**Revealing the prevalence of “hidden hunger”: global and regional estimates of micronutrient deficiencies among preschool-age children and non-pregnant women of reproductive age**

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**Abstract (max 300 words)**

*Background*

Micronutrient deficiencies (MNDs) compromise immune systems, hinder child growth and development, and limit human capital worldwide. Yet the only existing estimate of the global prevalence of deficiency was from over three decades ago. It was based only on anemia, which is not necessarily attributable to a MND. We aimed to transparently estimate the global and regional prevalence of deficiencies in one or more micronutrients among preschool-age children (PSC) and non-pregnant women of reproductive age (NPW).

*Methods*

We reanalysed and pooled individual-level micronutrient status biomarker data from nationally representative, population-based surveys. We used Bayesian hierarchical logistic regression to estimate the prevalence of deficiency in one or more of three core micronutrients globally and in seven regions for the period 2005–2019.

*Findings*

We estimated the global prevalence of deficiency in at least one of three core micronutrients to be 56% (95% uncertainty interval 48 to 64) among PSC, and 69% (59 to 78) among NPW. This translates into a global total of 372 (319 to 425) million PSC and 1.2 (1.0 to 1.4) billion NPW with MNDs. Regionally, three quarters of PSC with MNDs live in South Asia (99 million, 80 to 118), Sub-Saharan Africa (98 million, 83 to 113), or East Asia and the Pacific (85 million, 61 to 110). Over half (57%) of NPW with MNDs live in East Asia and the Pacific (384 million, 279 to 470) or South Asia (307 million, 255 to 351).

*Interpretation*

There is a large burden of MNDs among women and children worldwide, especially in low- and middle-income countries, but also in high-income countries.

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**Research in context**

*Evidence before this study*

For decades, the nutrition community has cited a global burden of micronutrient (vitamin and mineral) deficiency affecting 2 billion people. This estimate is critical to draw attention to the problem and should be used to track global progress towards improvement. However, the estimate was based on anemia, not micronutrient deficiencies (MNDs), and is over three decades old.

*Added value of this study*

This study provides an updated estimate of MNDs worldwide and regionally between 2005–2019 using individual-level micronutrient status biomarkers of multiple micronutrients. We estimate that worldwide there are about 1.6 billion PSC and NPW with one or more MND. Importantly, this approach provides a transparent method to estimate the global and regional prevalence and it can be replicated as more and better data from nationally-representative surveys become available.

*Implications of all the available evidence*  
Few population-based data sources measure MNDs. Whether this critical evidence gap biased our prevalence estimates is an important question that must be addressed as additional surveys become available. Nevertheless, the results clearly illustrate that micronutrient malnutrition is a critical public health problem among PSC and NPW. The problem affects populations in all regions of the world, including high-income countries. The oft-cited 2 billion micronutrient malnourished is likely a major underestimate of the true global burden of micronutrient malnutrition when considering all essential micronutrients, and all age and sex groups. These deficiencies are compromising immune systems, constraining the growth and development of children, and ultimately limiting the human capital of populations and nations.

**Introduction**

The direct effects of micronutrient deficiencies (MNDs) on morbidity and mortality outcomes in individuals and indirect effects on societies have been extensively investigated.1,2 Deficiencies in iron, vitamin A, zinc, folate, vitamin B12, vitamin D, and iodine can each have severe consequences, including increased susceptibility to infections, blindness, reduced growth, cognitive impairment, decreased work productivity, and in extreme situations death.3–8 Evidence of deficiency and severe health consequences has also emerged for other micronutrients in specific settings, such as thiamine deficiency and sudden infant death in several countries in Asia.9 Women of reproductive age, pregnant women, and young children are particularly vulnerable to the effects of micronutrient malnutrition due to high requirements and often, low intake. Increasing micronutrient intake of the general population or populations with increased requirements such as pregnant women and young children through improved diets, staple food fortification, biofortification, or supplementation consistently demonstrates potential to effectively reduce the burden of maternal and child morbidity, neurodevelopment, and mortality.10–13

However, despite its public health importance, the global prevalence and number of people with MNDs is not well quantified. This is in part because the majority of MNDs remain undiagnosed, due to lack of specific symptoms—thus often referred to as hidden hunger—and the lack of micronutrient status biomarker data in many population-based surveys.14 For over three decades the nutrition community has quoted the number of people affected by MNDs worldwide at approximately 2 billion people.15 While the original source of this estimate is often uncited in reports, it is based on the estimated number of people with anemia.15 However, anemia is not synonymous with MNDs. Some MNDs cause anemia while others do not, and there are causes of anemia that are unrelated to micronutrient status.16

Robust global and regional estimates with transparent methods of those experiencing MNDs are essential for tracking progress towards global goals, informing funding and programmatic priorities, and supporting advocacy efforts to drive these.17 Estimates of the burden of MNDs face three main constraints.18 First, micronutrient status biomarker data that provide reliable population prevalence estimates remain sparse,14 and smaller non-representative studies have limited value for estimating burden and identifying priority population subgroups. Limited and often outdated data are available for preschool-age children (PSC) and non-pregnant adolescent girls and women of reproductive age (NPW), but even less data are collected on school-age children, adolescent boys, pregnant women, men, and the elderly. Second, recommendations on appropriate micronutrient status biomarkers and standardization of field and laboratory methodologies have been published.19 Yet published studies report on a variety of field methods, biomarkers, different assays for the same biomarker, different approaches to adjust for inflammation, and varying cut-offs to define deficiency, all of which limit the comparability of their results. The third challenge is that there are 38 known essential nutrients,20 although status data of only a few of these are collected in representative surveys.21 We also know that MNDs do not always occur alone,1,22 yet standardized methods to account for this co-existence when estimating the number affected have not been proposed.

Our primary objective for this study was to estimate the global and regional prevalence of deficiencies in one or more micronutrients among PSC (primarily 6–59 months) and NPW (primarily 15–49 years) by reanalysing and pooling individual-level micronutrient status biomarker data from nationally-representative, population-based surveys that met pre-determined inclusion criteria, using a transparent set of definitions for deficiency and defined methods to adjust for inflammation and assay used. This estimation of the global and regional prevalence of MNDs among PSC and NPW will permit replication and updates of these estimates as additional survey data become available.

**Methods**

Included data were collected between 2005–2019, which we grouped into six geographic regions of low- and middle-income countries (LMIC); we included high-income countries in a seventh group. For simplicity we refer hereafter to these groupings as regions (see further details on regions and included datasets in appendix Tables 1–2). Our analysis focused on PSC and NPW because more data on micronutrient status are available for these groups, and previous evidence suggests these groups bear high burdens of deficiency.14

Our analysis followed seven steps:

1. Establish consensus on a set of sentinel micronutrients, and their biomarkers that should be included in the analysis;
2. Identify, review, access, and assess population-based individual-level biomarker datasets containing at least two of the six sentinel micronutrients;
3. Adjust the micronutrient status biomarker concentrations for inflammation, where applicable, using the Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) approach and apply thresholds to identify individuals with deficiencies in each micronutrient;
4. Identify three core micronutrients for PSC and NPW;
5. Include in the final analysis data sources identified in step 2 that measure at least two of the three core micronutrients identified in step 4;
6. Apply regression models (details below and in appendix) to estimate the prevalence of deficiency of the unmeasured micronutrient when only two of the three core micronutrients were measured; and
7. Apply statistical models to estimate the global and regional prevalence of deficiency in one or more of the core micronutrients in PSC and NPW.

These estimates have been documented following the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER; appendix Table 2).23

*Establishing a set of sentinel micronutrients for consideration in the analysis*

The primary data source for this analysis was micronutrient status biomarker data collected as part of household surveys representative of the population (hereafter called nutrition surveys). An initial set of six sentinel micronutrients were selected *a priori,* based on the following criteria: (1) they were measured in multiple nutrition surveys alongside other biomarkers within the same individuals, (2) they can have severe or long-term health consequences, and (3) prevalence of deficiency is high in many countries. These sentinel micronutrients were iron, vitamin A, zinc, vitamin B12, folate, and vitamin D. This list was finalized following its review and agreement by an external advisory panel of micronutrient experts.

*Data identification, access, analysis, and inclusion*

The aim of this analysis was to determine the prevalence of deficiency in one or more micronutrients among PSC and NPW. We included datasets that were representative of ≥3 first-level administrative divisions within a country, contained anonymized individual-level biomarker data for ≥2 of the three sentinel micronutrients, and met minimum data quality criteria (appendix 2).

Our primary data sources were datasets included in the BRINDA collaboration. To identify additional eligible datasets we used a snowball approach where we searched the internet, the peer-reviewed literature, and the Micronutrients database of the WHO Vitamin and Mineral Nutrition Information System (VMNIS)21 and contacted individuals and country representatives to request access using our own networks (appendix 2).

Micronutrient status biomarker data were adjusted for inflammation following the BRINDA approach (appendix 3).24 Comparable definitions of deficiency were applied to all surveys, using cut-offs widely accepted and published in the available literature (Table 1, appendix Table 4). Assay-adjusted cut-offs were used for folate because the assay used can bias folate measurement (appendix 3, appendix Tables 6–7).25

We identified few datasets which measured all six sentinel micronutrients in the same individuals (two in PSC, four in NPW). Therefore, we simplified the analysis by reducing to three the number of micronutrients included in the final analysis. We aimed to identify a maximum of three core micronutrients which could be used to identify the majority of individuals with any micronutrient deficiency. Two factors were considered: (1) micronutrient deficiencies that had a higher prevalence or often occurred independently and were therefore needed to capture a large proportion of individuals with any deficiency, and (2) micronutrients that were more frequently measured in the datasets initially included. We selected zinc, iron, and vitamin A as core micronutrients for PSC and zinc, iron, and folate as core micronutrients for NPW (appendix 4). We excluded data sources that did not measure at least two core micronutrients (appendix 5).

*Statistical methods*

All statistical analyses were conducted separately for PSC and NPW. Prevalence of deficiency in one or more measured core micronutrients and its effective sample size was computed for each survey and population group, taking into account complex survey design and weighting, where relevant (appendix 5).

Data sources that measured only two of the three core micronutrients underestimate the prevalence of deficiency when considering all three core micronutrients. To adjust for this bias, we fitted four regression models to estimate the deficiency prevalence of the unmeasured micronutrient (appendix 6). An effective sample size was computed that accounted for uncertainty from the surveys’ sample design and from this additional analysis step.

We fit a Bayesian hierarchical logistic regression model to estimate the country-level prevalence of deficiency in one or more of the three core micronutrients globally and in each of the seven regions (appendix 7). This approach has been recommended for global and regional estimates of health indicators with limited data available.26 The model’s hierarchical structure allowed the estimate for each region to be informed by data from the region and also by data from other regions, particularly in regions where data were sparse or inconsistent. One time-varying country-level covariate, the socio-demographic index,27 a measure of a country’s level of development, allowed for borrowing strength from countries of similar development level.

We fit the Bayesian model using a Markov Chain Monte Carlos (MCMC) algorithm. We obtained 4000 posterior samples of the model coefficients, from which we computed 4000 samples of the prevalence of deficiency in one or more core micronutrients for each dataset listed in appendix Table 1. Numbers of persons affected by MNDs were computed for each sample by multiplying country-demographic group population totals for 2013 (the median data year) from the UN Population Division’s 2019 Revision of the World Population Prospects by the prevalence of deficiency in one or more core micronutrients.28 All reported uncertainty intervals represent the 2.5th–97.5th percentiles of these 4000 samples.

**Results**

*Datasets identified, accessed, and included*

We identified and accessed 24 datasets from nationally representative surveys in 22 countries that met the inclusion criteria (appendix tables 6–7, appendix figure 3). Of the included datasets, 18 provided data for both PSC and NPW, with an additional four providing data for PSC only, and two for NPW only. The 22 datasets from 20 countries for PSC (appendix table 7) included at least one data source for each region except for the Middle East and North Africa region, and only one dataset was available for each of high-income and Europe and Central Asia. The median year of data collection was 2012.5 and the median number of micronutrients available out of the six sentinel micronutrients was four. For NPW, 20 datasets from 19 countries were included, with at least two countries for each country group except for the Middle East and North Africa, for which there were no available data. The median year of data collection was 2013 and the median number of micronutrients available out of the six sentinel micronutrients was 4.5.

*Estimated prevalence of MNDs in country datasets*

Among PSC from individual country survey data, iron status was available in all 22 datasets, vitamin A in 21, and zinc in 16 (Table 2). Iron deficiency among PSC was ≥20% in 13 datasets (>50% in Liberia and Pakistan), 10–19% in eight datasets, and <10% in only Cambodia (5%) (Table 2). Zinc deficiency was ≥20% in 12 datasets (>50% in Cambodia, Malawi, Cameroon, and Viet Nam), 10–19% in four datasets, and <10% in no countries (Table 2). Vitamin A deficiency was 51% in Pakistan and 39% in Afghanistan, 10–19% in Colombia, India, Ecuador, Bangladesh, Ghana, and Ethiopia, and <10% in 13 datasets (Table 2). Data availability for other micronutrients was sparse; of the 22 surveys of PSC, 8 measured folate, 7 measured vitamin B12, and 7 measured vitamin D, with highly variable prevalence of deficiency for each of these micronutrients (Table 2). Only two countries (both lower middle-income) measured all six sentinel micronutrients in PSC and they both indicated very high prevalence of having one or more sentinel MNDs (81% in Cambodia and 80% in India) (Table 2, Figure 1). However, an additional five country surveys measured at least five of the six sentinel micronutrients, which permitted visualization of coexisting deficiencies in an individual, in measured micronutrients (Figure 1). Like Cambodia and India, Cameroon (78%) and Viet Nam (68%) had very high prevalence of at least one of five measured sentinel MNDs (Figure 1). The prevalence of any sentinel MND in the UK (37%, driven primarily by iron deficiency) was similar to prevalence in Guatemala (38%) and higher than in Mexico (29%) (Figure 1). The prevalence of deficiencies in two or more measured sentinel micronutrients was highly variable from about 41% in Cameroon and 40% in India to just 1% in the UK (Figure 1).

Among NPW from individual country survey data, iron status was available in all 20 datasets, folate and vitamin A in 16, and zinc and vitamin B12 in 15 (Table 3). Iron, zinc, and folate deficiency were highly prevalent among NPW in most countries (Table 3). Iron deficiency among NPW was ≥20% in 10 datasets (>40% in Azerbaijan, Mexico in 2012, and Pakistan), including the US (22%) and UK (21%), 10–19% in six datasets, and <10% in Georgia, Cambodia, Bangladesh, and Ethiopia (Table 3). Zinc deficiency was ≥20% in 13 datasets (>50% in Cameroon, Vietnam, Cambodia, Malawi, and Ecuador), 14% in the US and 10% in the UK, and <10% in no countries (Table 3). Folate deficiency was ≥20% in 11 datasets (>50% in Côte d’Ivoire, Bangladesh, Cambodia, Ghana, India, and Georgia), 10–19% in the UK (19%), Nepal (16%), and Ecuador (10%), and <10% in only Mexico in 2012 (3%) and the US (0%) (Table 3). Vitamin A deficiency was 42% in Pakistan, 10–19% in India (12%) and Afghanistan (10%), and <10% in 13 datasets (Table 3). Vitamin B12 deficiency was 52% in Pakistan, 29% in India, 20% in Azerbaijan, 10–19% in six datasets, and <10% in six datasets (Table 3). Data availability for vitamin D deficiency was sparse (measured in seven of 20 surveys) and highly variable; 78% in Afghanistan, 31% in Pakistan, 24% in India, 22% in the UK, and <10% in Cambodia, the US, and Vietnam. Only four datasets contained all six sentinel micronutrients and they all indicated prevalence of deficiency in at least one out of the six to be >50%: 89% in India, 85% in Cambodia, 78% in Viet Nam, and 55% in the UK (Table 3, Figure 2). An additional seven country surveys measured at least five of the six sentinel micronutrients (Figure 2). Among these, prevalence of deficiency in one or more measured sentinel micronutrients was very high in Pakistan, Bangladesh, and Cameroon (all 93%), Malawi (75%), and Ecuador (68%). The prevalence of deficiency in one or more measured sentinel micronutrients was higher in the UK (55%) than in Guatemala (44%), and similar to the prevalence in Ethiopia (55%). The prevalence of deficiencies in two or more measured sentinel micronutrients was highly variable, from 69% in Pakistan and 57% in India to only 7% in Guatemala.

*Regional and global estimates of deficiency in at least one of three core micronutrients*

Regionally, among PSC the estimated prevalence of deficiency in at least one of three core micronutrients was highest in Sub-Saharan Africa (62%, 95% uncertainty interval [UI] 53 to 72) and lowest in Europe and Central Asia (45%, 27 to 64), high-income (45%, 25 to 68), and Latin America and the Caribbean (48%, 38 to 58) (Table 4, Figure 3). Among NPW the estimated prevalence of deficiency in at least one of three core micronutrients was also highest in Sub-Saharan Africa (80%, 70 to 89) and lowest in high-income countries (48%, 26 to 73) (Table 4, Figure 4). Uncertainty intervals for both PSC and NPW were largest in the Middle East and North Africa due to lack of data sources, followed by high-income, Europe and Central Asia, and East Asia and Pacific, due to only one or two included data sources.

Globally, the estimated prevalence of deficiency in at least one of three core micronutrients was 56% (48 to 64) among PSC, and 69% (59 to 78) among NPW (Table 4, Figures 3–4). This translates into a global total of 372 (319 to 425) million PSC and 1.2 (1.0 to 1.4) billion NPW with MNDs (Table 4). Considering regional populations, three quarters of PSC with MNDs live in South Asia (99 million, 80 to 118), Sub-Saharan Africa (98 million, 83 to 113), or East Asia and the Pacific (85 million, 61 to 110) (Table 3). Over half (57%) of NPW with MNDs live in East Asia and the Pacific (384 million, 279 to 470) or South Asia (307 million, 255 to 351).

**Discussion**

Our analysis suggests that between 2005–2019 there were about 1.6 billion PSC and NPW with one or more MNDs worldwide. This number should not be interpreted as a reduction from the previous 2 billion estimate, which is over three decades old and was based on anemia alone. Rather it can be considered a new starting point for global monitoring of a better-informed estimate of MNDs. When including all age and sex groups, and all essential micronutrients, the actual number of people with MNDs worldwide is likely well over 2 billion.

Robust estimates of the global burden of undernutrition and related health issues are essential for advocacy, policy making, and priority setting by donors and policy makers alike, and in some instances can be used to track progress towards global goals. However, to better meet these objectives, estimates should be accurate, representative, and reliable, which requires an increased investment in monitoring of micronutrient status biomarkers. To track progress over time, estimates must also be updated periodically using comparable methods, or at minimum, a transparent approach that critically reviews implications of any difference in assumptions or methodology.

Our analytical approach to estimating the global prevalence of MNDs among PSC and NPW has important strengths. First, we relied on individual-level data of direct measurement of micronutrient status biomarkers. Previous efforts to estimate the burden of micronutrient malnutrition have used proxy measures (eg, food availability data or stunting prevalence for zinc deficiency) or standardized adjustment factors to estimate the proportion of anemia due to iron deficiency, usually 50%29 or 60%,30 which may not be appropriate.3 Second, we used a transparent and standardized approach to identify micronutrients upon which we based our analysis, taking into account burden and data availability. Third, we systematically identified, accessed, and pooled individual-level data from population-representative surveys, allowing for the application of standardized and recommended cut-offs and adjustments for inflammation as necessary. Fourth, we imputed the prevalence of unmeasured MNDs and made regional and global estimates, accounting for uncertainty in multiple steps of the analysis. Finally, in this paper and the associated appendices we provided detailed documentation of the methods and assumptions for transparency and to enable replication.

The primary limitation of our analysis is the lack of recent population-based micronutrient status biomarker data. Most importantly, this lack of data prevented us from including other population subgroups in our analysis, some of which may also experience a high prevalence of MNDs, including pregnant women, adolescents, the elderly, school-age children, and to a lesser extent, adult men.14 Due to limited data availability, we were unable to make estimates by country or assess change over time. The lack of up-to-date micronutrient status data has been well-recognized and a recent publication has laid out several recommendations to address this problem.14 Additionally, although thresholds for deficiency and adjustments for inflammation were consistently applied to all data sources, these are based on limited data and may not have identified individuals who experienced a functional impairment due to their MNDs. Moreover, some of the included biomarkers such as serum zinc and retinol are not well suited for identifying deficiency in individuals. Further, biomarkers and laboratory methods differed by data source, which may have affected their accuracy and comparability. Thresholds used to define folate deficiency were adjusted for the assay used to improve comparability, however, the adjustments were based on limited data and designed for population-level rather than individual-level analysis. When considered together, it is not clear whether these limitations may have led to an under- or overestimate of the prevalence of one or more of the three core MNDs; our uncertainty intervals do not reflect these limitations. Finally, we limited our analysis to three core micronutrients in each population group based on their prevalence and frequency of measurement in population-based data sources; by definition, these underestimated the full prevalence of MNDs.

Importantly, data on the prevalence and burden of MNDs is lacking or limited to a minimal selection of micronutrients and population groups and is rarely updated routinely in most countries. Yet the pattern of MNDs varies across countries and regions and, therefore, it is essential to characterize each condition accordingly at the population level. We encourage re-assessment of the global burden of MNDs periodically, using and improving upon the standardized methodological approach proposed here, particularly as additional and more comprehensive data become available.

**Author contributions**

TB, GAS, MNNM, and LMN designed the study and prepared the first draft of the paper. GAS led the data analysis, with support from HL. GAS prepared the appendix. GB, JK, LR, SO, SYH, and WF were on the Advisory Panel. All authors provided feedback on the analysis and the manuscript and have read and approved the final version. LMN holds final responsibility for its content.

**Declaration of interests**

All authors, no interests to disclose.

The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Estimates and computer code are available at: <https://github.com/GAINAlliance/hiddenhunger>

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**Figures**



**Figure 1. Prevalence of isolated or ≥2 micronutrient deficiencies among children primarily 6–59 months.** Results shown for datasets containing at least five of the six sentinel micronutrients. Surveys in Mexico and Guatemala did not measure folate, the United Kingdom did not measure zinc, Cameroon did not measure vitamin D, and Viet Nam did not measure vitamin B12. Exact age ranges varied slightly by survey and are specified in appendix Table 6. Sample sizes and deficiency cutoff definitions are also in appendix Table 6.



**Figure 2. Prevalence of isolated or ≥2 micronutrient deficiencies among non-pregnant women primarily 15–49.** Results shown for datasets containing at least five of the six sentinel micronutrients. The Guatemala survey did not measure folate while the survey in Pakistan did measure folate but is not included here. The surveys in Ecuador, Ethiopia, Malawi, Cameroon, and Bangladesh did not measure vitamin D. Age ranges were 20–49 for Ecuador and 15–19 for India. Other age ranges varied slightly by survey and are specified in appendix Table 7. Sample sizes and deficiency cutoff definitions are also in appendix Table 7.



**Figure 3. Estimated prevalence of deficiency in iron, zinc, or vitamin A among children primarily 6–59 months (2005–2019).** Direct survey estimates, survey estimates that were adjusted for one unmeasured micronutrient, and regional and global estimates are shown. Error bars show 95% uncertainty intervals. Exact age ranges vary slightly and are listed in appendix Table 6. Sample sizes are also listed in appendix Table 6.



**Figure 4. Estimated prevalence of deficiency in iron, zinc, or folate among non-pregnant women primarily 15–49 (2006–2019).** Direct survey estimates, survey estimates that were adjusted for one unmeasured micronutrient, and regional and global estimates are shown. Error bars show 95% uncertainty intervals. Age ranges were 20–49 for Ecuador and 15–19 for India. Other age ranges varied slightly by survey and are specified in appendix Table 7. Sample sizes are also listed in appendix Table 7.

**Tables**

**Table 1. Definition of deficiency and adjustment for inflammation for each included biomarker.1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Biomarker** | **Definition of deficiency** | **Population** | **Adjust for inflammation?** |
| Vitamin B12 | Serum B12 | <150 pmol/L | All | No |
| Folate2 | Red blood cell folate | <340 nmol/L | All | No |
| Folate2 | Serum folate | <10 nmol/L | All | No |
| Vitamin A3 | Serum retinol | <0.7 μmol/L | All | Preschool-age children only |
| Vitamin A3 | Retinol-binding  protein | <0.7 μmol/L | All | Preschool-age children only |
| Zinc4 | Serum zinc | <9.9 μmol/L | Children <10 years  (morning, non-fasting) | Yes, provided  conditions are met |
| Zinc4 | Serum zinc | <8.7 μmol/L | Children <10 years  (afternoon, non-fasting) | Yes, provided  conditions are met |
| Zinc4 | Serum zinc | <10.7 μmol/L | Females ≥10 years  (morning, fasting) | No |
| Zinc4 | Serum zinc | <10.1 μmol/L | Females ≥10 years  (morning, non-fasting) | No |
| Zinc4 | Serum zinc | <9.0 μmol/L | Females ≥10 years  (afternoon, non-fasting) | No |
| Iron | Serum ferritin | <12 µg/L | Children <5 years | Yes |
| Iron | Serum ferritin | <15 µg/L | Individuals ≥5 years | Yes |
| Vitamin D | Serum 25-  hydroxyvitamin D | <25 nmol/L | All | No |

1 References for definitions of deficiency and adjustments for inflammation are available in appendix Table 4.

2 When both red blood cell folate and serum folate were measured in a survey, red blood cell folate data were used. Folate thresholds were adjusted for survey assay (see text and appendix Tables 6–7).

3 When both serum retinol and retinol-binding protein are measured in a survey, serum retinol was used, provided that it was available for the full biological measurement sample. If serum retinol was only available for a subsample, retinol-binding protein data were used.

4 For surveys with blood collection throughout the day or if the blood collection protocol was not reported, the average of the morning non-fasting and afternoon non-fasting cutoffs was used (ie, <9.3 μmol/L for children and <9.55 μmol/L for women). Specific thresholds used for each survey are listed in appendix 5.

**Table 2. Prevalence of deficiency by type for each dataset included in the analysis, children primarily 6–59 months.1**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Iron deficiency, % (95% UI)** | **Zinc deficiency, % (95% UI)** | **Vitamin A deficiency, % (95% UI)** | **Any core deficiency, % (95% UI)2** | **Sample size (any core deficiency)3** | **Folate deficiency, % (95% UI)** | **Vitamin B12 deficiency, % (95% UI)** | **Vitamin D deficiency, % (95% UI)** | **Any sentinel deficiency, % (95% UI)4** |
| Afghanistan, 2013 | 24 (20, 29) | 12 (8, 16) | 39 (34, 44) | 54 (49, 59) | 651 | ·· | ·· | 29 (24, 35) | ·· |
| Azerbaijan, 2013 | 22 (19, 26) | 17 (14, 20) | 7 (5, 9) | 40 (36, 44) | 1019 | ·· | ·· | ·· | ·· |
| Bangladesh, 2011 | 11 (7, 17) | 32 (24, 41) | 15 (11, 20) | 52 (41, 63) | 302 | ·· | ·· | ·· | ·· |
| Cambodia, 2014 | 5 (3, 7) | 67 (59, 75) | 7 (4, 9) | 71 (62, 78) | 534 | 30 (25, 35) | 2 (1, 4) | 3 (2, 5) | 81 (74, 86) |
| Cameroon, 2009 | 34 (30, 39) | 57 (52, 61) | 9 (7, 12) | 72 (68, 76) | 776 | 18 (14, 23) | 15 (12, 20) | ·· | ·· |
| Colombia, 2010 | 14 (12, 15) | 39 (37, 41) | 19 (17, 21) | 57 (55, 59) | 4091 | ·· | ·· | ·· | ·· |
| Côte d’Ivoire, 2007 | 39 (35, 43) | ·· | 3 (2, 4) | ·· | 746 | ·· | ·· | ·· | ·· |
| Ecuador, 2012 | 11 (9, 14) | 28 (25, 31) | 16 (13, 19) | 43 (40, 46) | 2017 | 8 (7, 10) | ·· | ·· | ·· |
| Ethiopia, 2015 | 17 (14, 20) | 21 (17, 25) | 11 (9, 14) | 40 (36, 44) | 1116 | ·· | ·· | ·· | ·· |
| Ghana, 2017 | 30 (26, 34) | ·· | 13 (11, 16) | ·· | 1165 | ·· | ·· | ·· | ·· |
| Guatemala, 2013–16 | 11 (9, 13) | 25 (18, 34) | 0 (0, 1) | 31 (22, 40) | 144 | ·· | 20 (15, 27) | ·· | ·· |
| India, 2016–18 | 30 (28, 33) | 19 (17, 21) | 18 (16, 20) | 53 (50, 55) | 6514 | 52 (49, 54) | 14 (12, 16) | 9 (7, 10) | 80 (77, 83) |
| Liberia, 2011 | 51 (47, 55) | ·· | 5 (4, 7) | ·· | 1434 | ·· | ·· | ·· | ·· |
| Malawi, 2015–16 | 22 (17, 28) | 61 (55, 67) | 8 (6, 11) | 74 (69, 78) | 1080 | ·· | ·· | ·· | ·· |
| Mexico, 2006 | 35 (32, 39) | 27 (24, 32) | ·· | ·· | 1253 | ·· | 3 (1, 4) | ·· | ·· |
| Mexico, 2012 | 18 (16, 21) | ·· | 7 (6, 9) | ·· | 2595 | 1 (0, 1) | 0 (0, 1) | ·· | ·· |
| Mexico, 2018–19 | 17 (13, 20) | 13 (10, 17) | 2 (1, 4) | 28 (24, 33) | 965 | ·· | 1 (1, 2) | 8 (6, 11) | ·· |
| Nepal, 2016 | 27 (24, 30) | 22 (19, 25) | 3 (2, 4) | 44 (41, 48) | 1647 | 8 (6, 11) | ·· | ·· | ·· |
| Nicaragua, 2005 | 45 (38, 52) | ·· | 1 (0, 1) | ·· | 953 | ·· | ·· | ·· | ·· |
| Pakistan, 2011 | 51 (49, 53) | 40 (38, 42) | 51 (49, 54) | 86 (85, 87) | 6638 | ·· | ·· | 13 (12, 15) | ·· |
| United Kingdom, 2008–19 | 31 (23, 40) | ·· | 3 (1, 11) | ·· | 140 | 2 (1, 5) | ·· | 12 (7, 20) | ·· |
| Viet Nam, 2010 | 19 (15, 23) | 56 (50, 61) | 6 (4, 9) | 66 (61, 71) | 360 | 7 (4, 13) | ·· | 14 (10, 19) | ·· |

1 Exact age ranges vary slightly and are listed in appendix Table 6. Definitions of deficiency are specified in Table 1. Empty cells indicate missing data or exclusion of the survey micronutrient. UI, uncertainty interval.

2 Core micronutrients are iron, zinc, and vitamin A. Prevalence is only shown for surveys containing all three core micronutrients.

3 Sample size varies by deficiency; sample size for any measured core deficiency is shown in this column.

4 Sentinel micronutrients are iron, zinc, vitamin A, folate, vitamin B12, and vitamin D. Prevalence is only shown for surveys containing all six sentinel micronutrients.

**Table 3. Prevalence of deficiency by type for each dataset included in the analysis, non-pregnant women primarily 15–49.1**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Survey** | **Iron deficiency, % (95% UI)** | **Zinc deficiency, % (95% UI)** | **Folate deficiency, % (95% UI)** | **Any core deficiency, % (95% UI)2** | **Sample size (any core deficiency)3** | **Vitamin A deficiency, % (95% UI)** | **Vitamin B12 deficiency, % (95% UI)** | **Vitamin D deficiency, % (95% UI)** | **Any sentinel deficiency, % (95% UI)4** |
| Afghanistan, 2013 | 33 (28, 39) | 23 (18, 29) | ·· | ·· | 1044 | 10 (8, 13) | ·· | 78 (74, 82) | ·· |
| Azerbaijan, 2013 | 43 (40, 45) | ·· | 35 (31, 39) | ·· | 2551 | 0 (0, 1) | 20 (16, 24) | ·· | ·· |
| Bangladesh, 2011 | 9 (6, 13) | 41 (35, 48) | 84 (79, 87) | 91 (86, 94) | 699 | 6 (4, 9) | 7 (3, 13) | ·· | ·· |
| Cambodia, 2014 | 4 (2, 6) | 63 (57, 69) | 61 (55, 67) | 84 (80, 88) | 689 | 3 (2, 4) | 1 (0, 3) | 4 (3, 7) | 85 (80, 88) |
| Cameroon, 2009 | 18 (13, 24) | 84 (78, 89) | 35 (28, 44) | 92 (88, 94) | 332 | 1 (0, 2) | 14 (10, 20) | ·· | ·· |
| Côte d’Ivoire, 2007 | 22 (19, 26) | ·· | 91 (88, 94) | ·· | 792 | 1 (0, 1) | 18 (12, 26) | ·· | ·· |
| Ecuador, 2012 | 17 (16, 19) | 57 (55, 59) | 10 (9, 11) | 68 (66, 69) | 7230 | 3 (2, 4) | 1 (1, 2) | ·· | ·· |
| Ethiopia, 2015 | 9 (7, 11) | 21 (17, 24) | 32 (28, 36) | 49 (44, 53) | 1607 | 5 (3, 7) | 14 (11, 16) | ·· | ·· |
| Georgia, 2009 | 2 (1, 2) | ·· | 52 (44, 59) | ·· | 407 |  |  | ·· | ·· |
| Ghana, 2017 | 20 (16, 24) | ·· | 59 (53, 65) | ·· | 466 | 2 (1, 3) | 7 (5, 10) | ·· | ·· |
| Guatemala, 2013–16 | 16 (15, 17) | 25 (18, 34) | ·· | ·· | 209 | 0 (0, 0) | 15 (12, 17) | ·· | ·· |
| India, 2016–18 | 37 (34, 41) | 31 (28, 35) | 58 (54, 61) | 81 (77, 84) | 2348 | 12 (9, 15) | 29 (26, 33) | 24 (21, 28) | 89 (86, 92) |
| Malawi, 2015–16 | 15 (12, 19) | 58 (52, 64) | 23 (18, 29) | 72 (67, 77) | 746 | 3 (2, 5) | 13 (9, 17) | ·· | ·· |
| Mexico, 2006 | 35 (32, 39) | 29 (25, 34) | ·· | ·· | 1813 | ·· |  | ·· | ·· |
| Mexico, 2012 | 43 (39, 46) | ·· | 3 (2, 4) | ·· | 3603 | ·· | 2 (1, 2) | ·· | ·· |
| Nepal, 2016 | 19 (16, 21) | 25 (22, 28) | 16 (13, 19) | 49 (46, 52) | 2125 | 1 (1, 2) |  | ·· | ·· |
| Pakistan, 2011 | 42 (41, 44) | 46 (44, 48) | ·· | ·· | 7390 | 42 (40, 44) | 52 (50, 55) | 31 (29, 33) | ·· |
| United Kingdom, 2008–19 | 21 (18, 24) | 10 (8, 12) | 19 (16, 22) | 43 (39, 46) | 1310 | 1 (0, 2) | 7 (5, 9) | 22 (19, 25) | 55 (51, 59) |
| United States, 2015–16 | 22 (17, 27) | 14 (10, 19) | 0 (0, 1) | 32 (26, 39) | 551 | ·· | ·· | 3 (2, 6) | ·· |
| Viet Nam, 2010 | 18 (16, 20) | 67 (63, 71) | 22 (19, 25) | 78 (74, 81) | 1348 | 1 (1, 2) | 12 (9, 15) | 9 (7, 13) | 78 (73, 83) |

1 Age ranges were 20–49 for Ecuador and 15–19 for India. Other age ranges varied slightly by survey and are specified in appendix Table 7. Definitions of deficiency are specified in Table 1. Empty cells indicate missing data or exclusion of the survey micronutrient. UI, uncertainty interval.

2 Core micronutrients are iron, zinc, and folate. Prevalence is only shown for surveys containing all three core micronutrients.

3 Sample size varies by deficiency; sample size for any measured core deficiency is shown in this column.

4 Sentinel micronutrients are iron, zinc, vitamin A, folate, vitamin B12, and vitamin D. Prevalence is only shown for surveys containing all six sentinel micronutrients.

**Table 4. Prevalence of and number of people with deficiencies in one or more of three core micronutrients, world and different regions (2005–2019).1**

|  |  |  |
| --- | --- | --- |
| **Region** | **Prevalence of any deficiency, % (95% UI)** | **Number of people with any deficiency, millions (95% UI)** |
| *Children primarily 6–59 months* | | |
| World | 56 (48, 64) | 372 (319, 425) |
| East Asia & Pacific | 58 (42, 75) | 85 (61, 110) |
| Europe & Central Asia | 45 (27, 64) | 14 (8, 19) |
| High Income | 45 (25, 68) | 30 (16, 45) |
| Latin America & Caribbean | 48 (38, 58) | 24 (19, 29) |
| Middle East & North Africa | 53 (26, 78) | 22 (11, 32) |
| South Asia | 57 (46, 68) | 99 (80, 118) |
| Sub-Saharan Africa | 62 (53, 72) | 98 (83, 113) |
| *Non-pregnant women primarily 15–49 years* | | |
| World | 69 (59, 78) | 1203 (1031, 1358) |
| East Asia & Pacific | 72 (52, 88) | 384 (279, 470) |
| Europe & Central Asia | 68 (46, 86) | 68 (46, 86) |
| High Income | 48 (26, 73) | 126 (68, 190) |
| Latin America & Caribbean | 63 (47, 79) | 96 (71, 119) |
| Middle East & North Africa | 68 (34, 93) | 60 (31, 83) |
| South Asia | 74 (61, 85) | 307 (255, 351) |
| Sub-Saharan Africa | 80 (70, 89) | 1. (139, 178) |

1 Core micronutrients for children are iron, zinc, and vitamin A, and for women are iron, zinc, and folate. Definitions of deficiency are specified in Table 1. UI, uncertainty interval.