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

**Appendix**

CONTENTS

[1. Objective 4](#_Toc94512100)

[Appendix Table 1. Countries/territories in each geographic region or analysis grouping. 4](#_Toc94512101)

[Appendix Table 2. Locations of GATHER reporting items for *Revealing the prevalence of “hidden hunger”: global and regional estimates of micronutrient deficiencies among preschool-age children and non-pregnant women of reproductive age*. 6](#_Toc94512102)

[2. Data identification, access and initial inclusion 7](#_Toc94512103)

[Appendix Table 3**.**  Thresholds for excluding outliers prior to fitting regressions to adjust for inflammation. 10](#_Toc94512104)

[3. Adjustment for inflammation and application of thresholds for deficiency 10](#_Toc94512105)

[Appendix Table 4.Definition of deficiency and adjustment for inflammation for each included biomarker. 11](#_Toc94512106)

[4. Selection of core micronutrients 12](#_Toc94512107)

[Appendix Figure 1. Prevalence of any of three core micronutrient deficiencies and of any measured deficiencies, children 6-59 months. 13](#_Toc94512108)

[Appendix Figure 2. Prevalence of any of three core micronutrient deficiencies and of any measured deficiencies, nonpregnant women 15-49 years. 14](#_Toc94512109)

[5. Final inclusion of data sources 14](#_Toc94512110)

[Appendix Table 5. Types of prevalence computed for each survey and population. 15](#_Toc94512111)

[Appendix Table 6. Included data sources and their characteristics (children 6-59 months) 17](#_Toc94512112)

[Appendix Table 7. Included data sources and their characteristics (non-pregnant women 15-49 years). 18](#_Toc94512113)

[Appendix Figure 3. Geographic distribution of included data sources 21](#_Toc94512114)

[6. Methods for estimating prevalence of unmeasured deficiencies 22](#_Toc94512115)

[Appendix Table 8. Regression variables for each model used to predict unmeasured micronutrient deficiency. 23](#_Toc94512116)

[7. Methods for estimating regional and global prevalence of at least one micronutrient deficiency 24](#_Toc94512117)

[Appendix Figure 4. Prevalence of iron, vitamin A or zinc deficiency vs. SDI, children 6-59 months 26](#_Toc94512118)

[Appendix Figure 5. Prevalence of iron, folate or zinc deficiency vs. SDI, non-pregnant women 15-49 years 27](#_Toc94512119)

[References 28](#_Toc94512120)

# 1. Objective

We aimed to estimate the prevalence of at least one micronutrient deficiency in non-pregnant women of reproductive age (15-49 years) and preschool-aged children (6-59 months) during the period 2005-2019, globally and in seven epidemiologically relevant groups of countries (listed in Appendix Table 1 and referred to as regions in the text). Our analysis focused on non-pregnant women of reproductive age and pre-school aged children because data on micronutrient status are most often available for these population groups. Our analysis included the following six steps:

1. Identification, access and initial inclusion of population-based individual-level biomarker data containing at least two of six sentinel micronutrients;
2. Adjustment of micronutrient biomarker concentrations for inflammation using the BRINDA approach and application of thresholds to identify individuals with micronutrient deficiencies;
3. Identification of three core micronutrients for each population group, that is, micronutrients whose deficiencies often occur alone and which are more commonly measured;
4. Final inclusion of data sources identified in step 1 that measure at least 2 of 3 core micronutrients;
5. Applying a statistical model to estimate the prevalence of deficiency of the unmeasured micronutrient when only two of the core micronutrients were measured; and
6. Applying a statistical model to estimate global and regional prevalence of at least one of the core micronutrients in each population group.

These estimates have been documented following the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) (1). The locations where GATHER reporting items are reported are given in Appendix Table 2.

### Appendix Table 1. Countries/territories in each geographic region or analysis grouping.[[1]](#footnote-2)

| **Region or analysis grouping** | **Countries/territories** |
| --- | --- |
| East Asia & Pacific | Cambodia, China, Democratic People's Republic of Korea, Fiji, Indonesia, Kiribati, Lao People's Democratic Republic, Malaysia, Micronesia (Federated States of), Mongolia, Myanmar, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Timor-Leste, Tonga, Vanuatu, Viet Nam |
| Europe & Central Asia | Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Georgia, Kazakhstan, Kyrgyzstan, Montenegro, Republic of Moldova, Republic of North Macedonia, Romania, Russian Federation, Serbia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan |
| High Income | Australia, Austria, Bahamas, Bahrain, Barbados, Belgium, Brunei Darussalam, Canada, Chile, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kuwait, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Oman, Poland, Portugal, Puerto Rico, Qatar, Republic of Korea, Saudi Arabia, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, China, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States of America, Uruguay |
| Latin America & Caribbean | Argentina, Belize, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Venezuela |
| Middle East & North Africa | Algeria, Djibouti, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Lebanon, Libya, Morocco, Occupied Palestinian Territory, Syrian Arab Republic, Tunisia, Yemen |
| South Asia | Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka |
| Sub-Saharan Africa | Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe |

Appendix Table 2. Locations of GATHER reporting items for *Revealing the prevalence of “hidden hunger”: global and regional estimates of micronutrient deficiencies among preschool-age children and non-pregnant women of reproductive age*.

| Item # | Checklist item | Location reported |
| --- | --- | --- |
| Objectives and funding | | |
| 1 | Define the indicator(s), populations (including age, sex, and geographic entities), and time period(s) for which estimates were made. | Appendix section 1 |
| 2 | List the funding sources for the work. | Abstract |
| Data Inputs | | |
| *For all data inputs from multiple sources that are synthesized as part of the study:* | | |
| 3 | Describe how the data were identified and how the data were accessed. | Appendix section 2 |
| 4 | Specify the inclusion and exclusion criteria. Identify all ad-hoc exclusions. | Appendix sections 2 and 5 |
| 5 | Provide information on all included data sources and their main characteristics. For each data source used, report reference information or contact name/institution, population represented, data collection method, year(s) of data collection, sex and age range, diagnostic criteria or measurement method, and sample size, as relevant. | Appendix section 5, https://github.com/GAINAlliance/hiddenhunger |
| 6 | Identify and describe any categories of input data that have potentially important biases (e.g., based on characteristics listed in item 5). | Appendix section 3 |
| *For data inputs that contribute to the analysis but were not synthesized as part of the study:* | | |
| 7 | Describe and give sources for any other data inputs. | Appendix sections 6-7 |
| *For all data inputs:* | | |
| 8 | Provide all data inputs in a file format from which data can be efficiently extracted (e.g., a spreadsheet rather than a PDF), including all relevant meta-data listed in item 5. For any data inputs that cannot be shared because of ethical or legal reasons, such as third-party ownership, provide a contact name or the name of the institution that retains the right to the data. | https://github.com/GAINAlliance/hiddenhunger |
| Data analysis | | |
| 9 | Provide a conceptual overview of the data analysis method. A diagram may be helpful. | Appendix section 1 |
| 10 | Provide a detailed description of all steps of the analysis, including mathematical formulae. This description should cover, as relevant, data cleaning, data pre-processing, data adjustments and weighting of data sources, and mathematical or statistical model(s). | Appendix sections 3, 6, 7 |
| 11 | Describe how candidate models were evaluated and how the final model(s) were selected. | Appendix sections 6-7 |
| 12 | Provide the results of an evaluation of model performance, if done, as well as the results of any relevant sensitivity analysis. | Appendix sections 6-7 |
| 13 | Describe methods for calculating uncertainty of the estimates. State which sources of uncertainty were, and were not, accounted for in the uncertainty analysis. | Appendix sections 6-7 |
| 14 | State how analytic or statistical source code used to generate estimates can be accessed. | https://github.com/GAINAlliance/hiddenhunger |
| Results and Discussion | | |
| 15 | Provide published estimates in a file format from which data can be efficiently extracted. | https://github.com/GAINAlliance/hiddenhunger |
| 16 | Report a quantitative measure of the uncertainty of the estimates (e.g. uncertainty intervals). | Table 4 |
| 17 | Interpret results in light of existing evidence. If updating a previous set of estimates, describe the reasons for changes in estimates. | Paragraph 1 of discussion |
| 18 | Discuss limitations of the estimates. Include a discussion of any modelling assumptions or data limitations that affect interpretation of the estimates. | Paragraph 4 of discussion |

# 2. Data identification, access and initial inclusion

Following advice from the Advisory Panel to USAID Advancing Nutrition, an initial set of six sentinel micronutrients were selected for which (1) biomarkers are commonly collected at the population level along with other micronutrient biomarkers within the same individuals, (2) the consequences of deficiency can be severe and long-term, and (3) prevalence of deficiency is high in many countries. The micronutrients selected as sentinel micronutrients were iron, vitamin A, zinc, vitamin B12, folate, and vitamin D. Iodine was excluded because it is not typically measured along with other micronutrient status biomarkers within the same individuals. Population-level biomarker data are collected in population-based household surveys, in which blood samples are collected from a randomly selected sample of a population (hereafter called nutrition surveys). These nutrition surveys were the primary data source for this analysis.

The aim of this analysis is to determine the prevalence of at least one micronutrient deficiency, which requires information on the overlap among multiple micronutrient deficiencies at the individual level. Such data are not typically reported together with the results of nutrition surveys, which are generally limited to reporting the prevalence of each micronutrient deficiency separately. Therefore, our data search and access strategy was designed to obtain access to individual-level nutrition survey databases, while ensuring that the sources were representative of the population at the national level or at least three first-level administrative divisions within the country. Our primary source of data was datasets already compiled by the BRINDA collaboration[[2]](#footnote-3), which were all assessed for inclusion. A supplemental search was conducted to identify additional datasets, particularly recent nationally representative datasets from countries with large populations. We searched “micronutrient deficiencies” and “country name” for the 50 most populous countries in Google and Google Scholar and reviewed the first 10 results from each search, sorted by relevance. We reviewed the Micronutrients Database of the WHO Vitamin and Mineral Nutrition Information System and reached out to our network of collaborators and the expert advisory group supporting this analysis for additional data sets. We requested access to all additional qualifying datasets identified from this supplemental search process.

We initially included data sources if:

* Plasma or serum (hereafter referred to as serum) concentrations of biomarkers of at least two of six sentinel micronutrients—serum ferritin, serum retinol or retinol-binding protein (RBP), serum zinc, serum folate or red blood cell (RBC) folate, serum vitamin B12, and serum 25(OH)D—were measured in children aged 6-59 months or non-pregnant women aged 15-49 years;
* C-reactive protein (CRP) or α-1-acid-glycoprotein (AGP) was measured in the same population;
* a probabilistic sampling method with a defined sampling frame was used and data were representative of at least three first administrative units within a country;
* data were collected in or after 2005; and
* we were able to obtain anonymized individual-level data for reanalysis.

From the individual-level data, we included data on children aged 6 to 59 months and non-pregnant women aged 15 to 49 years. Measurement of biomarkers of micronutrient status in children younger than 6 months of age is not common in surveys because it requires a blood sample. For this reason, most data sources excluded infants younger than 6 months by design. Some surveys that were designed to capture children under 5 years of age included some children who were 60 months of age; we included the measurements on 60-month-old children. Some data sources did not cover the full target age range. We included these data as long as any children 6-59 months or non-pregnant women aged 15-49 years were included in the study/survey sample. Age ranges for each included data source are reported in Section 5. We included data collected in or after 2005, in order to maximize inclusion of recent surveys in low-and-middle income countries, without including older data from high-income countries.

All biomarker data were converted to SI units. To identify possible error codes or other data quality issues, discrete histograms of biomarker or inflammation marker values and were visually inspected. Based on these inspections, we excluded the following data:

* serum folate data, Pakistan 2011 non-pregnant women: 40% of observations were at the lower (1.42) or upper (45.3) bounds of the distribution.
* serum B12 data, Ethiopia 2015 pre-school aged children: the serum B12 distribution was bimodal (which is atypical) and the data were not included in the survey’s final report.

In other survey-biomarker pairs, up to 10% of observations were assigned a plausible low or high value, which were presumed to be values that were below or above the analytical limit of detection. These data were included, as is appropriate when computing prevalence estimates.

Exclusion of biologically implausible values is recommended when analysing nutrition survey data, however, standard plausible ranges are not currently well defined (2). Implausible values have the potential to bias regression coefficients. In contrast, infrequent implausible values will have a limited effect on prevalence values. Visual inspection of discrete histograms (described above) revealed few apparent implausible values in the included datasets. Because apparent outliers were infrequent, the main motivation for removing implausible values is to avoid biasing regression coefficients. Therefore, outliers were identified considering the distribution of logged values of biomarkers included in adjustment regressions (described in Section 3). Outliers were identified based on all individual-level data included from the BRINDA collaboration, which represents a wide range of populations and nutritional statuses. A conservative threshold was chosen: any value greater than six median absolute deviations (MADs) above the median log value or less than six MADs below the median log value was removed. Outlier thresholds are shown in Appendix Table 3.

### Appendix Table 3**.** Thresholds for excluding outliers prior to fitting regressions to adjust for inflammation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Pre-school aged children (6-59 months)** | | **Non-pregnant women of reproductive age (15-49 years)** | |
| **Biomarker** | **Lower exclusion threshold** | **Upper exclusion threshold** | **Lower exclusion threshold** | **Upper exclusion threshold** |
| Serum ferritin (µg/l) | 0.11 | 6412 | 0.094 | 12978 |
| Serum zinc (μmol/L) | 1.6 | 62 | not adjusted for inflammation | |
| Retinol binding protein (μmol/L) | 0.15 | 5.7 |
| Serum retinol (μmol/L) | 0.082 | 8.4 |
| AGP (g/L) | 0.098 | 8.0 | 0.12 | 5.2 |
| CRP (mg/L) | 0 | 48291 | 0 | 4064 |

# 3. Adjustment for inflammation and application of thresholds for deficiency

Concentrations of some micronutrient biomarkers are affected by inflammation, including inflammation caused by acute infection (3). These may lead to under- or over-estimates of the prevalence of micronutrient deficiency. Several analytic approaches have been proposed to adjust for inflammation prior to computing prevalence of deficiency (3). We applied the BRINDA regression adjustments for inflammation, which are described elsewhere (3–5). Briefly, separate regressions relating each log micronutrient biomarker concentration to one or two markers of inflammation are fit. The basic ordinary-least-squares regression takes the following form:

Where MB is the serum micronutrient biomarker concentration, CRP is C-reactive protein, and AGP is α-1-acid-glycoprotein. The regression is modified if CRP or AGP is not measured in the survey dataset. Individual serum micronutrient biomarker concentrations are then counterfactually adjusted to a reference level of AGP and/or CRP, as specified by the BRINDA regression approach (3–5). For some included surveys, the BRINDA reference level of CRP—0.10 mg/L in pre-school aged children and 0.16 mg/L in non-pregnant women—are below the survey’s level of detection for CRP. In those cases, BRINDA regressions are modified to counterfactually adjust serum micronutrient biomarker concentration to the specific survey’s lower level of detection, to avoid adjusting serum micronutrient biomarker values in individuals without inflammation. Included surveys with CRP limits of detection above the BRINDA thresholds are as follows:

* Ecuador 2012, 1.9 mg/L
* Bangladesh 2012, 0.3 mg/L
* United Kingdom 2008-19 and Georgia 2008: 1.0 mg/L
* India 2016-18, level of detection varied with a maximum of 3.3 mg/L

The specific micronutrient-population groups on which this adjustment was carried out are summarized in Appendix Table 4.

Definitions of deficiency are summarized in Appendix Table 4. Included surveys used a variety of folate assays, which may affect folate measurements. Rogers and colleagues have recommended that assay-adjusted folate cutoffs should be used (6). We have applied assay factors to adjust the WHO folate thresholds listed in Appendix Table 4. These survey-specific factors were obtained from Rogers and colleagues (6) if available, or if not, were provided by the US CDC (personal communications, Christine Pfeiffer, 11 November 2021 and 16 November 2021). The WHO thresholds were derived from measurements obtained by radioimmunoassay and in that context indicate metabolic folate insufficiency where homocysteine concentrations start to rise. When these thresholds are applied to measurements obtained by or adjusted to the microbiologic assay, as in our study, they are closer to the thresholds indicating risk of megaloblastic anaemia (<7 nmol/L for serum folate and <305 nmol/L for RBC folate (7)). Zinc thresholds were selected based on survey protocols, including time of day of blood collection and fasting/non-fasting blood collection (see Appendix Table 4). Survey-specific thresholds for zinc and folate are shown in Appendix Tables 6 and 7.

### Appendix Table 4.Definition of deficiency and adjustment for inflammation for each included biomarker.

| Micronutrient | Biomarker | Definition of deficiency | Population | Adjust for inflammation? |
| --- | --- | --- | --- | --- |
| B12 | Serum B12 | < 150 pmol/L (8) | All | No (9) |
| Folate1 | RBC folate | < 340 nmol/L (8) | All | No (9) |
| Folate1 | Serum folate | < 10 nmol/L (8) | All | No (9) |
| Vitamin A2 | Serum retinol | < 0.7 μmol/L (10) | All | Pre-school children only (4) |
| Vitamin A2 | Retinol-binding  protein | < 0.7 μmol/L (11,12) | All | Pre-school children only (4) |
| Zinc3 | Serum zinc | < 9.9 μmol/L (13) | Children < 10 years  (morning, non-fasting) | Yes, provided  conditions are met (5) |
| Zinc3 | Serum zinc | < 8.7 μmol/L ) (13) | Children < 10 years  (afternoon, non-fasting) | Yes, provided  conditions are met (5) |
| Zinc3 | Serum zinc | < 10.7 μmol/L (13) | Females ≥ 10 years  (morning, fasting) | No (5) |
| Zinc3 | Serum zinc | < 10.1 μmol/L (13) | Females ≥ 10 years  (morning, non-fasting) | No (5) |
| Zinc3 | Serum zinc | < 9.0 μmol/L (13) | Females ≥ 10 years  (afternoon, non-fasting) | No (5) |
| Iron | Serum ferritin | < 12 µg/l (14) | Children < 5 years | Yes (3) |
| Iron | Serum ferritin | < 15 µg/l (14) | Individuals ≥ 5 years | Yes (3) |
| Vitamin D | Serum 25-  hydroxyvitamin D | < 25 nmol/L (15) | All | No |

1. When both RBC folate and serum folate are measured in a survey, RBC folate data were used. Folate thresholds were adjusted for survey assay (see text and Appendix Tables 6 and 7).
2. When both serum retinol and RBP 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, RBP data were used.
3. 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 (i.e., < 9.3 μmol/L for children and < 9.55 μmol/L for women). Specific thresholds used for each survey are listed in Section 5.

# 4. Selection of core micronutrients

Few datasets measuring all six sentinel micronutrients in the same individuals were identified (4 in non-pregnant women, 2 in pre-school aged children). Estimation of the prevalence of any of the six deficiencies would require extrapolation from these studies to all populations worldwide. Therefore, we sought to simplify the analysis by reducing the number of micronutrients included in the final analysis. Our aim was to identify a maximum of three core micronutrients that could be used to identify the majority of individuals with any micronutrient deficiency. Limiting the analysis to three micronutrient deficiencies reduced the number of assumptions and modelling steps that were required. Two factors were considered: (1) micronutrient deficiencies that have a higher prevalence and/or often occur alone, and are therefore needed to capture a large proportion of individuals with any deficiency, and (2) micronutrients that are more frequently measured in the datasets initially included. Figures 1 and 2 (main paper) show the prevalence of any deficiency, by deficiency type, in surveys that measured at least 5 of the sentinel micronutrients. In these surveys, which were carried out in a variety of settings, iron deficiency and zinc deficiency frequently occurred alone for both pre-school children and non-pregnant women. These micronutrients also had the highest median prevalence of deficiency in the initially included datasets. For non-pregnant women, folate deficiency also had a higher median prevalence of deficiency than the other sentinel micronutrients, and frequently occurred alone (main paper Figure 2). For non-pregnant women, we selected zinc, iron and folate as core micronutrients. For children, the range of prevalence of vitamin D deficiency (IQR 2.9%-13.9%), vitamin A deficiency (IQR 4.3%-15.4%), and folate deficiency (IQR 4.2%-17.9%) were similar in the initially included datasets, while vitamin B12 deficiency had a lower prevalence range. Vitamin A deficiency was measured in all but two datasets (US continuous NHANES and Mexico 2006), while vitamin D deficiency was measured in just 8 of 23 initially included datasets and folate deficiency was measured in just 10 of 23 initially included surveys. Therefore, for children, we selected zinc, iron and vitamin A as core micronutrients.

Appendix Figures 1 and 2 compare the prevalence of deficiency of any of the three core micronutrients to the prevalence of deficiencies of any of 5 or 6 sentinel micronutrients in the datasets that measured at least 5 sentinel micronutrients. For most surveys, the prevalence of any of the three core micronutrients is similar to that of any of the measured micronutrients.

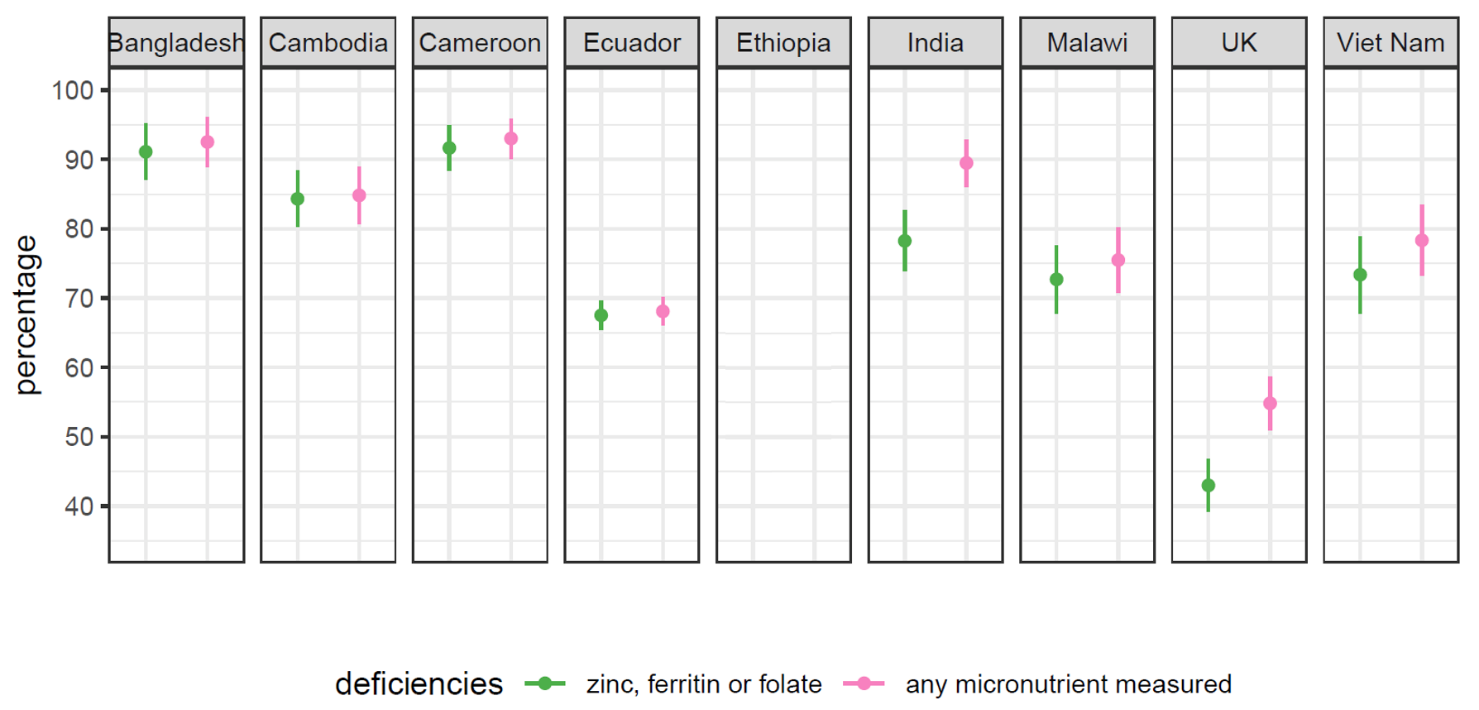
Appendix Figure 1. Prevalence of any of three core micronutrient deficiencies and of any measured deficiencies, children 6-59 months. Surveys that measure at least 5 of 6 sentinel micronutrients are shown.

Calendar

Description automatically generated with low confidence

Note: Surveys in Mexico and Guatemala did not measure folate, the survey in Cameroon did not measure vitamin D, and Viet Nam did not measure vitamin B12. Surveys in India and Cambodia measured all six sentinel micronutrients. Age ranges varied by survey and are specified in Appendix Table 6.

Appendix Figure 2. Prevalence of any of three core micronutrient deficiencies and of any measured deficiencies, nonpregnant women 15-49 years. Surveys that measure at least 5 of 6 sentinel micronutrients are shown.



Notes: The following surveys did not measure vitamin D status: Bangladesh, Cameroon, Ecuador, Ethiopia, and Malawi; Ecuador data include ages 20-49 because vitamin A status was not available for women 15-19 years, India age range is 15-19 years.

# 5. Final inclusion of data sources

Not all datasets identified in section 3 measured all three core micronutrients. We included datasets that measured at least two of three core micronutrients, with the third imputed if needed as described in section 6. This resulted in exclusion of two datasets for nonpregnant women (Colombia ENSIN 2010 and Liberia National Micronutrient Survey 2011) and one dataset for pre-school aged children (US continuous NHANES). For continuous survey programs, we excluded cycles in which two of three micronutrients were measured, provided that cycles measuring all three core micronutrients were available. This resulted in exclusion of most cycles of the US NHANES (women) and Guatemala SIVESNU (both populations). This resulted in a total of 22 datasets covering pre-school aged children and 20 datasets covering nonpregnant women of reproductive age. These datasets, together with key characteristics, are listed in Appendix Tables 6 and 7.

For each included dataset, the quantities listed in Appendix Table 5 were computed, as permitted by the biomarkers measured by the survey. If appropriate for the survey’s design, prevalence of deficiency was computed using sample weights that reflect differential probability of selection into the sample. To reflect the true availability of information, we estimated effective sample sizes based on the “*estat effects*” command of the Stata version 16.1 svy suite of commands (StataCorp, 2019).

### Appendix Table 5. Types of prevalence computed for each survey and population.

| Metric | Numerator | Denominator |
| --- | --- | --- |
| *Preschool aged children aged 6-59 months* | | |
| Prevalence of any core micronutrient deficiency | Any child who is iron deficient, vitamin A deficient, or zinc deficient | All children with valid measurements of serum ferritin, vitamin A status, and serum zinc |
| Prevalence of either iron or vitamin A deficiency | Any child who is iron deficient or vitamin A deficient | All children with valid measurements of serum ferritin and vitamin A status |
| Prevalence of either iron or zinc deficiency | Any child who is iron deficient or zinc deficient | All children with valid measurements of serum ferritin and serum zinc |
| p(zinc deficiency|no vitamin A deficiency, no iron deficiency) | Any child who is zinc deficient | All children who are not iron or vitamin A deficient, and who have valid measurements of serum ferritin, vitamin A status, and serum zinc |
| p(vitamin A deficiency|no zinc deficiency, no iron deficiency) | Any child who is vitamin A deficient | All children who are not zinc or iron deficient, and who have valid measurements of serum ferritin, vitamin A status, and serum zinc |
| *Non-pregnant women aged 15-49* | | |
| Prevalence of any core micronutrient deficiency | Any woman who is iron deficient, folate deficient, or zinc deficient | All women with valid measurements for serum ferritin, folate status, and serum zinc |
| Prevalence of either iron or folate deficiency | Any woman who is iron deficient or folate deficient | All women with valid measurements of serum ferritin and folate status |
| Prevalence of either iron or zinc deficiency | Any woman who is iron deficient or zinc deficient | All women with valid measurements of serum ferritin and serum zinc |
| p(zinc deficiency|no folate deficiency, no iron deficiency) | Any woman who is zinc deficient | All women who are not iron or folate deficient, and who have valid measurements of serum ferritin, folate status, and serum zinc |
| p(folate deficiency|no zinc deficiency, no iron deficiency) | Any woman who is folate deficient | All women who are not zinc or iron deficient, and who have valid measurements for serum ferritin, folate status, and serum zinc |

Note: Biomarkers were adjusted for inflammation if indicated, as described in Appendix section 3. Surveys which did not measure AGP or CRP were excluded. However, if an individual had a valid micronutrient biomarker value but an invalid or missing marker of inflammation, the individual was included without adjusting biomarker values for inflammation.

Appendix Table 6. Included data sources and their characteristics (children 6-59 months). All data sources are nationally representative household surveys that measured at least one measure of inflammation (either AGP or CRP). Surveys are categorized as having measured iron deficiency if serum ferritin has been measured, as having measured vitamin A if serum retinol or RBP has been measured, and zinc if serum zinc is measured. Sample size noted here refers to the sample size for the core deficiencies measured in the survey.

| **Country** | **Years** | **Age range (months)** | **Sample size** | **Core deficiencies measured** | **Zinc deficiency cutoff (μmol/l)** | **Serum folate cutoff (nmol/l)** | **RBC folate cutoff (nmol/l)** | **Data source** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Afghanistan | 2013 | 6-60 | 651 | iron, vitamin A, zinc | 9.3 |  |  | National Nutrition Survey |
| Azerbaijan | 2013 | 6-59 | 1019 | iron, vitamin A, zinc | 9.3 |  |  | Azerbaijan Nutrition Survey |
| Bangladesh | 2011 | 6-59 | 302 | iron, vitamin A, zinc | 9.3 |  |  | National Micronutrients Status Survey 2011-12 |
| Cambodia | 2014 | 6-60 | 534 | iron, vitamin A, zinc | 9.9 | 15.9 |  | Cambodia Demographic and Health Survey 2014 |
| Cameroon | 2009 | 12-60 | 776 | iron, vitamin A, zinc | 9.3 | 13.4 |  | Engle-Stone, R., Ndjebayi, A. O., Nankap, M., & Brown, K. H. (2012). Consumption of potentially fortifiable foods by women and young children varies by ecological zone and socio-economic status in Cameroon. The Journal of Nutrition, 142(3), 555-565. |
| Colombia | 2010 | 12-59 | 4091 | iron, vitamin A, zinc | 9.3 |  |  | Encuesta Nacional de la Situación Nutricional (ENSIN) |
| Côte d’Ivoire | 2007 | 6-59 | 746 | iron, vitamin A |  |  |  | Rohner, F., Tschannen, A. B., Northrop-Clewes, C., Kouassi-Gohou, V., Bosso, P. E., & Mascie-Taylor, C. N. (2012). Comparison of a possession score and a poverty index in predicting anaemia and undernutrition in pre-school children and women of reproductive age in rural and urban Cote d'Ivoire. Public Health Nutrition, 15(9), 1620-1629. |
| Ecuador | 2012 | 6-59 | 2017 | iron, vitamin A, zinc | 9.9 | 10.3 | 551 | Encuesta Nacional de Salud y Nutrición (ENSANUT-2012) |
| Ethiopia | 2015 | 6-59 | 1116 | iron, vitamin A, zinc | 9.3 |  |  | Ethiopian National Micronutrient Survey |
| Ghana | 2017 | 6-59 | 1165 | iron, vitamin A |  |  |  | Ghana Micronutrient Survey |
| Guatemala | 2013-2016 | 6-60 | 144 | iron, vitamin A, zinc | 9.3 |  |  | Sistema de Vigilancia Epidemiológica de Salud y Nutrición (SIVESNU) |
| India | 2016-2018 | 12-59 | 6514 | iron, vitamin A, zinc | 9.9 |  | 639 | Comprehensive National Nutrition Survey (CNNS) |
| Liberia | 2011 | 6-36 | 1434 | iron, vitamin A |  |  |  | Liberia National Micronutrient Survey 2011 |
| Malawi | 2015-2016 | 6-59 | 1080 | iron, vitamin A, zinc | 9.3 |  |  | Malawi Demographic and Health Survey 2015-2016 |
| Mexico | 2006 | 13-60 | 1253 | iron, zinc | 9.9 | \* |  | Encuesta Nacional de Salud y Nutrición (ENSANUT) |
| Mexico | 2018-2019 | 12-48 | 965 | iron, vitamin A, zinc | 9.9 |  |  | Encuesta Nacional de Salud y Nutrición (ENSANUT) |
| Mexico | 2012 | 12-60 | 2595 | iron, vitamin A |  | 11.4 |  | Encuesta Nacional de Salud y Nutrición (ENSANUT) |
| Nepal | 2016 | 6-59 | 1647 | iron, vitamin A, zinc | 9.3 |  | 340 | Nepal National Micronutrient Status Survey (NNMSS) |
| Nicaragua | 2005 | 6-60 | 953 | iron, vitamin A |  |  |  | Sistema Integrado de Vigilancia de Intervenciones Nutricionales (SIVIN) |
| Pakistan | 2011 | 6-59 | 6638 | iron, vitamin A, zinc | 9.3 |  |  | Pakistan National Nutrition Survey |
| United Kingdom | 2008-2019 | 12-48 | 140 | iron, vitamin A |  | 10 | 340 | National Diet and Nutrition Survey (NDNS) |
| Viet Nam | 2010 | 11-60 | 360 | iron, vitamin A, zinc | 9.9 | 12 |  | Laillou, A., Van Pham, T., Tran, N. T., Le, H. T., Wieringa, F., Rohner, F., et al. (2012). Micronutrient deficits are still public health issues among women and young children in Vietnam. PloS One, 7(4). |

\* An assay correction factor was not obtained for this survey.

Appendix Table 7. Included data sources and their characteristics (non-pregnant women 15-49 years). All data sources are nationally representative household surveys. Surveys are categorized as having measured iron deficiency if serum ferritin and one measure of inflammation (either AGP or CRP) have been measured, as having measured folate if serum folate or RBC folate have been measured, and zinc if serum zinc has been measured. Sample size noted here refers to the sample size for the core deficiencies measured in the survey.

| **Country** | **Years** | **Age range (years)** | **Sample size** | **Core deficiencies measured** | **Zinc deficiency cutoff (μmol/l)** | **Serum folate cutoff (nmol/l)1** | **RBC folate cutoff (nmol/l)** | **Data source** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Afghanistan | 2013 | 15-49 | 1044 | iron, zinc2 | 9.55 |  |  | National Nutrition Survey |
| Azerbaijan | 2013 | 15-49 | 2551 | iron, folate |  | 10 |  | Azerbaijan Nutrition Survey |
| Bangladesh | 2011 | 15-49 | 699 | iron, folate, zinc | 9.55 | 16.3 |  | National Micronutrients Status Survey 2011-12 |
| Cambodia | 2014 | 16-49 | 689 | iron, folate, zinc | 10.1 | 15.9 |  | Cambodia Demographic and Health Survey 2014 |
| Cameroon | 2009 | 15-47 | 332 | iron, folate, zinc | 9.55 | 13.4 |  | Engle-Stone, R., Ndjebayi, A. O., Nankap, M., & Brown, K. H. (2012). Consumption of potentially fortifiable foods by women and young children varies by ecological zone and socio-economic status in Cameroon. The Journal of nutrition, 142(3), 555-565. |
| Côte d’Ivoire | 2007 | 15-48 | 792 | iron, folate |  | 12 |  | Rohner, F., Tschannen, A. B., Northrop-Clewes, C., Kouassi-Gohou, V., Bosso, P. E., & Mascie-Taylor, C. N. (2012). Comparison of a possession score and a poverty index in predicting anaemia and undernutrition in pre-school children and women of reproductive age in rural and urban Cote d'Ivoire. Public Health Nutrition, 15(9), 1620-1629. |
| Ecuador | 2012 | 15-49 | 7230 | iron, folate, zinc | 10.7 | 10.3 | 551 | Encuesta Nacional de Salud y Nutrición (ENSANUT-2012) |
| Ethiopia | 2015 | 15-49 | 1607 | iron, folate, zinc | 9.55 | 13 | 442 | Ethiopian National Micronutrient Survey |
| Georgia | 2009 | 15-49 | 407 | iron, folate |  | 12 |  | Georgia National Nutrition Survey |
| Ghana | 2017 | 15-49 | 466 | iron, folate |  | 12 |  | Ghana Micronutrient Survey |
| Guatemala | 2013-2016 | 15-49 | 209 | iron, zinc | 9.55 |  |  | Sistema de Vigilancia Epidemiológica de Salud y Nutrición (SIVESNU) |
| India | 2016-2018 | 15-19 | 2348 | iron, folate, zinc | 10.7 |  | 639 | Comprehensive National Nutrition Survey (CNNS) |
| Malawi | 2015-2016 | 15-49 | 746 | iron, folate, zinc | 9.55 | 10 | 340 | Malawi Demographic and Health Survey 2015-2016 |
| Mexico | 2012 | 15-49 | 3603 | iron, folate |  | 11.4 |  | Encuesta Nacional de Salud y Nutrición (ENSANUT) |
| Mexico | 2006 | 15-49 | 1813 | iron, zinc | 10.7 |  |  | Encuesta Nacional de Salud y Nutrición (ENSANUT) |
| Nepal | 2016 | 15-49 | 2125 | iron, folate, zinc | 9.55 |  | 340 | Nepal National Micronutrient Status Survey (NNMSS) |
| Pakistan | 2011 | 15-49 | 7390 | iron, zinc | 9.55 |  |  | Pakistan National Nutrition Survey |
| United Kingdom | 2008-2019 | 15-49 | 1310 | iron, folate, zinc | 10.7 | 10 | 340 | National Diet and Nutrition Survey (NDNS) |
| United States of America | 2015-2016 | 15-49 | 551 | iron, folate, zinc | 9.55 | 10 | 340 | National Health and Nutrition Examination Survey (NHANES) |
| Viet Nam | 2010 | 15-49 | 1348 | iron, folate, zinc | 10.1 | 12 |  | Laillou, A., Van Pham, T., Tran, N. T., Le, H. T., Wieringa, F., Rohner, F., et al. (2012). Micronutrient deficits are still public health issues among women and young children in Vietnam. PloS one, 7(4). |

Notes:

1. Assay correction factors were obtained from reference (6), Tables 2-5, if the survey was included. For remaining surveys, correction factors were provided by the US CDC.
2. Folate deficiency was measured, however, folate was measured in a subsample that did not overlap with zinc and ferritin measurements.

Appendix Figure 3. Geographic distribution of included data sources. Two data sources on non-pregnant women and three data sources on pre-school aged children were obtained from Mexico; all other countries contributed no more than one data source per demographic group.

Map

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# 6. Methods for estimating prevalence of unmeasured deficiencies

As discussed in Section 5, all data sources that measured at least two of three core micronutrients were included. Serum ferritin and at least one marker of inflammation were measured in all included datasets for both population groups (non-pregnant women and preschool aged children). Other core micronutrients were not measured in some datasets. In order to make use of these datasets, we estimated the prevalence of all three deficiencies in these datasets. We initially aimed to do so by computing a correction factor for each of four country income groups, however, there were less than two data sources measuring all three core micronutrients in some country income-population groups. Therefore, we fit regressions with socio-demographic index (SDI) as a country-and-year-level covariate. SDI is a composite index of educational attainment, fertility levels, and gross national income per capita, which reflects a country’s development level (16). We also tested the inclusion of the prevalence of the two measured core deficiencies as a study-level covariate, but it did not improve Akaike information criterion (AIC) for any regression. Finally, we tested several measures of micronutrient availability in diet as country-level covariates (17), but found that either they did not improve model fit or fitted coefficients were implausible, *i.e.*, higher dietary availability was associated with higher prevalence of deficiency. The regression took the following form:

Where:

p(d3|no d1,no d2) in survey i, where d1, d2 are the measured deficiencies and d3 is the unmeasured deficiency

the effective sample size of πi, taking into account each survey’s design

fixed intercept

country-level covariate (listed in Appendix Table 8 for each model)

coefficient of the country-level covariate

computed as , to account for the surveys’ design effect

Four separate adjustment regression equations were fit using data from surveys that measured all three core micronutrients. Regressions were fit using the glm command, Stata version 16.1. Standard errors were estimated by drawing 500 bootstrap samples with replacement.

### Appendix Table 8. Regression variables for each model used to predict unmeasured micronutrient deficiency.

| Population | Dependent variable (π) | Covariates (X) |
| --- | --- | --- |
| Preschool-aged children (6-59 months) | p(zinc deficiency|no vitamin A deficiency, no iron deficiency) | Socio-demographic index (SDI) |
| Preschool-aged children (6-59 months) | p(vitamin A deficiency|no zinc deficiency, no iron deficiency) | SDI |
| Non-pregnant women 15-49 years | p(zinc deficiency|no folate deficiency, no iron deficiency) | SDI |
| Non-pregnant women 15-49 months | p(folate deficiency|no zinc deficiency, no iron deficiency) | SDI |

The prevalence of any deficiency (d1,2,3) for each survey *i* that measures deficiencies 1 and 2 but not the third is computed as:

where d1,2 refers to the prevalence of deficiency 1 or deficiency 2. Estimating the prevalence of an unmeasured micronutrient deficiency results in a less certain estimate than implied by the survey sample size and survey design. In order to propagate uncertainty to the next step, the following formulae were used to compute an effective sample size (n\*) for each survey that takes into account both the sampling uncertainty and the uncertainty from the regression-based adjustment:

# **7. Methods for estimating regional and global prevalence of at least one micronutrient deficiency**

Our aim was to estimate the prevalence of any of three core micronutrient deficiencies globally and in 7 world regions. To do so, we fit the following Bayesian hierarchical logistic regression:

Each survey *i* is nested in region *j*, with:

prevalence of any of three core deficiencies (d1,2,3) in survey *i* with effective sample size

fixed intercept

random intercepts for each region j

country-level covariate

coefficient of the country-level covariate

residual survey error (non-sampling error)

computed as , to account for uncertainty in the surveys’ estimated prevalence

The model’s hierarchical structure allows the estimate for each region to be informed by data from the region and by data from other regions, particularly in regions where data are sparse or inconsistent (all regions in this analysis). For surveys that measured all three core deficiencies, pi and ni were computed directly from the survey data as described in Section 5; in other cases, they were estimated as described in Section 6. One time-varying country-level covariate, the socio-demographic index, a measure of a country’s level of development, allows for borrowing strength from countries of similar development level. Each survey’s effective sample size reflects uncertainty from the survey’s complex survey design and from the use of a model to predict an unmeasured core micronutrient, if applicable. Finally, the residual error term allows country survey data to vary beyond what is expected from their effective sample sizes. This allows for non-sampling survey error as well for country-level deviations from what might be expected based on region and socio-demographic index. All analyses were done separately for children and non-pregnant women.

The basic model structure and candidate time-varying covariate (SDI) were selected *a priori.* Prior to model fitting, SDI was plotted against the prevalence of any deficiency to confirm the relationship was plausible and monotonic (Appendix Figures 4-5), and the fitted coefficient for SDI was checked to confirm that it was plausible (*i.e.*, higher SDI corresponds to lower prevalence of any deficiency). Trace plots were examined and the Gelman-Rubin convergence statistic was computed to confirm adequate mixing. Finally, posterior predictions were compared to input data to confirm model fit.

The following sources of uncertainty are reflected in the final uncertainty intervals: sampling error from each data source, non-sampling error, *e.g*. because of differences in laboratory methods employed, and uncertainty due to estimation of unmeasured deficiency. Uncertainty from adjustment of micronutrient biomarker concentrations for inflammation is not reflected in the uncertainty intervals, nor is uncertainty around thresholds used to define deficiency. Further, due to the limited number of countries with more than one data source, the model does not include separate terms for non-sampling survey error and for each country (as in nearly all cases, each country contributes only one survey so it would not be possible to estimate these). Not including a term for each country implicitly assumes that country covariates fully explain within-region country-to-country variability, which is likely not true. This approach underestimates uncertainty from making predictions from country-representative data.

We fit the Bayesian model using the bayes: melogit command in Stata version 16.1, which employs a Monte Carlos Markov Chain (MCMC) algorithm. Four chains were fit, and we obtained 1000 posterior samples of the model coefficients per chain (for a total of 4000 posterior samples). From these coefficient samples, 4000 samples of the prevalence of any deficiency were computed for each of 184 countries listed in Appendix Table 1. Numbers of persons affected by at least one micronutrient deficiency was computed for each sample by multiplying country-age-sex-group population totals for 2013 from the UN Population Division’s 2019 Revision of the World Population Prospects by the prevalence of at least one deficiency (18). Population data for 2013 were used because it was the median year of survey data included in the analysis. All reported uncertainty intervals represent the 2.5th-97.5th percentiles of these 4000 samples.

Appendix Figure 4. Prevalence of iron, vitamin A or zinc deficiency vs. socio-demographic index (SDI), children 6-59 months. Vertical bars represent 95% confidence interval. Data shown in green measured all three micronutrient deficiencies, and 95% confidence intervals reflect complex survey design. Data shown in blue were estimated as described in section 6 and confidence intervals include uncertainty from the complex survey design and the regression adjustment model.

Chart, box and whisker chart

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Appendix Figure 5. Prevalence of iron, folate or zinc deficiency vs. socio-demographic index (SDI), non-pregnant women 15-49 years. Vertical bars represent 95% confidence interval. Data shown in green measured all three micronutrient deficiencies, and 95% confidence intervals reflect complex survey design. Data shown in blue were estimated as described in section 6 and confidence intervals include uncertainty from the complex survey design and the regression adjustment model.

Chart, box and whisker chart

Description automatically generated

# **References**

1. Stevens GA, Alkema L, Black RE, Boerma JT, Collins GS, Ezzati M, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. PLOS Med [Internet]. 2016 Jun 28 [cited 2021 Mar 24];13(6):e1002056. Available from: https://dx.plos.org/10.1371/journal.pmed.1002056

2. Centers for Disease Control and Prevention, World Health Organization, Nutrition International, UNICEF. Micronutrient survey manual. Geneva; 2020.

3. Namaste SM, Aaron GJ, Varadhan R, Peerson JM, Suchdev PS. Methodologic approach for the Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr [Internet]. 2017 Jul 1 [cited 2021 Aug 17];106(suppl\_1):333S-347S. Available from: https://academic.oup.com/ajcn/article/106/suppl\_1/333S/4668571

4. Larson LM, Namaste SM, Williams AM, Engle-Stone R, Addo OY, Suchdev PS, et al. Adjusting retinol-binding protein concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr [Internet]. 2017 Jul 1 [cited 2021 Aug 17];106(suppl\_1):390S-401S. Available from: https://academic.oup.com/ajcn/article/106/suppl\_1/390S/4668591

5. McDonald CM, Suchdev PS, Krebs NF, Hess SY, Wessells KR, Ismaily S, et al. Adjusting plasma or serum zinc concentrations for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr [Internet]. 2020 Apr 1 [cited 2021 Aug 17];111(4):927–37. Available from: https://academic.oup.com/ajcn/article/111/4/927/5815488

6. Rogers LM, Cordero AM, Pfeiffer CM, Hausman DB, Tsang BL, De-Regil LM, et al. Global folate status in women of reproductive age: a systematic review with emphasis on methodological issues. Ann N Y Acad Sci [Internet]. 2018 [cited 2021 Nov 17];1431(1). Available from: https://pubmed.ncbi.nlm.nih.gov/30239016/

7. Institute of Medicine Food and Nutrition Board. Dietary reference intakes: thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, pantothenic acid, biotin, and choline. Washington, D.C.: National Academy Press; 1998.

8. de Benoist B. Conclusions of a WHO Technical Consultation on folate and vitamin B12 deficiencies. Food Nutr Bull. 2008;29(2 SUPPL.).

9. Young MF, Guo J, Williams A, Whitfield KC, Nasrin S, Kancherla V, et al. Interpretation of vitamin B-12 and folate concentrations in population-based surveys does not require adjustment for inflammation: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project. Am J Clin Nutr [Internet]. 2020 Apr 1 [cited 2021 Aug 17];111(4):919–26. Available from: https://academic.oup.com/ajcn/article/111/4/919/5815478

10. World Health Organization. Serum retinol cencentrations for determining the prevalence of vitamin A deficiency in populations [Internet]. Geneva; 2011. Available from: https://www.who.int/vmnis/indicators/retinol.pdf

11. Semba RD, Yuniar Y, Gamble M V., Natadisastra G, Muhilal. Assessment of Vitamin A Status of Preschool Children in Indonesia Using Plasma Retinol‐binding Protein. J Trop Pediatr [Internet]. 2002 Apr 1 [cited 2022 Jan 31];48(2):84–7. Available from: https://academic.oup.com/tropej/article/48/2/84/1690193

12. Gamble M V., Ramakrishnan R, Palafox NA, Briand K, Berglund L, Blaner WS. Retinol binding protein as a surrogate measure for serum retinol: studies in vitamin A–deficient children from the Republic of the Marshall Islands. Am J Clin Nutr [Internet]. 2001 Mar 1 [cited 2022 Jan 31];73(3):594–601. Available from: https://academic.oup.com/ajcn/article/73/3/594/4737411

13. International Zinc Nutrition Consultative Group. IZiNCG Technical Brief [Internet]. Davis, CA; 2012 [cited 2021 Aug 17]. Available from: www.izincg.org

14. Engle-Stone R, Nankap M, Ndjebayi AO, Erhardt JG, Brown KH. Plasma ferritin and soluble transferrin receptor concentrations and body iron stores identify similar risk factors for iron deficiency but result in different estimates of the national prevalence of iron deficiency and iron-deficiency anemia among women and children in Cameroon. J Nutr [Internet]. 2013 Mar [cited 2022 Jan 30];143(3):369–77. Available from: https://pubmed.ncbi.nlm.nih.gov/23343673/

15. Scientific Advisory Committee on Nutrition. Vitamin D and Health [Internet]. 2016. Available from: https://www.gov.uk/government/groups/scientific-advisory-committee-on-nutrition

16. Global Burden of Disease Collaborative Network. Global Burden of Disease 2019 (GBD 2019) Covariates 1980-2019. Seattle: Institute for Health Metrics and Evaluation; 2020.

17. Beal T, Massiot E, Arsenault JE, Smith MR, Hijmans RJ. Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes. PLoS One [Internet]. 2017 Apr 1 [cited 2021 Nov 2];12(4):e0175554. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0175554

18. United Nations Department of Economic and Social Affairs. World Population Prospects 2019 [Internet]. New York: United Nations; 2019 [cited 2021 Mar 17]. Available from: https://population.un.org/wpp/

19. The World Bank Group. World Bank Analytical Classifications [Internet]. 2021 [cited 2021 Sep 21]. Available from: http://databank.worldbank.org/data/download/site-content/OGHIST.xlsx

1. World Bank Group geographic regions are used, with countries classified by the World Bank as high-income countries in calendar year 2020 (19) grouped separately. [↑](#footnote-ref-2)
2. https://brinda-nutrition.org/about-us/brinda-countries/ [↑](#footnote-ref-3)