate may serve as a kind of proxy indicator for these deficiencies.

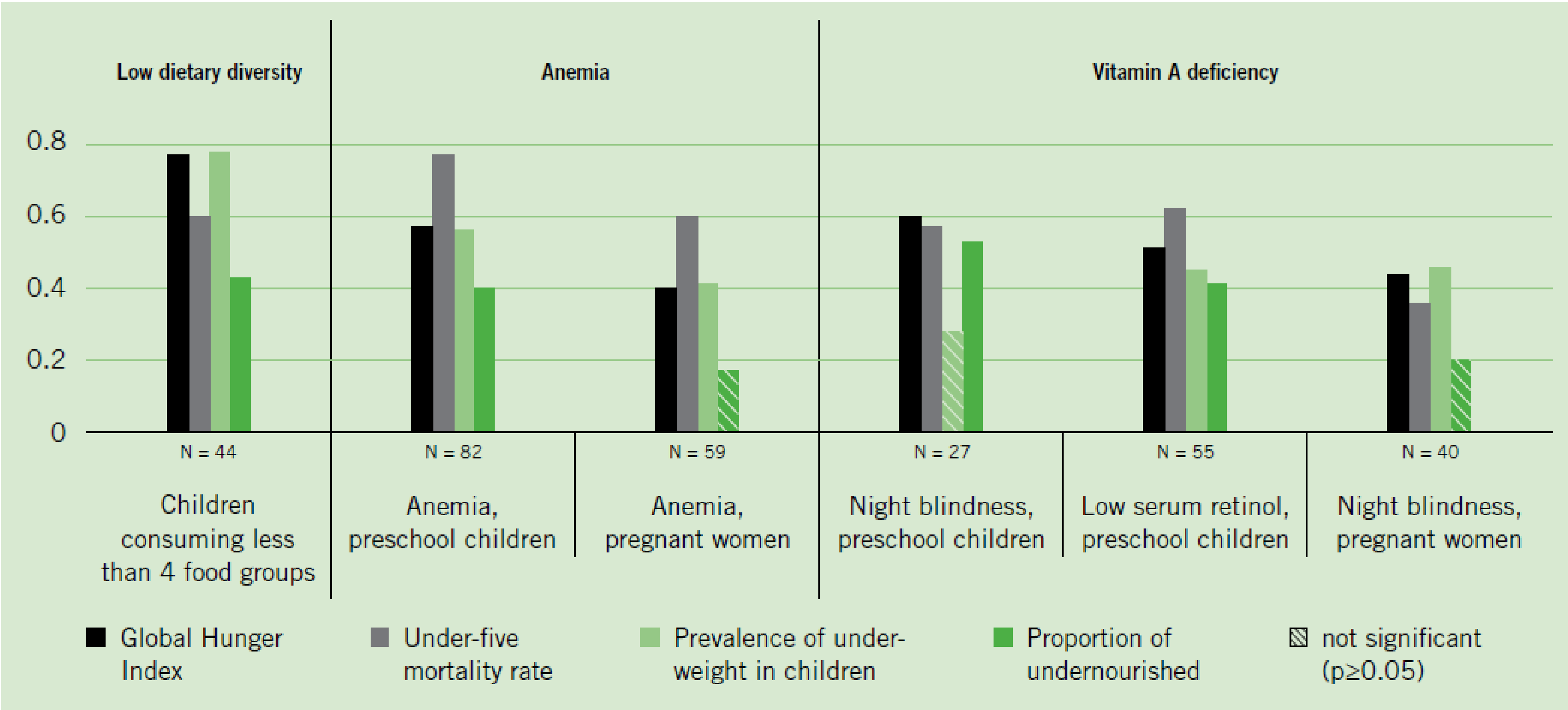
Table B-1: Global deaths in children younger than five years attributable to nutritional disorders

	Attributable deaths with UN prevalences*	Proportion of total deaths of children younger than 5 years	Attributable deaths with NIMS prevalences†	Proportion of total deaths of children younger than 5 years
Fetal growth restriction (<1 month)	817 000	11·8%	817 000	11·8%
Stunting (1–59 months)	1 017 000*	14·7%	1 179 000†	17·0%
Underweight (1–59 months)	999 000*	14·4%	1 180 000†	17·0%
Wasting (1–59 months)	875 000*	12·6%	800 000†	11·5%
Severe wasting (1–59 months)	516 000*	7·4%	540 000†	7·8%
Zinc deficiency (12–59 months)	116 000	1·7%	116 000	1·7%
Vitamin A deficiency (6–59 months)	157 000	2·3%	157 000	2·3%
Suboptimum breastfeeding (0–23 months)	804 000	11·6%	804 000	11·6%
Joint effects of fetal growth restriction and suboptimum breastfeeding in neonates	1 348 000	19·4%	1 348 000	19·4%
Joint effects of fetal growth restriction, suboptimum breastfeeding, stunting, wasting, and vitamin A and zinc deficiencies (<5 years)	3 097 000	44·7%	3 149 000	45·4%

Data are to the nearest thousand. *Prevalence estimates from the UN. †Prevalence estimates from Nutrition Impact Model Study (NIMS).

Source: Black et al. 2013

Figure B-1: Correlations of the Global Hunger Index with measures of hidden hunger



Spearman rank correlation coefficients can range from 0 (no association) to 1 (perfect association). All correlations with the GHI are statistically significant at p-value < 0.01. For the GHI components, solid color indicates significance at $p < 0.05$. Nationally representative survey data were used for indicators of micronutrient deficiencies and diet diversity. The latest available data were matched with the GHI and its components using the year of the survey and the GHI reference periods. N indicates the number of countries for which the correlation coefficients could be computed.

Definitions and data sources: Low dietary diversity: Proportion of children 6–23 months who consume fewer than four out of seven food groups (grains, roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin-A rich fruits and vegetables; other fruits and vegetables) (WHO 2010b; Kothari and Abderrahim 2010). Anemia: Proportion of preschool-age children whose hemoglobin level is less than 110 grams per liter, and proportion of pregnant women whose hemoglobin level is less than 110 grams per liter (World Bank 2014; MEASURE DHS 2014; de Benoist et al. 2008). Vitamin A deficiency: Proportion of preschool-age children with night blindness, proportion of pregnant women with night blindness, and proportion of preschool-age children whose serum retinol level is less than 0.70 micromole per liter (WHO 2009a).

Source: von Grebmer et al. 2014

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