FOOD GROUP DIVERSITY AND NUTRIENT ADEQUACY

DIETARY DIVERSITY AS A PROXY FOR MICRONUTRIENT ADEQUACY FOR DIFFERENT AGE AND SEX GROUPS IN MEXICO AND CHINA

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SUMMARY

Poor diet quality is a major cause of morbidity and mortality at all country income levels. Yet to date, low-cost, feasible metrics for population-level assessment and monitoring of diet quality are scarce. High-quality diets are safe, meet nutrient needs for healthy growth and development at all ages, and reduce risks of non-communicable disease. While comprehensive metrics covering multiple dimensions are desirable, there is also a role for simpler indicators reflecting nutrient adequacy. This is particularly so in contexts where diets lack diversity and deliver inadequate micronutrients.

To meet these needs, several simple food group diversity indicators have been developed. These include the Minimum Dietary Diversity (MDD) indicator for infants and young children, and a similar indicator, MDD-W, developed for women of reproductive age. However, there is demand for indicators for other demographic groups. This paper thus tests the relevance and performance of the MDD-W indicator and its underlying 10-point food group diversity score (FGDS) for various demographic groups using data from two large upper-middle-income countries, Mexico and China.

We found that the FGDS was consistently and reasonably strongly associated with a summary measure of micronutrient adequacy in both countries and for all age groups. The MDD-W cut-off of five or more food groups allows expression of the indicator in terms of population prevalence meeting this minimum, rather than as a score. This may have advantages for communication and target setting. However, while this cut-off worked well for most demographic groups in Mexico, it did not in China. We conclude that when more resource-intensive measurement is infeasible, FGDS is a meaningful proxy indicator of micronutrient adequacy for diverse demographic groups and in diverse country income settings. The issue of universal cut-offs remains challenging and unresolved, and additional studies in middle-income countries and with diverse age groups are warranted.

KEY MESSAGES

- Low-cost, feasible, population-level indicators of diet quality are needed for all demographic groups and for a variety of country income levels.
- A simple 10-food group dietary diversity score was consistently associated with micronutrient adequacy for all age and sex groups (two years and older) in two upper middle-income countries (China and Mexico).
- A cut-off of five or more food groups, currently in use for women of reproductive age, gave inconsistent results across the two countries.
- When low-cost dietary measurement is an imperative, a simple 10-food group score can be recommended as a proxy indicator of micronutrient adequacy of the diet, for all groups two years of age and older.

Acronyms

AUC	Area under the receiver operating characteristic curve
BMI	Body mass index
BMR	Basal metabolic rate
CHNS	China Health and Nutrition Survey
ENSANUT	Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey)
FGDS	A food group score with one point for each of ten food groups
MDD-W	Minimum dietary diversity indicator for women of reproductive age
MPA	Mean probability of adequacy across eleven micronutrients
NRV	Nutrient reference value
PA	Probability of adequacy
ROC	Receiver operating characteristic
WRA	Women of reproductive age, defined as 15–49 years

BACKGROUND AND OBJECTIVES

BACKGROUND

Metrics capturing various aspects of diet quality are required for diverse purposes, including population-level assessment and monitoring of trends.[1] Other uses include evaluating the impact of policy and programmatic interventions; targeting of interventions; screening and evaluating diets for individuals; and epidemiological research linking intakes to outcomes. Appropriate metrics vary by intended use.

A wide variety of metrics have been developed reflecting differing aspects of diet quality, which is multi-dimensional. Many metrics aim to capture (or proxy for) nutrient adequacy and/or non-communicable disease (NCD) risk reduction (1-3). There is increasing interest in environmental impacts of diets, but this has rarely been operationalised in diet quality metrics to date (4).

This paper focuses on an indicator developed as a proxy for micronutrient adequacy of the diet, and primarily for use in assessment and monitoring at population level. The indicator, Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) (5), was developed for a particular demographic group and was also designed primarily for contexts where diets are impoverished and often dominated by starchy staple foods. It was not developed to proxy for NCD risk reduction.

Importantly, the indicator was developed to meet measurement needs in contexts where quantitative or semi-quantitative methods would be too costly. It can be measured using a simple non-quantitative recall of food groups consumed the previous day (6). MDD-W is expressed as the proportion of women (15–49 years of age) who have consumed at least five out of ten defined food groups the previous day or night. Interpreted at population level, groups of women who achieve minimum dietary diversity (i.e., meet the threshold of five or more groups) are likely to have higher (more adequate) micronutrient intakes than groups of women who consume fewer food groups. The underlying 10-point score is also associated with micronutrient adequacy. The indicator was developed based on analyses of data from nine sites in six countries (five low-income and one lower-middle-income); subsequently, associations between MDD-W (and/or its underlying score) and nutrient intakes and adequacy have been demonstrated in a number of studies from diverse contexts (7–14).

Since its development, there has been fairly broad uptake of MDD-W (Figure 1), reflecting strong demand for metrics that reflect at least one dimension of diet quality and that can be measured with relatively simple and low-cost methods. Recently, the Demographic and Health Surveys (DHS) programme has included measurement and reporting of MDD-W in

[1] 'Metric' is a general term for a standard for evaluating. Metrics include complex indices, sometimes called composite indicators, and simple indicators aiming to capture one concept or dimension. Diet quality metrics may be complex indices or simpler indicators.

its latest survey round;[2] measurement of MDD-W was also piloted by the Gallup World Poll in several countries as part of a broader diet quality module.[3]

Though developed for women of reproductive age (WRA), MDD-W or its underlying score have sometimes been used to describe diversity for other age/sex groups (9), reflecting strong demand for metrics for other groups, as well as for WRA. Given its origins and use to date, there is limited information on associations with nutrient adequacy in upper-middle-income countries, although one recent multi-country study in Latin America demonstrated positive associations (10).

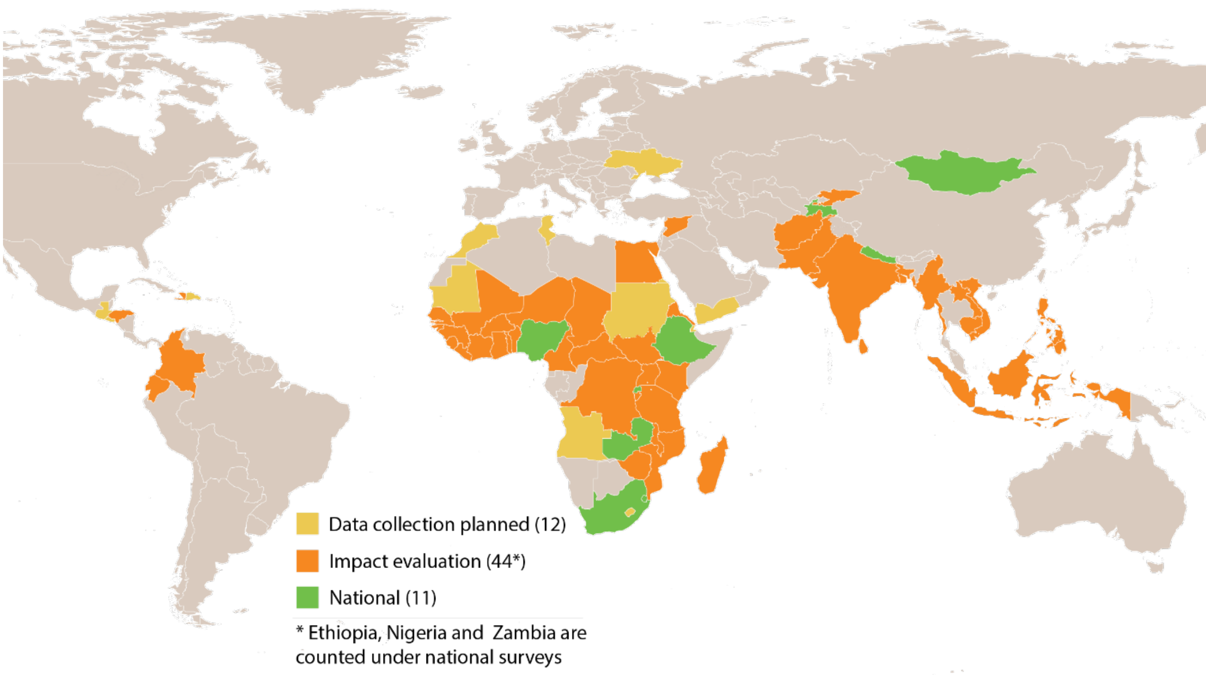

Figure 1: Map of countries that have collected or plan to collect data to estimate the prevalence of Minimum Dietary Diversity for Women of Reproductive Age. Reproduced with permission. FAO map adapted from Map No. 4170 Rev. 17, UNITED NATIONS, February 2019. Office of Information and Communications Technology, Geospatial Information Section. MDD-W data updated as per 2021.

OBJECTIVES

Given the strong demand for population-level metrics reflecting nutrient adequacy for diverse population groups, the objectives of the analysis reported in this paper are to:

1. Assess associations between MDD-W and its underlying score with micronutrient adequacy for individuals 2 years of age and older in two large upper-middle-income countries with nationally or provincially representative data, Mexico and China; and
2. Assess associations within each of these countries for diverse demographic groups.

[2] See: DHS-8 Questionnaires: Revision Process and New Content DHSM11.pdf (dhsprogram.com), accessed 12 April 2021.
[3] See: https://news.gallup.com/opinion/gallup/321968/global-diet-quality-project-aims-bridge-data-gap.aspx, accessed 12 April 2021.

METHODOLOGY

DATA SETS

Data were from two cross-sectional quantitative dietary intake surveys from Mexico and China. The Mexico data are nationally representative and are from the 2012 round of the Mexican National Health and Nutrition Survey (Encuesta Nacional de Salud y Nutrición, ENSANUT-2012). Dietary data were collected using an automated multiple-pass 24-hour recall method developed for the survey. A second recall was collected from 9% of the respondents. Recalls were on non-consecutive, randomly selected days of the week. Further details of the study design and dietary data collection are available (15).[4]

The China data are from the 2011 China Health and Nutrition Survey (CHNS), which covers nine provinces and three autonomous cities (Beijing, Shanghai, and Chongqing) that vary in geography, economic development, public resources, and health indicators. Quantitative 24-hour recall data were collected on three consecutive days and were complemented by weighing foods at the household level. Details of the study design and dietary data collection methods are available (16-18).

EXCLUSIONS

Records were excluded due to implausible intakes for 210 out of 10,822 observation days in Mexico and 175 out of 45,343 observation days in China. In addition, records were excluded if infant formula or food- or beverage-based nutritional supplements were reported to be consumed. These items were rare in both countries.[5] In addition, in both countries repeat recalls for individuals without observations for day 1 were subsequently excluded (20 observation days in Mexico and 63 observation days in China). Intakes were also evaluated relative to the Goldberg criteria (19). High and low energy intake reporters were not excluded for the main analysis, as this can introduce unknown biases (20,21); however, sensitivity analyses were performed excluding both low and high extremes (see Annex 1).

ANALYTIC APPROACH

The MDD-W was developed after analyses of a set of candidate indicators with varying numbers of food groups. A 10-food group indicator was selected based on the consistency and strength of its association to micronutrient adequacy. Since our objectives are to assess the same 10-food group indicator and to compare results for other populations to the original results, our analytic approach is similar. Methods are briefly described here; full descriptions of the original methods are published (5,22).

All analyses were performed separately for the following age/sex groups:

Children 2–4 years　　Girls 10–14 years　　Women 20–49 years

[4] Documentation and data are also available at: https://ensanut.insp.mx/, accessed 12 April 2021.

[5] Exclusions due to consumption of food- or beverage-based nutritional supplements totalled: 56 observation days for children 2–4 years and 47 observation days for older individuals in Mexico; and 48 observation days for children 2–4 years and 99 observation days for older individuals in China.

Children 5–9 years	Boys 10–4 years	Men 20–49 years
	Girls 15–19 years	Women 50+ years
	Boys 15–19 years	Men 50+ years

SUMMARY MEASURE OF MICRONUTRIENT ADEQUACY

We constructed an overall summary measure of micronutrient adequacy by first estimating probability of adequacy (PA) for a selected set of micronutrients. PA was assessed for the same set of 11 micronutrients as in the development of the MDD-W: Thiamine, vitamin C, riboflavin, vitamin A, niacin, calcium, vitamin B6, iron, folate, zinc, and vitamin B12. Once PA (ranging from 0 to 1.0) was estimated for each of the micronutrients, a summary measure, mean probability of adequacy (MPA), was calculated by taking the average across them. Annex 2 provides a summary of steps in calculation of PA and MPA, as well as additional general notes on statistical methods.

NUTRIENT REFERENCE VALUES

For all age/sex groups, nutrient reference values (NRVs) were primarily from a set of recently published harmonised NRVs proposed for global use (23). In addition, for WRA only, we also analysed with the set of NRVs used previously during development of the MDD-W. See Annex 1 for these sensitivity analyses, which illustrate the impact of selection of reference values on overall results. See Annex 3 for tables detailing both sets of NRVs used in the analyses.

The CHNS obtained information about pregnancy or lactation status only for ever-married women aged 18 years and older. Since pregnancies among unmarried girls and women are rare in China, intakes for adolescent girls 15–17 years and for women who were never married or whose family status was unknown were assessed relative to NRVs for non-pregnant, non-lactating adolescents and women.

FOOD COMPOSITION DATA AND TREATMENT OF FORTIFIED FOODS AND SUPPLEMENTS

For each country, we used food composition databases developed for the surveys (ENSANUT and CHNS). In Mexico, the food composition data base had been used in previous analyses of the 2012 ENSANUT (15,24,25). In China, the 2009 Chinese food composition data base (26) was used as the basis because it matched the 2011 CHNS data best. It was complemented with data from the 2018/2019 Chinese food composition data base (27,28) to fill in missing information and replace implausibly high iron values for some foods.

Associations between food group diversity and micronutrient adequacy can be influenced by inclusion or exclusion of nutrient supplements and fortified foods. For the purposes of these analyses nutrient supplements were excluded, and fortified food items were replaced with similar unfortified items. This is consistent with the approach taken in the development of the MDD-W and reflects our objective to assess the association of diverse unfortified foods to micronutrient adequacy. See Annex 4 for further details of food and beverage exclusions and substitutions.

CONSTRUCTION OF INDICATORS

Two food group indicators were constructed: a 10-point score (FGDS) and a dichotomous indicator (MDD-W) reflecting consumption of 0–4 vs. five or more of 10 defined groups (29). Consumption of at least 15 grams is required for a food group to 'count' in the score. The 10 food groups are: (1) Grains, white roots and tubers, and plantains, (2) Pulses (beans, peas, and lentils), (3) Nuts and seeds, (4) Dairy, (5) Meat, poultry, and fish, (6) Eggs, (7) Dark green leafy vegetables, (8) Other vitamin A-rich fruits and vegetables, (9) Other vegetables, and (10) Other fruits.

In Mexico, a small number of children in the youngest age group were still breastfed and breast milk quantities were specified following the method of Briefel et al. (2010) (30). Since this group is small, for the purposes of this analysis breast milk was considered as a dairy food and a child consuming breast milk received a 'point' for dairy.

ASSESSING THE RELATIONSHIP OF FGDS AND MDD-W TO NUTRIENT ADEQUACY

We used correlation analysis to describe relationships between the food group score and usual intakes of individual nutrients, and MPA, with and without controlling for total energy intake. Analyses were repeated in simple linear regressions controlling for age, height, and total energy intake.

Next, the overall predictive power of the food group score was assessed in receiver operating characteristic (ROC) analyses. ROC analyses generate a statistic, the area under the curve (AUC), which summarises the predictive power of the indicator across all food group score cut-offs. The AUC should be significantly different from 0.50 (a neutral value with no predictive power); a minimum value of 0.70 indicates relatively good predictive power (31). The AUC reflects how well the score predicts an MPA above any defined cut-off (e.g., MPA > 0.50, or MPA > 0.70). MPA theoretically can reach 1.0 if probability of adequacy for all micronutrients is 1.0. However, during development of MDD-W, few individuals had MPA above 0.80. Therefore, the decision of which MPA cut-offs to 'test' was based on the distribution of MPA in the study samples. For each age/sex group in each country, we examined the percent and number of individuals above each MPA cut-off. For simplicity, we aimed to identify a maximum MPA cut-off that could be analysed for all groups. For almost all age/sex groups, more than 2% of individuals exceeded the MPA cut-off of 0.80 (exception: adolescent girls 15–19 years of age in China). We therefore analysed MPA cut-offs of 0.50, 0.60, 0.70, and 0.80. However, for adolescents aged 15–19 years in China, fewer than 10 individuals were above MPA cut-offs of 0.80 (both sexes) and 0.70 (girls), yielding wide confidence intervals for AUC.

Next, indicator qualities (including sensitivity, specificity, and total misclassification) were assessed for the same four MPA cut-offs in combination with food group score cut-offs. As in the development of the MDD-W (5), we aimed for sensitivity and specificity both at 60%

or higher, but if no food group score cut-off was found where both sensitivity and specificity were at 60% or higher, combinations of > 50% sensitivity and > 60% specificity, and of > 60% sensitivity and > 50% specificity, were accepted. Total misclassification was assessed for all combinations of MPA and food group score cut-offs. When two food group cut-offs yielded similar results for sensitivity and specificity, the cut-off with the lower total misclassification is presented as 'best'. We considered misclassification at or below 30% to be desirable, but accepted misclassification of up to 40%, as was done during the development of MDD-W. In addition to assessing indicator qualities as described above, we also compared estimates of prevalence above MPA cut-offs to prevalence above the 'best' food group score cut-offs ('prevalence matching').

ADDITIONAL DESCRIPTIVE ANALYSES

The following additional descriptive analyses were performed to further assess and to inform interpretation of results:

- Comparison of MPA for individuals above and below best food group score cut-offs
- Proportions of individuals consuming various nutrient-dense food groups and combinations of food groups, comparing those above and below best food group score cut-offs

These additional descriptive analyses provide insight into the construct validity of the MDD-W.

SENSITIVITY ANALYSES

As noted above, several types of sensitivity analyses were undertaken to assess robustness of results. Some key results from the sensitivity analyses are presented in the main body of the report, including:

- Correlations of the food group diversity scores and MPA with and without controlling for energy
- Estimation of AUC for multiple MPA cut-offs

Additional sensitivity analysis results are presented in Annex 1 for:

- Analyses excluding low and high energy intake reporters and comparison of characteristics of low and high energy reporters versus 'acceptable' energy intake reporters
- For women of reproductive age: Comparison of two sets of NRVs in estimation of MPA, and impact on associations of FGDS and MDD-W with MPA
- Selected results for an alternative FGI score and MDD-W, where food groups were allowed to 'count' if at least 1 gram (rather than at least 15 grams) was consumed

RESULTS AND DISCUSSION

We present descriptive results for each country separately, then summarise indicator performance for both countries. Sensitivity analyses are presented in Annex 1, and supplementary results tables in Annex 5.

MEXICO - DESCRIPTION OF STUDY SAMPLE

In Mexico, data were available for 9,652 individuals after data cleaning and exclusions; see Annex 5 for the sample size for each age/sex group. Across all age/sex groups, most individuals lived in urban areas (67–78% across groups) and about 1 in 10 were indigenous (8–14% across groups). Among adults, education levels varied strongly by age category. Younger adults (20–49 years) were much more likely to have secondary education or higher (~70% of younger men and women, compared to ~20% of older women and ~30% of older men). Table 1 shows energy intakes in kilocalories by age and sex group. Energy intakes appear somewhat low for some groups. The possibility of under-reporting, and possible impact on results, is assessed and addressed in sensitivity analyses in Annex 1.

Table 1. Energy intake by age and sex, Mexico*

	Mean	SD	Median
Children 2–4 years	1318	825	1270
Children 5–9 years	1663	1112	1553
Girls 10–14 years	1782	966	1684
Boys 10–14 years	1994	1133	1896
Girls 15–19 years	1742	1015	1663
Boys 15–19 years	2236	1498	2081
Women 20–49 years	1728	1014	1627
Men 20–49 years	2215	1412	2012
Women 50+ years	1477	All	1397
Men 50+ years	1923	1240	1782

* Energy intake in kilocalories per day. Estimates consider survey design.

Patterns of macronutrient and sugar intake were generally similar across ages and sexes:

- Carbohydrate intake ranged from 55% of energy (children 2–9 years) to 61% among older men (50+ years)
- Intake of sugars ranged from 11% to 15% of energy and was lowest among older adults
- Protein intake ranged from 12% to 14% of energy across all groups
- The percent of protein from animal sources ranged from 51% in older men to 64% among 2–4-year-old children
- Fat intake was 30–32% of energy in most groups and was slightly lower (27–28%) among older adults
- These intakes of macronutrients fall within Acceptable Macronutrient Distribution Ranges (AMDRs) (32)

Results for PA for individual micronutrients are provided in Annex 5 for each age/sex group. The nutrients with the lowest PA varied by age, but for most age groups 10 years and older, PAs for vitamins A, B6, C, and folate were among the lowest.

Figure 2 shows MPA, summarising probability of adequacy across the eleven vitamins and minerals for each age/sex group. At population level, the mean MPA is highest (~0.7) for children 2-9 years of age and lowest for adolescent girls 15–19 years of age and adult women (~0.25 for all age groups 15 through 50+). Median MPA is significantly higher for boys and men than for girls and women at each age where results are shown by sex. However, MPA is low for both sexes.

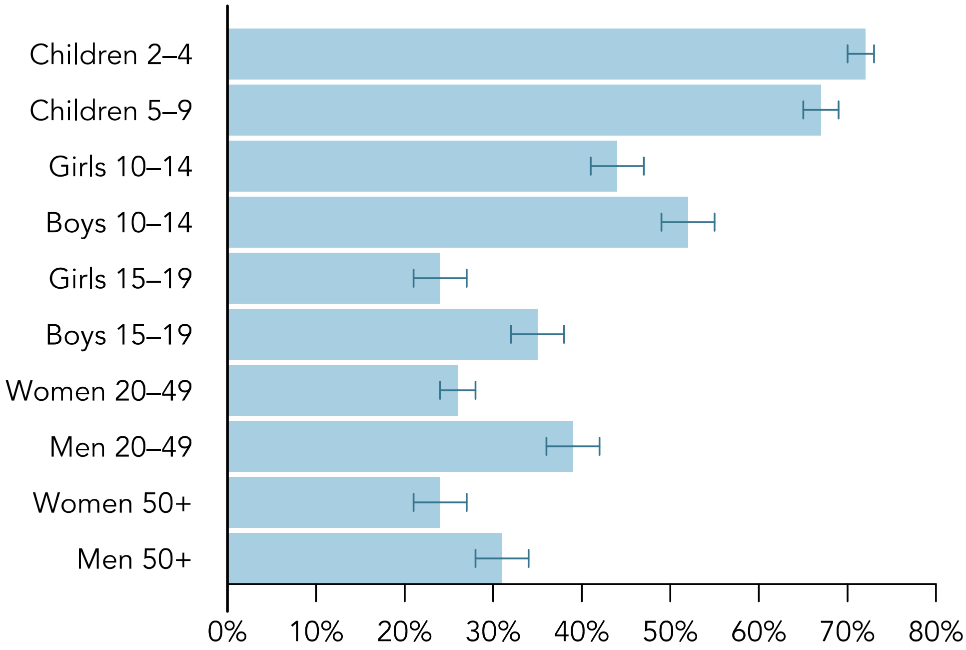

Figure 2: Mean probability of adequacy across eleven micronutrients, by age and sex, Mexico. Error bars show 95% confidence intervals.

The proportion of individuals exceeding any given MPA cut-off also varied by age. Among older adolescents and adults, few reached the higher MPA cut-offs. Table 2 shows results for an MPA cut-off of > 0.80; see Annex 5 for details for several other MPA cut-offs. MPA was significantly associated with energy intakes, with simple correlations ranging from 0.33–0.43 across age/sex groups.

Table 2. Percent and number of individuals exceeding MPA of 0.70 and 0.80, Mexico

	MPA > 0.70		MPA > 0.80	
	Percent	Number	Percent	Number
Children 2–4 years	61	986	49	796
Children 5–9 years	52	1043	39	783
Girls 10–14 years	20	152	12	96
Boys 10–14 years	30	244	20	164
Girls 15–19 years	7	48	3	20
Boys 15–19 years	12	68	6	33
Women 20–49 years	6	62	2	25

Men 20–49 years	16	109	7	51
Women 50+ years	8	59	5	34
Men 50+ years	8	48	3	19

Low energy intake reporting is a common problem in dietary studies and was also found in this study. To explore the possibility that true MPA are higher, and the results in Figure 3 are influenced by inclusion of low reporters for energy intakes, all analyses were repeated with low and high energy intake reporters excluded. As expected, PAs and MPA increased after exclusion of low and high energy intake reporters. However, main results and conclusions for indicator performance remain similar (see Annex 1 for details).

Patterns of food group consumption were broadly similar across all age/sex groups. The four most-commonly consumed food groups (with at least 15 grams consumed by more than half of individuals) were the same across all age/sex groups: 1) grains; 2) flesh foods (meat/poultry/fish); 3) dairy; and 4) other (non-vitamin A-rich) vegetables. The proportion consuming dairy declined slightly after childhood but remained substantial [57–65% among older teens and adults (15+ years)]. Dark green leafy vegetables and nuts were rarely consumed; fewer than 5% consumed 15 grams or more of these food groups, at any age.

Consistent with these similar food group patterns, FGDS was also very similar across all groups, with mean scores ranging from 4.1 to 4.4, and the same median score of 4 across all age/sex groups. When quantities less than 15 grams were allowed to 'count' in the score, FGI were about one point higher. See Annex 1 for further discussion. Distributions of FGDS were also broadly similar across all age/sex groups (Figure 3).

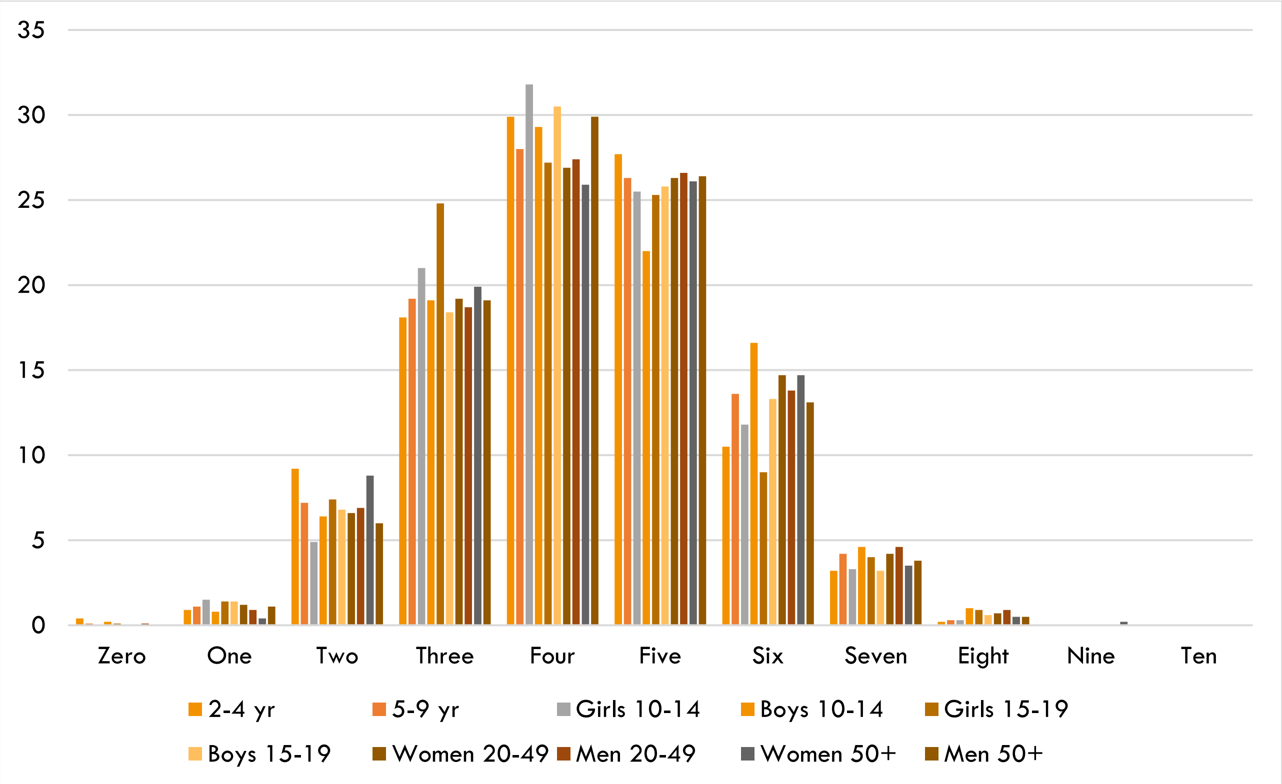

Figure 3: Percent at each food group diversity score (FGDS), by age and sex, Mexico

CHINA - DESCRIPTION OF STUDY SAMPLE

In China, data were available for 15,019 individuals after data cleaning and exclusions; see Annex 5 for the sample size for each age/sex group. Over half of the respondents lived in rural areas. This varied slightly by age, with children under 10 being more likely to live in rural areas (about two-thirds), while adolescent girls aged 15–19 years were more likely than other age/sex groups to live in urban areas (50%). The majority of respondents were ethnic Han Chinese, with 8–14% (depending on age group) belonging to ethnic minorities.

Among adults, education levels varied strongly by age, particularly for women. Younger adults (20–49 years) were much more likely to have secondary education or higher (77% of younger women and 85% of younger men, compared to 39% of older women and 59% of older men).

Table 3 shows energy intakes in kilocalories by age and sex group. Energy intakes appear somewhat low for some groups. The possibility of under-reporting, and any impact on results, is assessed and addressed in sensitivity analyses in Annex 1.

Table 3. Energy intake in kilocalories, by age and sex, China

	Mean	SD	Median
Children 2–4 years	1072	615	967
Children 5–9 years	1368	710	1293
Girls 10–14 years	1499	754	1420
Boys 10–14 years	1839	800	1773
Girls 15–19 years	1631	860	1538
Boys 15–19 years	2023	1028	1862
Women 20–49 years	1811	1381	1703
Men 20–49 years	2201	1605	2091
Women 50+ years	1750	1383	1651
Men 50+ years	2054	1543	1937

Patterns of macronutrient and sugar intake were similar across ages and sexes:

- Carbohydrate intake ranged from 55%–57% of energy
- Intake of sugars ranged from 1–3% of energy, much lower than in Mexico where the range was 11–15%
- Protein intake ranged from 14–15% of energy across all groups
- The percent of protein from animal sources ranged from 37% in older women (50+) to 47% among 2–4-year-old children, notably lower than in Mexico where the range was 51%–64%
- Fat intake ranged from 28–31% of energy
- These intakes of macronutrients fall within Acceptable Macronutrient Distribution Ranges (AMDRs) (32)

Results for PA for individual micronutrients are provided in Annex 5 for each age/sex group. PAs for riboflavin, vitamin B6, and calcium were lowest for most age groups, and niacin was highest.

Figure 4 shows MPA, summarising probability of adequacy across the eleven vitamins and minerals for each age/sex group. At population level, the mean MPA is highest (~0.5) for children 2–9 years of age and lowest for adolescent girls 15–19 years of age (0.26). Median MPA is significantly higher for males at 10–14, 20–49, and 50+ years of age, but is low for both sexes.

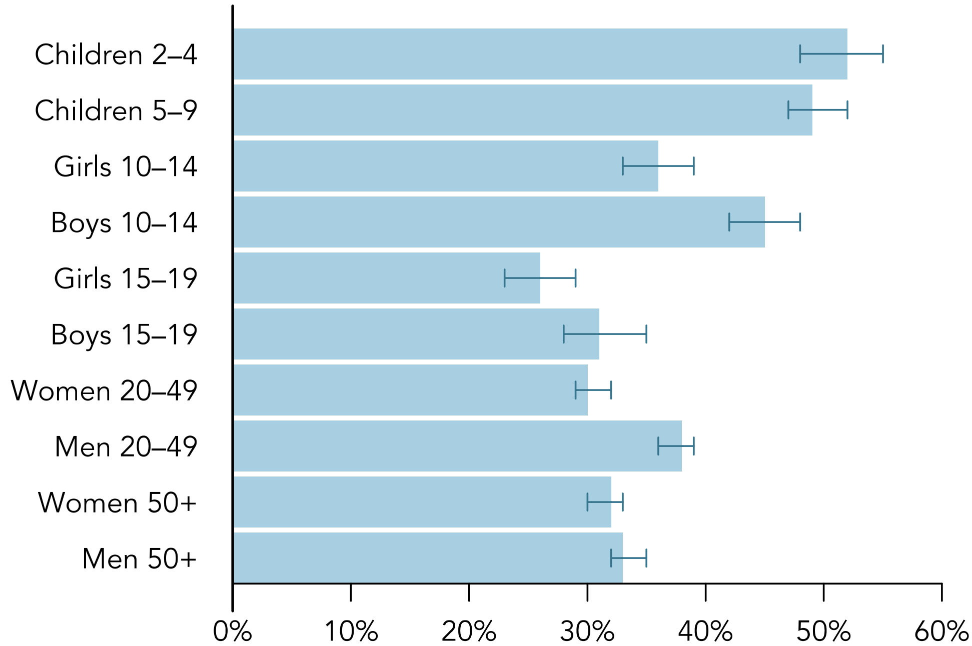

Figure 4: Mean probability of adequacy across eleven micronutrients, by age and sex, China. Error bars show 95% confidence intervals.

The proportion of individuals exceeding any given MPA cut-off also varied by age. Among older adolescents and adults, very few reached the higher MPA cut-offs. Table 4 shows results for MPA cut-offs of> 0.70 and> 0.80; see Annex 5 for details for several other MPA cut-offs.

Table 4. Percent and number of individuals exceeding MPA of 0.70 and 0.80, China

	MPA > 0.70		**MPA > 0.80**	
	Percent	**Number**	**Percent**	**Number**
Children 2–4 years	33	147	23	102
Children 5–9 years	27	206	17	131
Girls 10–14 years	11	36	5	17
Boys 10–14 years	16	57	11	38
Girls 15–19 years	4	7	1	2
Boys 15–19 years	5	11	3	7
Women 20–49 years	6	207	3	87
Men 20–49 years	9	251	4	117
Women 50+ years	7	249	3	120
Men 50+ years	7	231	4	120

Although associations were weaker than in the Mexico sample, MPA was associated with energy intakes with simple correlations ranging from 0.11–0.32. As noted, we explored the possibility that true MPA are higher, and the results in Figure 6 showing low MPA are influenced by inclusion of low reporters for energy intakes. All analyses were repeated with low and high energy intake reporters excluded. As expected, PAs and MPA increased after exclusion of low and high energy intake reporters. However, main results and conclusions for indicator performance remain similar (see Annex 1 for details).

Patterns of food group consumption were broadly similar across all age/sex groups. The three most consumed food groups (consumed by more than half of individuals) were the same across all age/sex groups: 1) grains; 2) flesh foods (meat/poultry/fish); and 3) other (non-vitamin A rich) vegetables. Four groups were consumed by one-third to one-half in all age/sex groups: dark green leafy vegetables, pulses, eggs, and other (non-vitamin A-rich) fruits. Dairy consumption was less common and generally declined with age from a high of 36% among children 2–4 years of age to a low of 8% among men aged 20–49 years. Nuts were consumed by fewer than 10% of respondents in most age/sex groups.

Consistent with these similar food group patterns, FGDS was also similar across all age/sex groups, with mean scores ranging from 4.5 to 4.8. For most age/sex groups the median score was 5, but older women and men (50+ years of age) had a median score of 4. In China, allowing small quantities (less than 15 grams) to count in the score had very little impact on FGI scores. See Annex 1 for further discussion. Distributions of FGDS were also broadly similar across all age/sex groups (Figure 5).

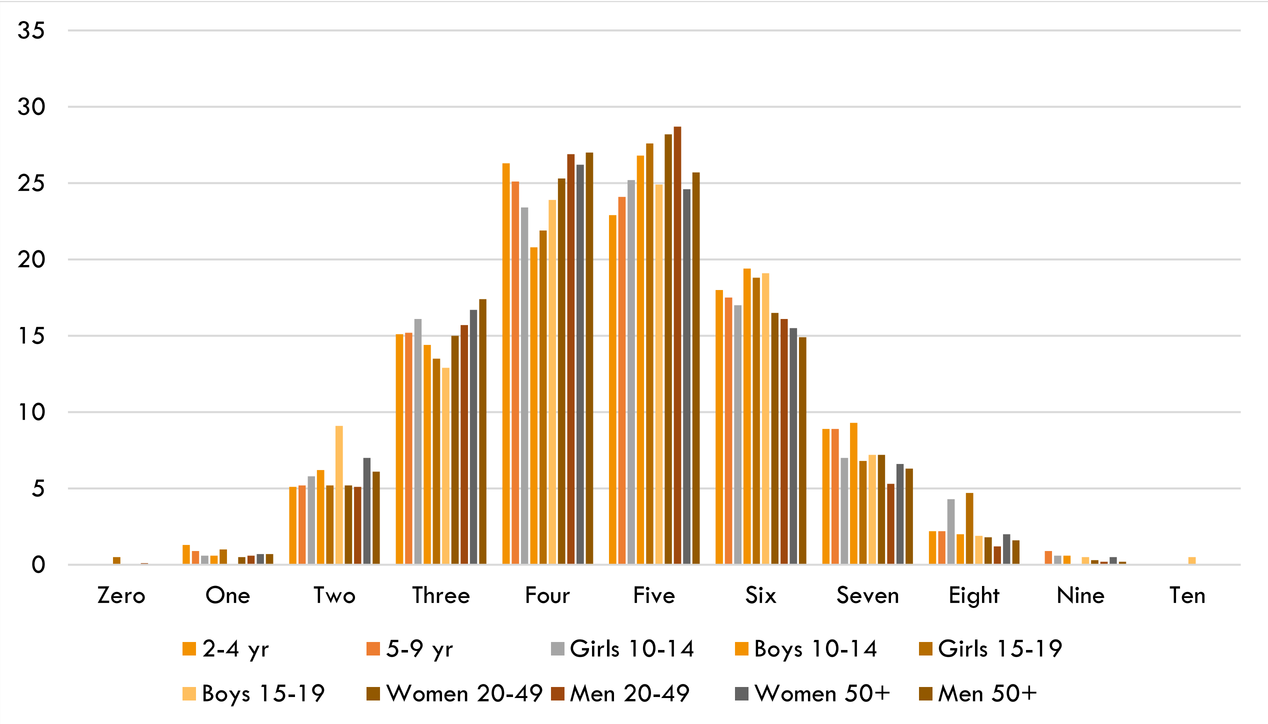

Figure 5: Percent at each food group diversity score (FGDS), by age and sex, China

INDICATOR PERFORMANCE

CORRELATION AND REGRESSION

The first step in assessing the performance of the indicator is examination of simple correlations of FGDS with MPA, both with and without controlling for total energy intake. Energy is controlled for because FGDS is associated with energy intake, so associations between FGDS and MPA could also be driven by total energy intakes. Table 5 shows the relationship between FGDS and MPA for each age and sex group, in each country. For Mexico, when not controlling for energy, correlations are all statistically significant (P < 0.001) and range from 0.38–0.57. Relationships between FGDS and MPA are linear. After controlling for total energy intake, all correlations remain significant (P < 0.001) but are attenuated, ranging from 0.20–0.43. Correlations are largest (> 0.40) for children 2–9 years of age and for boys 10–14 years of age.

For China, when not controlling for energy, correlations are all significant (P < 0.001) and range from 0.36–0.59, and most relationships between FGDS and MPA are again linear. After controlling for total energy intake, all correlations remain significant (P < 0.001) and range from 0.38–0.53. When controlling for energy, correlations appear slightly attenuated for children and some adolescent groups, but without attenuation for adults. Correlations between FGDS and MPA are largest (~ 0.50) for children 2–9 years of age and for girls 15–19 years of age and are ~0.40 for all other groups.

Table 5. Relationship between Mean Probability of Adequacy and food group indicator (FGDS) by age and sex

	Food group indicator (FGDS)		**MPA**		**Correlation coefficient (not controlling for energy intake)[a]**		**Test for linear trend[b]**	**Partial correlation controlling for energy intake[a]**	
Mexico	**(mean)**	**(median)**	**(mean)**	**(median)**					
Children 2–4 years	4.2	4.0	0.72	0.79	0.57	***	0.46	0.43	***
Children 5–9 years	4.3	4.0	0.67	0.72	0.56	***	0.67	0.42	***
Girls 10–14 years	4.2	4.0	0.44	0.41	0.49	***	0.25	0.33	***
Boys 10–14 years	4.4	4.0	0.52	0.53	0.53	***	0.72	0.41	***
Girls 15–19 years	4.1	4.0	0.24	0.16	0.45	***	0.80	0.25	***
Boys 15–19 years	4.3	4.0	0.35	0.30	0.38	***	0.80	0.20	***
Women 20–49 years	4.3	4.0	0.26	0.21	0.46	***	0.76	0.30	***
Men 20–49 years	4.4	4.0	0.39	0.36	0.42	***	0.08	0.24	***
Women 50+ years	4.3	4.0	0.24	0.16	0.48	***	0.73	0.28	***
Men 50+ years	4.3	4.0	0.31	0.29	0.50	***	0.58	0.34	***
China	**(mean)**	**(median)**	**(mean)**	**(median)**					
Children 2–4 years	4.7	5.0	0.52	0.53	0.59	***	0.61	0.53	***
Children 5–9 years	4.7	5.0	0.49	0.50	0.54	***	0.57	0.49	***
Girls 10–14 years	4.7	5.0	0.36	0.35	0.46	***	0.15	0.41	***
Boys 10–14 years	4.8	5.0	0.45	0.44	0.49	***	0.09	0.40	***

	Food group indicator (FGDS)		MPA		Correlation coefficient (not controlling for energy intake)[a]		Test for linear trend[b]	Partial correlation controlling for energy intake[a]	
Girls 15–19 years	4.8	5.0	0.26	0.23	0.57	***	0.16	0.53	***
Boys 15–19 years	4.7	5.0	0.31	0.27	0.39	***	0.16	0.38	***
Women 20–49 years	4.7	5.0	0.30	0.27	0.39	***	0.06	0.40	***
Men 20–49 years	4.5	5.0	0.38	0.36	0.36	***	0.00	0.39	***
Women 50+ years	4.5	4.0	0.32	0.28	0.41	***	0.88	0.41	***
Men 50+ years	4.5	4.0	0.33	0.30	0.39	***	0.43	0.41	***

[a] * Indicates a Pearson's correlation coefficient that is statistically significant at $p < 0.05$; ** indicates $p < 0.01$, and *** indicates $p < 0.001$.

[b] Significance of coefficient for a quadratic term in a regression of MPA on each food group diversity indicator; a significant quadratic term suggests the relationship is not linear.

For all age/sex groups in Mexico and for children and some adolescents in China, the results in Table 5 show some attenuation of associations when energy is controlled for, indicating that both total quantity of food and food group diversity contribute to micronutrient adequacy. For adults in China there is no attenuation of associations when energy is controlled for, indicating that food group diversity drives the association. Associations between FGDS and MPA were confirmed in regressions controlling for age, height, and pregnancy/lactation status, in addition to total energy intake (all P for regression coefficients for FGDS < 0.001).

Results for individual micronutrients are shown in Annex 5, again showing relationships between the individual micronutrient and FGDS with and without controlling for total energy intakes. In Mexico, before controlling for energy, associations for all micronutrients were significant (P < 0.001) for all age/sex groups. After controlling for energy, all associations remained significant for children 2–9 years of age, and nearly all remained significant for adolescents and adults. Usual intakes of iron were not associated with FGDS for most older age groups; in addition, for boys and men 15–49 years of age usual intakes of thiamine and niacin were not associated with FGDS. In China, before controlling for energy, associations for all micronutrients were significant (P < 0.05) for all age/sex groups. After controlling for energy, all associations remained significant for children 2–9 years of age and for adults 20 years of age and older, and nearly all remained significant for adolescents. Usual intakes of iron were not associated with FGDS for 10–14-year-olds (both sexes) and for 15–19-year-old boys, and usual intakes of thiamine were not associated with FGDS for adolescent boys (10–19 years).

Figures 6a-c (Mexico) and 7a-c (China) illustrate how MPA changed with increases in the FGDS score, for each age/sex group. Increases were marked and consistent for ages 2–4 and 5–9 years. Increases were less marked for adults. MPA at each FGDS score tended to be slightly higher for males for some age groups in each country.

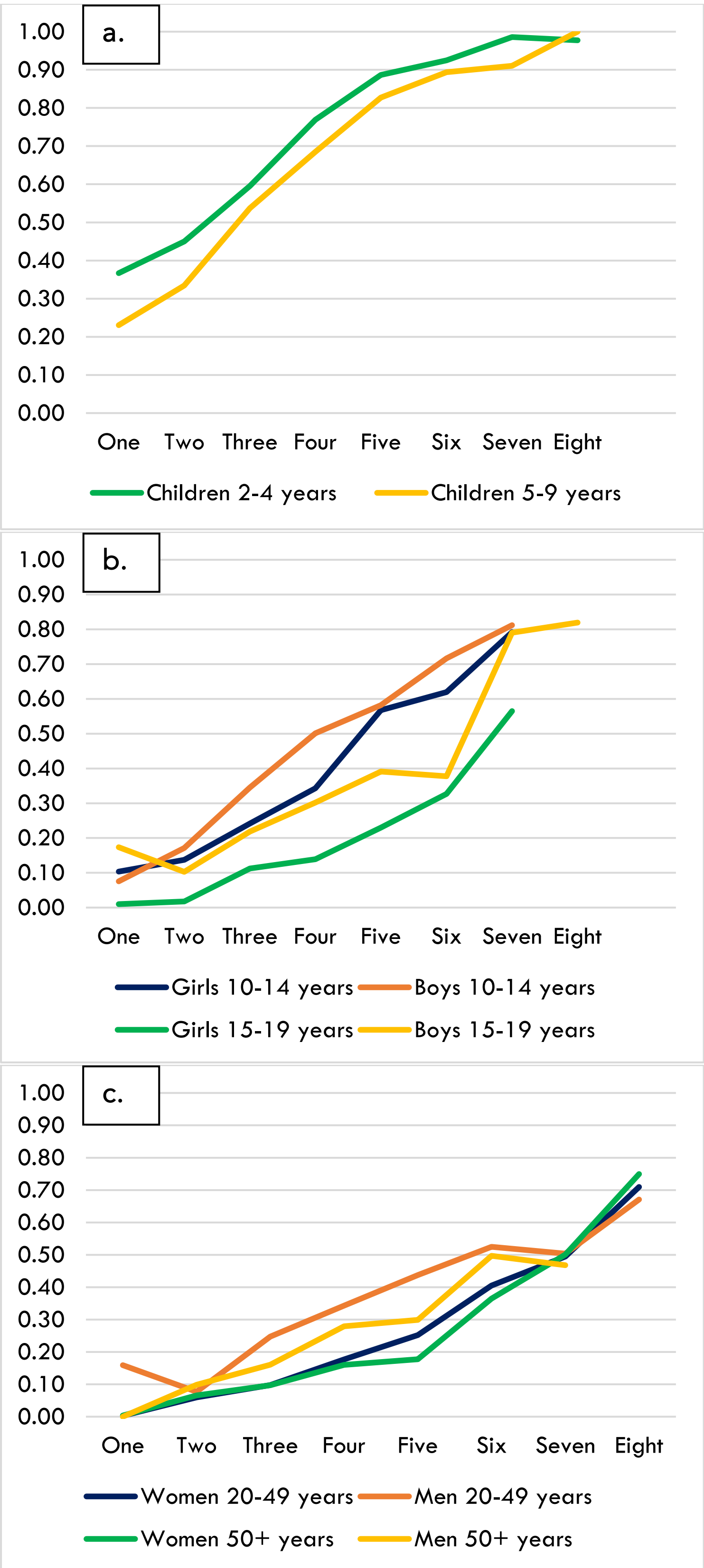

Figure 6: Increase in median MPA by FGDS score, Mexico. (a) Children 2–9 years of age; (b) Adolescents 10–19 years of age; (c) Adults 20 years and older. MPA = Mean Probability of Adequacy across 11 micronutrients; FGDS = food group diversity score (range 0–10). Data points representing fewer than 5 observations are not shown.

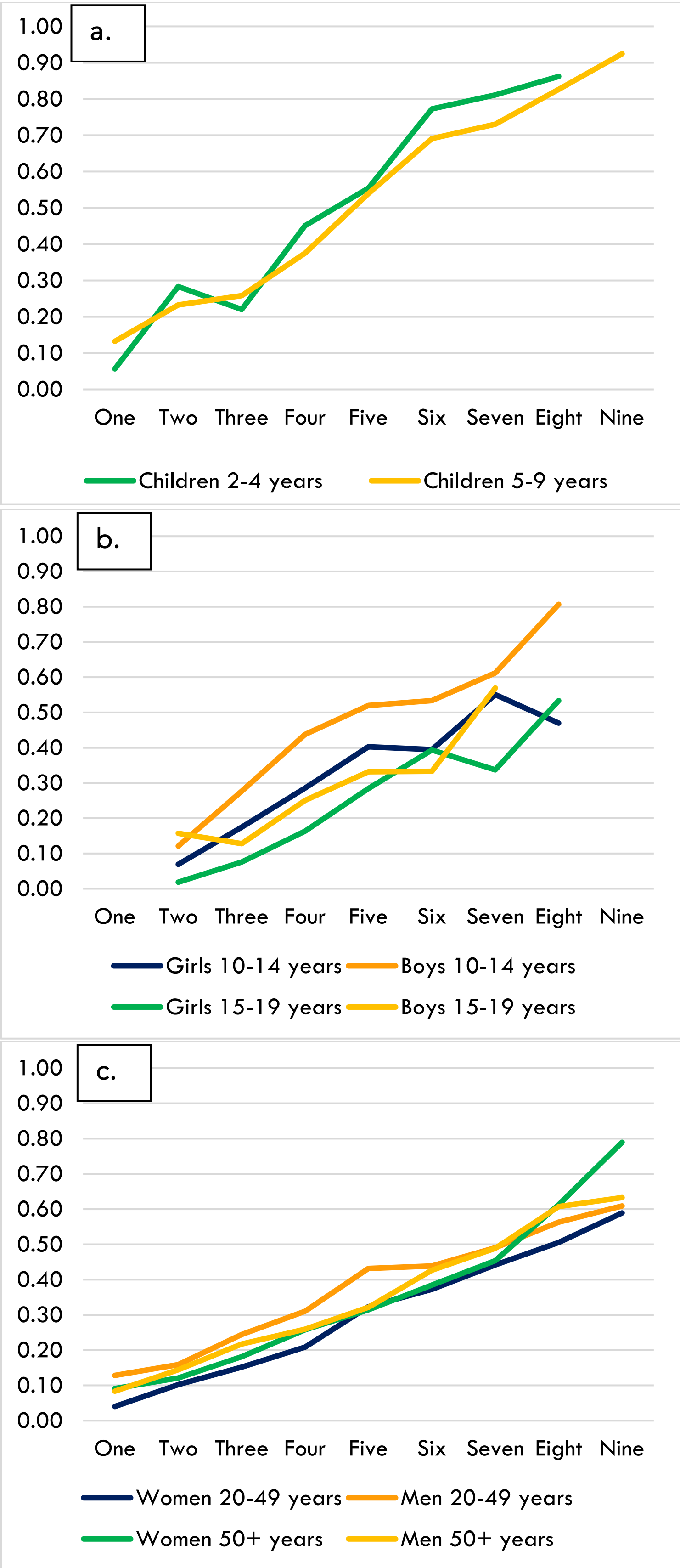

Figure 7: Increase in median MPA by FGDS score, China. (a) Children 2–9 years of age; (b) Adolescents 10–19 years of age; (c) Adults 20 years and older. MPA = Mean Probability of Adequacy across 11 micronutrients; FGDS = food group diversity score (range 0–10). Data points representing fewer than 5 observations are not shown.

RECEIVER OPERATING CHARACTERISTIC ANALYSIS

Next, AUC were calculated for FGDS for all age/sex groups and for MPA cut-offs of 0.50, 0.60, 0.70, and 0.80. Table 6 summarises AUC for Mexico and Table 7 summarises AUC for China.

For Mexico, AUC are above our criterion value of 0.70 for all age/sex groups except in the case of the lower MPA cut-offs for boys and men 15–49 years of age. AUC are above 0.70 for all age/sex groups for the MPA cut-off of 0.80. This supports the correlation and regression analyses and indicates that FGDS has reasonable predictive strength as a proxy for the overall micronutrient adequacy of the diet (MPA).

For China, with one exception, AUC are above 0.70 for children and adolescents and for older adults (50+ years of age). For adults 20–49 years of age, AUC are below 0.70 for some (women) or all (men) MPA cut-offs. For adolescents 15–19 years of age, confidence intervals for AUC are wider due to smaller sample sizes in this age range, and for girls 15–19 years, AUC are not significantly different from 0.50 for higher MPA cut-offs.

Table 6. Areas under the curve for FGDS, Mexico

	AUC[a]		SEM[b]	95% CI[c]
Children 2–4 years				
MPA > 0.50	0.79	***	0.01	0.77-0.82
MPA > 0.60	0.80	***	0.01	0.78-0.82
MPA > 0.70	0.78	***	0.01	0.76-0.80
MPA > 0.80	0.78	***	0.01	0.76-0.80
Children 5–9 years				
MPA > 0.50	0.77	***	0.01	0.75-0.79
MPA > 0.60	0.76	***	0.01	0.74-0.78
MPA > 0.70	0.76	***	0.01	0.74-0.78
MPA > 0.80	0.76	***	0.01	0.74-0.78
Girls 10–14 years				
MPA > 0.50	0.72	***	0.02	0.68-0.75
MPA > 0.60	0.73	***	0.02	0.69-0.76
MPA > 0.70	0.72	***	0.02	0.68-0.76
MPA > 0.80	0.74	***	0.02	0.69-0.78
Boys 10–14 years				
MPA > 0.50	0.75	***	0.02	0.72-0.79
MPA > 0.60	0.75	***	0.02	0.71-0.78
MPA > 0.70	0.76	***	0.02	0.72-0.79
MPA > 0.80	0.76	***	0.02	0.73-0.80
Girls 15–19 years				
MPA > 0.50	0.72	***	0.03	0.67-0.77
MPA > 0.60	0.73	***	0.03	0.67-0.80
MPA > 0.70	0.74	***	0.04	0.66-0.82
MPA > 0.80	0.78	***	0.05	0.69-0.87

Boys 15–19 years				
MPA > 0.50	0.65	***	0.02	0.60-0.70
MPA > 0.60	0.66	***	0.03	0.60-0.71
MPA > 0.70	0.67	***	0.03	0.61-0.74
MPA > 0.80	0.75	***	0.04	0.67-0.82
Women 20–49 years				
MPA > 0.50	0.74	***	0.02	0.70-0.78
MPA > 0.60	0.77	***	0.02	0.73-0.81
MPA > 0.70	0.79	***	0.03	0.74-0.84
MPA > 0.80	0.80	***	0.04	0.72-0.87
Men 20–49 years				
MPA > 0.50	0.66	***	0.02	0.62-0.70
MPA > 0.60	0.68	***	0.02	0.63-0.72
MPA > 0.70	0.73	***	0.02	0.68-0.77
MPA > 0.80	0.72	***	0.04	0.65-0.79
Women 50+ years				
MPA > 0.50	0.77	***	0.02	0.73-0.82
MPA > 0.60	0.78	***	0.03	0.72-0.84
MPA > 0.70	0.80	***	0.04	0.72-0.87
MPA > 0.80	0.78	***	0.05	0.68-0.89
Men 50+ years				
MPA > 0.50	0.73	***	0.03	0.68-0.78
MPA > 0.60	0.76	***	0.03	0.71-0.82
MPA > 0.70	0.79	***	0.04	0.72-0.86
MPA > 0.80	0.84	***	0.04	0.76-0.92

[a] * Indicates AUC is statistically significant at $p < 0.05$; ** indicates $p < 0.01$, and *** indicates $p < 0.001$. The p-value results from testing the null hypothesis that AUC=0.5 ("neutral" diagonal line on ROC graph).

[b] Standard error of the mean; c Confidence interval.

Table 7. Areas under the curve for FGDS, China

	AUC[a]		SEM[b]	95% CI[c]
Children 2–4 years				
MPA > 0.50	0.80	***	0.02	0.76-0.84
MPA > 0.60	0.79	***	0.02	0.75-0.83
MPA > 0.70	0.79	***	0.02	0.75-0.83
MPA > 0.80	0.78	***	0.02	0.74-0.83
Children 5–9 years				
MPA > 0.50	0.76	***	0.02	0.73-0.80
MPA > 0.60	0.78	***	0.02	0.75-0.81
MPA > 0.70	0.76	***	0.02	0.72-0.80
MPA > 0.80	0.76	***	0.02	0.72-0.80
Girls 10–14 years				
MPA > 0.50	0.71	***	0.03	0.65-0.77
MPA > 0.60	0.73	***	0.03	0.67-0.80
MPA > 0.70	0.74	***	0.04	0.66-0.82
MPA > 0.80	0.75	***	0.05	0.66-0.84

Boys 10–14 years				
MPA > 0.50	0.71	***	0.03	0.66-0.76
MPA > 0.60	0.73	***	0.03	0.68-0.78
MPA > 0.70	0.75	***	0.03	0.70-0.81
MPA > 0.80	0.78	***	0.03	0.72-0.85
Girls 15–19 years				
MPA > 0.50	0.71	***	0.05	0.62-0.80
MPA > 0.60	0.75	***	0.06	0.64-0.87
MPA > 0.70	0.66		0.09	0.49-0.82
MPA > 0.80	0.77		0.21	0.36-1.00
Boys 15–19 years				
MPA > 0.50	0.77	***	0.04	0.69-0.85
MPA > 0.60	0.74	***	0.05	0.64-0.83
MPA > 0.70	0.73	**	0.07	0.60-0.87
MPA > 0.80	0.71	*	0.10	0.51-0.91
Women 20–49 years				
MPA > 0.50	0.69	***	0.01	0.67-0.71
MPA > 0.60	0.70	***	0.01	0.67-0.72
MPA > 0.70	0.69	***	0.02	0.65-0.73
MPA > 0.80	0.72	***	0.03	0.67-0.78
Men 20–49 years				
MPA > 0.50	0.66	***	0.01	0.64-0.68
MPA > 0.60	0.66	***	0.01	0.64-0.69
MPA > 0.70	0.65	***	0.02	0.62-0.68
MPA > 0.80	0.64	***	0.03	0.59-0.69
Women 50+ years				
MPA > 0.50	0.71	***	0.01	0.69-0.73
MPA > 0.60	0.73	***	0.01	0.70-0.75
MPA > 0.70	0.74	***	0.02	0.71-0.77
MPA > 0.80	0.74	***	0.02	0.70-0.79
Men 50+ years				
MPA > 0.50	0.70	***	0.01	0.68-0.72
MPA > 0.60	0.72	***	0.01	0.69-0.74
MPA > 0.70	0.72	***	0.02	0.69-0.76
MPA > 0.80	0.74	***	0.02	0.70-0.79

[a] *Indicates AUC is statistically significant at $p < 0.05$; ** indicates $p < 0.01$, and *** indicates $p < 0.001$. The p-value results from testing the null hypothesis that AUC=0.5 (“neutral” diagonal line on ROC graph).

[b] Standard error of the mean; c Confidence interval.

SENSITIVITY AND SPECIFICITY ANALYSIS

Next, indicator performance was assessed for dichotomous indicators; that is, with FGI score cut-offs. For example, the MDD-W employs a cut-off of 5 or more food groups and was developed based on analysis of its prediction of MPA > 0.60. In this study, with larger data sets from middle-income countries, sufficient numbers of individuals had higher MPA and we could evaluate several MPA cut-offs (0.50, 0.60, 0.70, and 0.80). For FGI score cut-offs, we evaluated all cut-offs from ≥ 1 food group through ≥ 8 food groups, but we report results for a subset of food group cut-offs that provided the best balance between sensitivity and specificity. Results are summarised in Table 8, and more detailed tables are presented in Annex 5 for the MPA cut-off of 0.60.

For some age/sex groups, the best cut-off was consistent across all MPA cut-offs, while for others, one FGDS score was a better cut-off for distinguishing at the lower MPA cut-offs, while another (higher) FGDS score was better for the higher MPA cut-offs. For Mexico, the FGDS cut-off of 5 or more food groups (as in the MDD-W) most frequently provided the best balance between sensitivity and specificity. With few exceptions, the 'best' cut-off resulted in both sensitivity and specificity above 60%. For China, results were more mixed, with the FGDS cut-off of 5 or more groups providing the best balance for several age/sex/MPA combinations and the FGDS cut-off of 6 providing the best balance in more cases. For some age/sex/MPA combinations, no cut-off provided both sensitivity and specificity of over 50%. For several MPA levels for adults, the food group cut-off that provided the best balance between sensitivity and specificity resulted in misclassification higher than our criterion of 40%.

Table 8. Food group cut-offs with the best balance between sensitivity and specificity[a]

Mexico	**MPA > 0.5**	**MPA > 0.6**	**MPA > 0.7**	**MPA > 0.8**
Children 2–4 years	**≥ 4**	**≥ 4**	≥ 4	**≥ 5**
Children 5–9 years	≥ 4	≥ 4	**≥ 5**	**≥ 5**
Girls 10–14 years	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
Boys 10–14 years	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
Girls 15–19 years	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
Boys 15–19 years	≥ 5	**≥ 5**	**≥ 5**	≥ 5
Women 20–49 years	**≥ 5**	**≥ 5**	**≥ 6**	**≥ 6**
Men 20–49 years	≥ 5	**≥ 5**	**≥ 5**	**≥ 5**
Women 50+ years	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
Men 50+ years	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
China	**MPA > 0.5**	**MPA > 0.6**	**MPA > 0.7**	**MPA > 0.8**
Children 2–4 years	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 6**
Children 5–9 years	**≥ 5**	**≥ 5**	≥ 6	**≥ 6**
Girls 10–14 years	≥ 5	≥ 6	≥ 6	≥ 6
Boys 10–14 years	≥ 5	≥ 6	≥ 6	**≥ 6**
Girls 15–19 years	--	**≥ 6**	--	--
Boys 15–19 years	**≥ 6**	≥ 6	**≥ 6**	**≥ 6**
Women 20–49 years	**	≥ 6	≥ 6	**≥ 6**
Men 20–49 years	≥ 5	**	**	--
Women 50+ years	≥ 5	≥ 6	≥ 6	≥ 6
Men 50+ years	≥ 5	**	≥ 6	**≥ 6**

[a] Cells are shaded grey when the best food group cut-off matches the MDD-W cut-off of 5 or more food groups. Yellow-shaded cells indicate a lower food group cut-off performed better, and amber-shaded cells indicate a higher food-group cut-off performed better.

Cut-offs are bolded when both sensitivity and specificity were at or above 60% and in red font when one of these was more than 50% but less than 60%.

A '—' indicates that there were no combinations with sensitivity and specificity both above 50%.

A "**" indicates that misclassification was > 40%, which exceeds our criterion.

PREVALENCE MATCHING

In addition to assessing sensitivity, specificity, and misclassification, we also compared the proportion of individuals above the best FGDS cut-off to the actual proportion above the corresponding MPA cut-off; in other words, we examined how well the prevalence at or above the 'best' food group cut-off – selected for balancing sensitivity and specificity – would match the prevalence above MPA of 0.50, 0.60, 0.70, etc.

Mexico

For the two youngest age groups (children 2–4 and 5–9 years), prevalence matching results were consistent with the sensitivity and specificity analyses. That is, the FGDS cut-off providing the best balance of sensitivity and specificity also gave the best 'match' with the prevalence above the corresponding MPA cut-off. For younger adolescents 10-14 years of age (both sexes), the best FGDS cut-off for balancing sensitivity and specificity (≥ 5 food groups) also gave the best match for prevalence above the lower MPA cut-offs of 0.50 and 0.60. However, at higher MPA cut-offs of 0.70 and 0.80, the best match was with a higher FGDS cut-off, but with unacceptably low sensitivity (< 50%). For older adolescents and adults (both sexes), with one exception, the best FGDS cut-off for balancing sensitivity and specificity was not the best cut-off for matching prevalence, and differences between the percent above the FGDS cut-off and the percent above the MPA cut-off were large (10–41 percentage point differences). However, the FGDS cut-offs that provided the best match again had unacceptably low sensitivity.

China

In China, except for the lower MPA cut-offs for the youngest children, the best cut-off for balancing sensitivity and specificity did not correspond to the best cut-off for matching the prevalence above the corresponding MPA cut-off. In almost all cases, a higher FGDS cut-off yielded a better match, but with unacceptably low sensitivity, as for Mexico. For children 2–9 years of age, most differences in prevalence between those above the FGDS cut-off and those above the MPA cut-off were less than 10 percentage points. However, for adolescents and adults, most differences were larger.

ADDITIONAL DESCRIPTIVE ANALYSES

Next, we compared the median MPA for individuals above and below the best FGDS cut-offs.

Mexico

For children 2–4 and 5–9 years of age, the best cut-offs differed depending on selection of the MPA cut-off. Figure 8 shows the differences in median MPA below and above cut offs of ≥ 4 food groups and ≥ 5 food groups. For all older age groups, a cut-off of ≥ 5 food groups was best for some or all MPA cut-offs. Differences in median MPA below and above the cut-off of ≥ 5 food groups are shown for adolescents and adults 20 years and older in Figure 8. The absolute differences between point estimates of median MPA among those below and above FGDS cut-offs tend to decrease with age (0.26–0.32 for 2–14-year-olds, and 0.13–0.23 for 15 years and older). However, in relative terms the differences are large at all ages;

for example, for girls and women 10 years of age and older, the median MPA among those consuming 5 or more food groups is 2–3 times higher than the MPA of those below the food group cut-off.

China

For China, best cut-offs were either ≥ 5 food groups or ≥ 6 food groups, for various age/sex/MPA cut-off combinations. Figure 9 shows differences in median MPA at both FGDS cut-offs, for each age/sex group.

As in Mexico, the absolute difference between point estimates of median MPA below and above the FGDS cut-offs decreased with age and was highest for children 2–4 years of age (0.38–0.42, depending on FGDS cut-off) and lowest among adults 20 years of age and older (0.15–0.19). As for Mexico, in relative terms the differences are large at all ages.

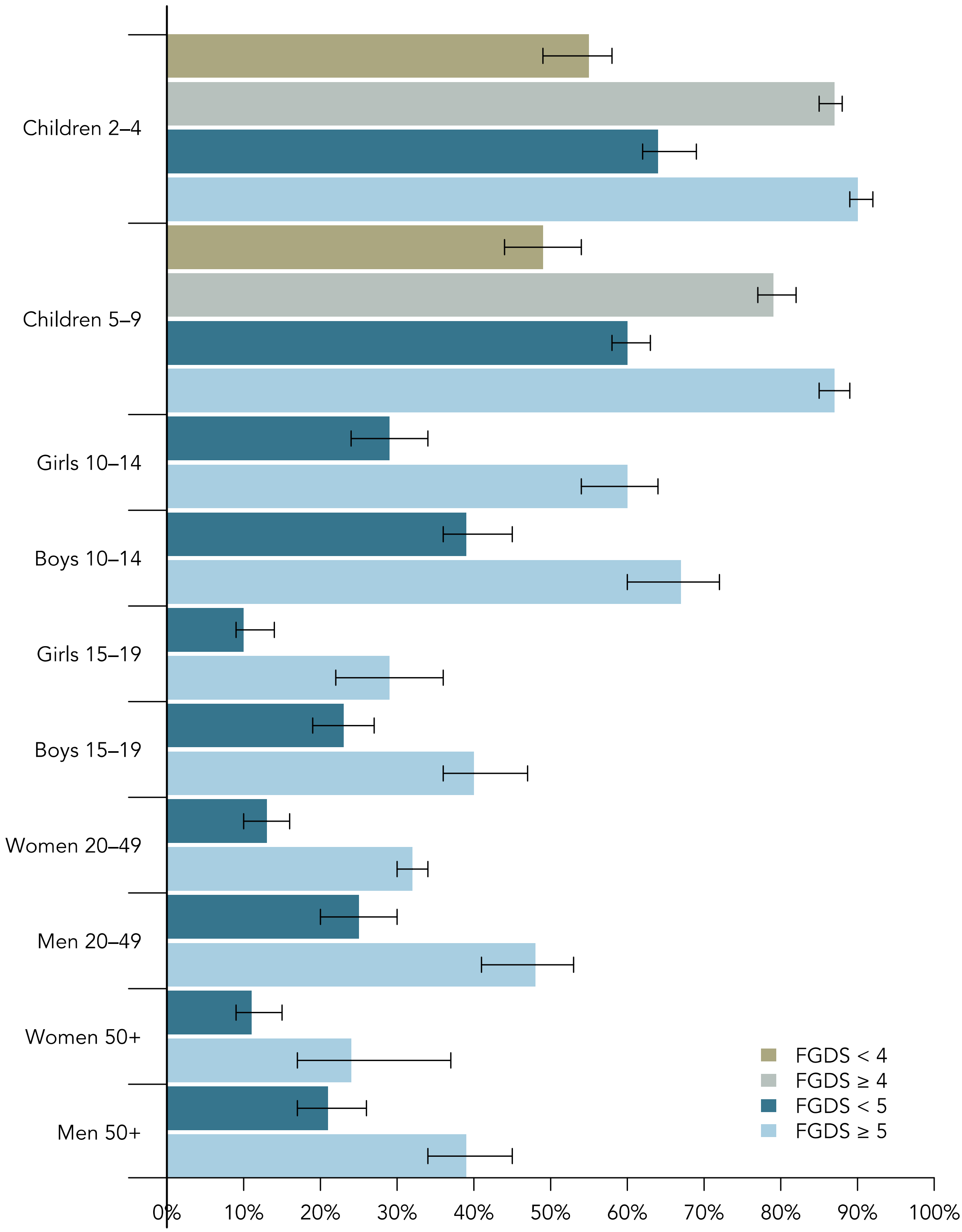

Figure 8: Median MPA below and above best FGDS cut-offs, Mexico. MPA = Mean Probability of Adequacy across 11 micronutrients; FGDS = food group diversity score (range 0–10). Differences in median MPA are statistically significant (all P-values < 0.001, except for women 50 years and older, P = 0.001). Error bars show 95% confidence intervals.

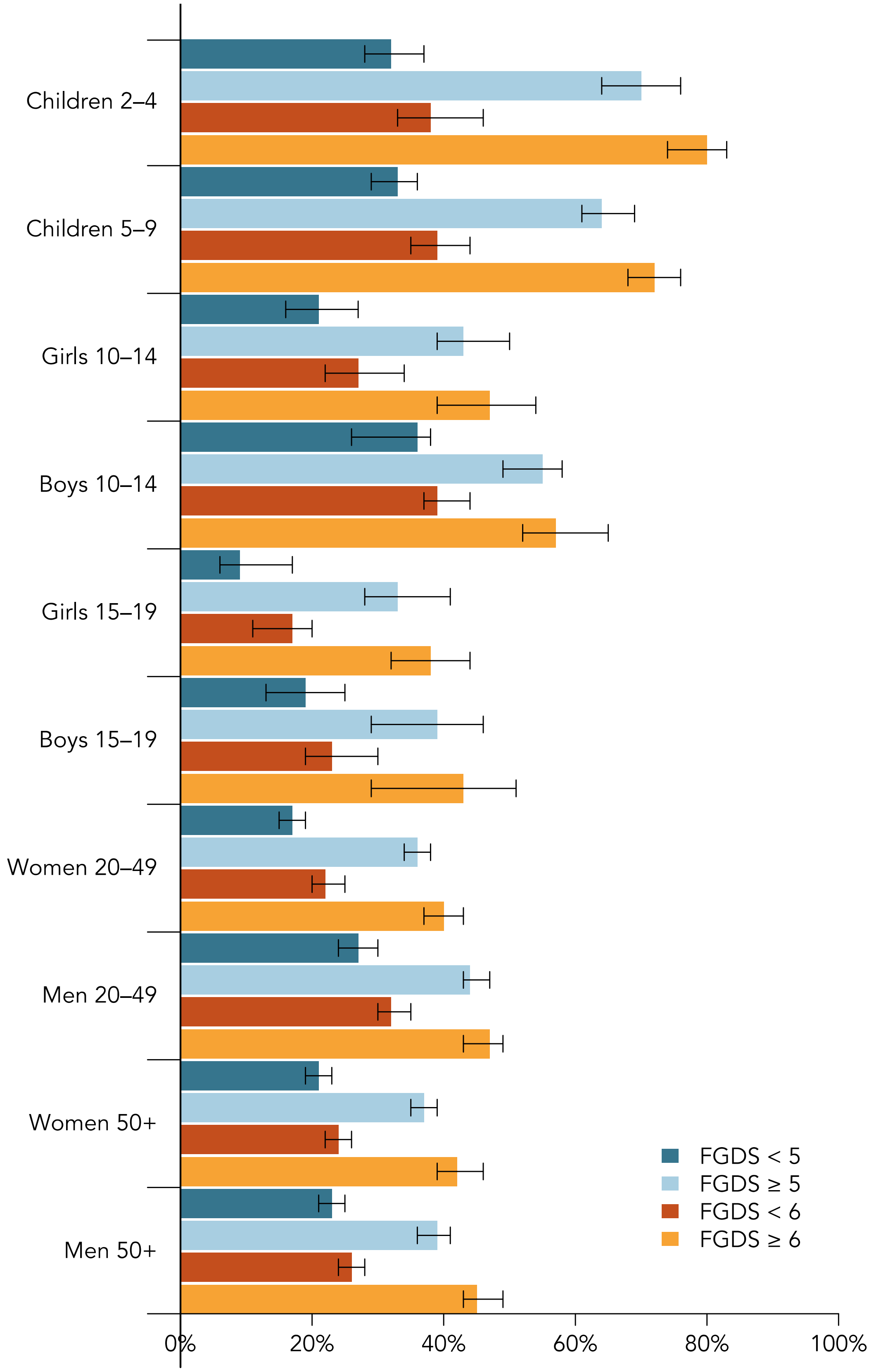

Figure 9: Median MPA below and above best FGDS cut-offs, China. MPA = Mean Probability of Adequacy across 11 micronutrients; FGDS = food group diversity score (range 0–10). Differences in median MPA are statistically significant (all P-values < 0.001

except for boys 15–19 years, P = 0.002 for 5 food group cut-off and 0.011 for 6 food group cut-off). Error bars show 95% confidence intervals.

Finally, we examined food group intake patterns above and below FGDS cut-offs.

Mexico

For these analyses we used the MDD-W cut-off of 5 or more food groups; in Mexico, 44% of respondents met this threshold for food group diversity.

Table 9 shows the percent who consumed various nutrient-rich food groups and food group combinations, comparing those below to those at or above the MDD-W food group cut-off, for all age/sex groups. Differences in consumption were marked for most food groups, and all differences were significant (P < 0.001). Similar patterns of differences were seen when children and adolescents were examined separately (results not shown).

Table 9. Percent consuming various nutrient rich food groups, Mexico[a]

Food group(s)	**< 5 food groups**	**≥ 5 food groups**	**All**	
Any animal source food	89	100	94	***
Flesh foods or eggs	75	97	85	***
Dairy	49	83	64	***
Both flesh foods or eggs, and dairy	36	80	55	***
Pulses, nuts or seeds	23	46	33	***
Any fruit or vegetable	64	98	79	***
Any fruit	23	68	43	***
Any vegetable	51	88	67	***
Two or more fruit or vegetable groups	12	68	37	***

[a] Flesh foods include meat, poultry and fish. There were five fruit and vegetable groups: 1) dark green leafy vegetables, 2) other vitamin A-rich vegetables, 3) other (non–vitamin A-rich) vegetables, 4) vitamin A-rich fruit, and 5) other fruit. Pearson's chi-squared was computed and then corrected for survey design and converted into an F-statistic. *** indicates a P-value of < 0.001.

Animal-source food consumption was common. Those achieving the MDD-W cut-off were more than twice as likely as those below the cut-off to consume the combination of both dairy and another animal-source food (meat, poultry, fish, or egg). They were also twice as likely to consume pulses, nuts, or seeds; three times as likely to consume fruit; and more than five times as likely to consume two or more of the fruit and vegetable groups.

China

Table 10 shows the same comparison for China (all age/sex groups). In China, 51% consumed 5 or more food groups. In addition, because the cut-off of 6 or more food groups performed better for many age/sex/MPA cut-offs in China, comparisons are also shown for FGDS≥ 6; 25% of the respondents met this higher threshold for diversity.

Table 10. Percent consuming various nutrient rich food groups, China[a]

Food group(s)	< 5 food groups	≥ 5 food groups	All	
Any animal source food	71	98	85	***
Flesh foods or eggs	70	98	84	***
Dairy	3	25	14	***
Both flesh foods or eggs, and dairy	2	24	13	***
Pulses, nuts or seeds	28	62	46	***
Any fruit or vegetable	92	100	96	***
Any fruit	17	60	39	***
Any vegetable	90	99	94	***
Two or more fruit or vegetable groups	34	87	61	***
Food group(s)	**< 6 food groups**	**≥ 6 food groups**	**All**	
Any animal source food	80	100	85	***
Flesh foods or eggs	79	99	84	***
Dairy	6	38	14	***
Both flesh foods or eggs, and dairy	5	38	13	***
Pulses, nuts or seeds	37	71	46	***
Any fruit or vegetable	95	100	96	***
Any fruit	27	74	39	***
Any vegetable	93	99	94	***
Two or more fruit or vegetable groups	50	96	61	***

[a] Flesh foods include meat, poultry and fish. There were five fruit and vegetable groups: 1) dark green leafy vegetables, 2) other vitamin A-rich vegetables, 3) other (non-vitamin A-rich) vegetables, 4) vitamin A-rich fruit, and 5) other fruit. Pearson's chi-squared was computed and then corrected for survey design and converted into an F-statistic.*** indicates a P-value of < 0.001.

In China, flesh foods and vegetables were commonly consumed. Among less commonly consumed food groups (dairy, fruit, and pulses/nuts/seeds), both food group cut-offs provide contrasts. Those above either cut-off were about twice as likely as those below the cut-off to consume pulses/nuts/seeds, fruits, and two or more fruit and vegetable groups, and were six to eight times more likely to consume dairy. Unlike in Mexico, where the contrasts were similar across age groups, in China the contrasts were stronger for children and adolescents. For example, children 2–9 years of age who were above either FGDS cut-off were about three times more likely to consume fruit and four times more likely to consume dairy.

CONCLUSIONS

In this report we aimed to assess associations of MDD-W and its underlying score (FGDS) with micronutrient adequacy (MPA) in two large upper-middle-income countries, and in diverse demographic groups. To date, few studies document performance of the FGDS and MDD-W using nationally or provincially representative data from large upper-middle-income countries, including both rural and urban settings, and for all ages two and older. Analysis of data from additional upper-middle-income countries, and from diverse age groups at all country income levels, would be useful.

Associations reported here between FGDS and MPA are reasonably strong and similar to those reported during development of MDD-W (5). Specifically, correlations and AUC for all age/sex groups, in both countries, are in similar ranges. For example, the AUC, which summarises the predictive strength of the indicator, ranged from 0.62–0.81 across nine data sets in the analyses during indicator development (5), and ranged from 0.65–0.84 and 0.64–0.80 across age/sex groups in Mexico and China, respectively, across four MPA cut-offs. This supports the potential use of FGDS as a proxy indicator of micronutrient adequacy of the diet for children two years of age and older, adolescents, and adults in China and Mexico.

Concerning the use of the MDD-W cut-off of five or more food groups, results were mixed. In our results for Mexico, this cut-off generally provided the best balance between sensitivity and specificity for most age/sex groups at most MPA cut-offs. A similar study from Mexico also aimed to determine cut-offs and, using different methods, identified different cut-offs for some age groups.[6] The two analyses differed in: selection of nutrient reference values; age groupings; the food composition table employed; and the range of MPA cut-offs considered. Our differing results highlight that selection of food group cut-offs may vary depending on study methodologies. In our results for China, a higher cut-off of six or more food groups performed better for most age/sex groups. In China, use of the MDD-W cut-off of five or more food groups would result in high levels of misclassification due to low specificity - meaning that individuals with low MPA would be wrongly classified as having higher likelihood of micronutrient adequacy.

Results were similar when considering the age range for which the MDD-W was developed; that is, grouping girls and women of reproductive age (15–49 years; see Annex 1). In our analysis the MDD-W cut-off of five food groups would be selected in Mexico but had low specificity in China. During development of MDD-W using data from low- and lower middle-income countries, it was also the case that results were not consistent across all countries. The cut-off of five or more food groups performed best in the largest number of contexts but resulted in rather high misclassification in some contexts (33).

In the case of MDD-W, the results from indicator development were presented and discussed in an expert consultation. The benefits of a feasible, lower-cost standard dichotomous indicator for use in global monitoring were balanced against the lower performance in some contexts, and the MDD-W - including the five-food-group cut-off - was affirmed.[7]

Looking beyond the results for indicator characteristics (sensitivity, specificity, and misclassification) our other analyses provide support for construct validity in both countries. In Mexico, comparisons of mean MPA in groups consuming fewer than five compared to five or more food groups (Figure 8) showed significant differences, and the magnitude of

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[6] Sonia Rodríguez-Ramírez, Tania G Sánchez-Pimienta, Carolina Batis, Gustavo Cediel,Joaquín A Marrón-Ponce. Minimum Dietary Diversity in Mexico: Establishment of cut-off point to predict micronutrients adequacy. Unpublished document, currently under review.

[7] See: https://www.fantaproject.org/news-and-events/impact-story-measuring-quality-womens-diets, for summary of the process.

the differences was meaningful. The cut-off also provided a meaningful distinction in likelihood of consumption of nutrient-rich food groups that are less likely to be consumed in Mexico - pulses/nuts/seeds, and fruit - and in diversity in fruit and vegetables consumed (Table 9). In China, comparisons of mean MPA using both cut-offs (≥ 5 and ≥ 6) showed significant and meaningful differences (Figure 9). Comparisons of food group consumption above and below each cut-off also provided meaningful contrasts (Table 10). These comparisons support construct validity of the indicator in this context.

In conclusion, this analysis has shown that when more resource-intensive measurement is infeasible, FGDS is a meaningful proxy indicator of micronutrient adequacy of the diet for diverse demographic groups and in diverse country income settings. Importantly, FGDS was not developed to reflect NCD risk and should be complemented by other indicators. This analysis has also demonstrated that the issue of universal cut-offs remains challenging and unresolved, requiring additional studies in middle-income countries and with diverse age/sex groups.

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ANNEXES

ANNEX 1: SENSITIVITY ANALYSES

ANALYSES EXCLUDING LOW AND HIGH ENERGY INTAKE REPORTERS

Intakes were evaluated relative to Goldberg criteria, using the same cut-offs as in the Women's Dietary Diversity Project (WDDP): Individuals with energy intakes below 0.9 x BMR (basal metabolic rate) were considered 'low energy reporters', and individuals with energy intakes above 3.0 x BMR 'high energy reporters' (5,22).[8] Reported intakes outside these ranges were not excluded for the main analysis as this can introduce unknown biases (20,21); however, sensitivity analyses were performed excluding both low and high extremes. In addition, low energy reporters, 'acceptable' energy reporters, and high energy reporters were compared based on characteristics known to be associated with under-reporting in other contexts (body mass index (BMI), sex, age group, SES group, education level, smoking, and dieting[9] to assess the potential for differential bias in reporting across these groups.

In Mexico, nearly one-quarter of individuals in the sample were excluded based on a BMR factor of < 0.9 (low energy intake reporters) or > 3.0 (high energy intake reporters); most of these (over 90% of potential mis-reporters) were low energy intake reporters. The highest proportion of exclusions from the original sample was among older women, as shown in Table A1-1.

In China, approximately one in five were excluded, and, as in Mexico, over 90% of the potential mi-reporters were low energy intake reporters. In China, the highest proportion of exclusions was among young children 2–4 years of age and adolescents.

Table A1-1. Exclusions by age and sex group

	Mexico		China	
Age/sex group	Number	Percent[a]	Number	Percent[a]
Children 2–4 years	280	17	139	31
Children 5–9 years	341	17	181	23
Adolescent girls 10–14 years	153	20	103	31
Adolescent boys 10–14 years	163	20	76	21
Adolescent girls 15–19 years	186	28	55	29
Adolescent boys 15–19 years	148	25	71	34
Women 20–49 years	335	30	632	20
Men 20–49 years	186	26	632	23
Women 50+ years	282	37	638	18
Men 50+ years	183	28	585	18
Total	**2257**	**23**	**3112**	**21**

[8] The cut-off of 0.9 corresponds to the lower 95% confidence limit for a low physical activity level (PAL), with a PAL factor of 1.55, based on a single day of intake (rounded to one decimal from a BMR factor of 0.87) (19). The higher cut-off of 3.0 corresponds to the higher 95% confidence limit for high physical activity (PAL factor = 1.95), based on four days of intake (rounded to one decimal from a BMR factor of 2.95). An upper confidence limit of the BMR factor for single-day intakes and high physical activity would have been preferable but was not provided by Black, 2000 (19).

[9] Information on self-reported dieting is available for China only, for children 6–17 years only.

[a] As a percent of the total sample from the first recall day.

Table A1-2 shows the difference in energy intakes before and after exclusions.

Table A1-2. Median energy intakes (kilocalories) before and after exclusion of extreme energy intake reporters, by age and sex

	Mexico			China		
	Before	**After**	**Difference**	**Before**	**After**	**Difference**
Children 2–4 years	1270	1323	53	967	1130	163
Children 5–9 years	1553	1622	69	1293	1415	122
Girls 10–14 years	1684	1835	151	1420	1656	236
Boys 10–14 years	1896	2031	135	1773	1957	184
Girls 15–19 years	1663	1907	244	1538	1744	206
Boys 15–19 years	2081	2372	291	1862	2218	356
Women 20–49 years	1627	1862	235	1703	1827	124
Men 20–49 years	2012	2332	320	2091	2314	223
Women 50+ years	1397	1661	264	1651	1771	120
Men 50+ years	1782	2057	275	1937	2076	139

Considering the lower energy needs of young children, the kilocalorie difference before and after exclusions in China represents a large proportion of intake compared to that for other age groups. One possibility is that food consumed outside of the home (for example in day care or pre-school settings) was not entirely captured.

In both countries, patterns of macronutrient and sugar intake (as a percent of total energy intake) were very similar before and after exclusions.

Estimated MPA before and after exclusions are shown in Table A1-3.

Table A1-3. Mean probability of adequacy before and after exclusion of extreme energy intake reporters, by age and sex

Mexico	**Before exclusions**		**After exclusions**		**Difference**	
	Mean	**Median**	**Mean**	**Median**	**Means**	**Medians**
Children 2–4 years	0.72	0.79	0.77	0.83	0.05	0.04
Children 5–9 years	0.67	0.72	0.73	0.76	0.06	0.04
Girls 10–14 years	0.44	0.41	0.52	0.52	0.08	0.11
Boys 10–14 years	0.52	0.53	0.60	0.61	0.08	0.08
Girls 15–19 years	0.24	0.16	0.33	0.27	0.09	0.11
Boys 15–19 years	0.35	0.30	0.44	0.43	0.09	0.13
Women 20–49 years	0.26	0.21	0.35	0.32	0.09	0.11
Men 20–49 years	0.39	0.36	0.49	0.51	0.10	0.15
Women 50+ years	0.24	0.16	0.38	0.33	0.14	0.17
Men 50+ years	0.31	0.29	0.41	0.40	0.10	0.11
China	**Before exclusions**		**After exclusions**		**Difference**	
	Mean	**Median**	**Mean**	**Median**	**Means**	**Medians**
Children 2–4 years	0.52	0.53	0.63	0.66	0.11	0.13
Children 5–9 years	0.49	0.50	0.58	0.59	0.09	0.09
Girls 10–14 years	0.36	0.35	0.45	0.46	0.09	0.11

Boys 10–14 years	0.45	0.44	0.52	0.52	0.07	0.08
Girls 15–19 years	0.26	0.23	0.34	0.32	0.08	0.09
Boys 15–19 years	0.31	0.27	0.40	0.40	0.09	0.13
Women 20–49 years	0.30	0.27	0.35	0.34	0.05	0.07
Men 20–49 years	0.38	0.36	0.44	0.43	0.06	0.07
Women 50+ years	0.32	0.28	0.36	0.33	0.04	0.05
Men 50+ years	0.33	0.30	0.37	0.35	0.04	0.05

Exclusions of extreme energy intake reporters resulted in higher estimates of mean and median MPA for all age/sex groups. In Mexico, differences were smaller for children under 10 years of age, but in China differences were large for young children and smallest for adults (20+ years).

Higher MPA are naturally accompanied by an increase in the percent of individuals above MPA cut-offs, as illustrated in Table A1-4 for one cut-off (MPA > 0.70).

Table A1-4. Percent and number above a Mean Probability of Adequacy cut-off of 0.70 before and after exclusion of extreme energy intake reporters, by age and sex

Mexico	Before exclusions		After exclusions	
	Percent	**Number**	**Percent**	**Number**
Children 2–4 years	61	986	69	929
Children 5–9 years	52	1043	59	973
Girls 10–14 years	20	152	24	149
Boys 10–14 years	30	244	38	245
Girls 15–19 years	7	48	11	51
Boys 15–19 years	12	68	19	83
Women 20–49 years	6	62	10	77
Men 20–49 years	16	109	22	113
Women 50+ years	8	59	13	61
Men 50+ years	8	48	12	54
China	**Before exclusions**		**After exclusions**	
	Percent	**Number**	**Percent**	**Number**
Children 2–4 years	33	147	46	143
Children 5–9 years	27	206	33	197
Girls 10–14 years	11	36	14	31
Boys 10–14 years	16	57	20	56
Girls 15–19 years	4	7	4	6
Boys 15–19 years	5	11	7	10
Women 20–49 years	6	207	7	182
Men 20–49 years	9	251	12	248
Women 50+ years	7	249	8	225
Men 50+ years	7	231	8	218

In Mexico, after exclusions there were 4-8 percentage point increases in the proportion exceeding an MPA of 0.70. In China, differences were small for adults (1–3 percentage points) and largest for the youngest children, with a 13-percentage point increase for 2–4-year-olds.

In both countries, patterns of food group intake were similar before and after exclusions, with the same food groups consumed by at least 50% in all age/sex groups and the same food groups rarely consumed by any group. In Mexico, mean food group scores (out of 10) increased slightly to a range of 4.3–4.6, compared to 4.1–4.4 before exclusions. Median scores (previously '4' for all age/sex groups) increased to 5 for adults 20–49 years of age and also for women 50 years or older.

In China, mean food group scores also increased slightly to a range of 4.6–4.9, compared to 4.5–4.8 before exclusions. Median scores remained at '5' for all groups under 50 years of age and increased to '5' for adults 50+ years of age.

Correlations between FGDS and MPA remained significant (all $P < 0.001$) and the relationship between them was linear for most age/sex groups. FGDS also remained significant in regressions controlling for age, height, pregnancy/lactation, and total energy intake, as was the case before exclusions ($P < 0.001$ for all age/sex groups, both countries).

In the ROC analysis for Mexico, all AUC decreased slightly, and all remained statistically significantly different from 0.50 ($P < 0.001$ for all age/sex groups at all MPA cut-offs). Point estimates for AUC remained above our criterion value of 0.70 for most age/sex groups for all or most MPA cut-offs. As before, AUC were below 0.70 for adolescent boys 15–19 years (3 of 4 MPA cut-offs) and men 20-49 years (2 of 4 MPA cut-offs). In addition, AUC was 0.68–0.69 for 3 of 4 MPA cut-offs for girls 10–14 years of age, for one cut-off for girls 15–19 and for one cut-off for men 50 years and older.

In China, AUC increased slightly for some age/sex/MPA combinations and decreased slightly for others. AUC remained significant ($P < 001$) for most age/sex groups and were not significant for several MPA cut-offs for older adolescents, as before. Differences in point estimates of AUC were larger for adolescents, where small sample sizes entail wide confidence intervals. AUC remained above the criterion value for most or all MPA cut-offs for children under 15 and for older adults 50+ years of age. For older adolescents and adults 20–49 years of age, AUC were slightly below 0.70 (0.66–0.69) for some or all MPA cut-offs.

In summary, in both countries, results for indicator performance, including overall predictive power and best FGDS cut-offs, remained largely the same.

In addition to repeating analyses after excluding low and high energy intake reporters, we also compared low and high reporters to 'acceptable' reporters, to gain insight into potential biases and into how misreporting could be impacting results. Because we were more concerned with potential under-reporting, we compared groups based on characteristics that have previously been identified as associated with under-reporting, including age, sex, BMI, education level, socioeconomic status, and smoking (20). In Mexico, low and high energy reporting was not associated with sex, smoking, or a proxy for socioeconomic status but was associated with age, BMI, and education level. In China, because of the large sample size, most associations were statistically significant, but some percentage point differences were small and not of practical significance.

Table A1.5 shows differences in energy intake reporting in association to the characteristics noted above. For Mexico, all significant associations are included in the table. For China, associations are included when the prevalence of low or high energy intake reporting differed by at least 5 percentage points across sub-groups.

Table A1.5. Characteristics of low, acceptable, and high energy intake reporters[a]

Mexico	**Percent low**	**Percent acceptable**	**Percent high**	**P-value[b]**
2–4 years	13	82	5	0.000
5–9 years	13	83	4	
10–14 years	18	81	1	
15–19 years	27	72	1	
20–49 years	27	72	1	
50+ years	33	67	0	
Underweight	14	72	14	0.000
Normal weight	17	81	2	
Overweight	25	74	1	
Obese	37	63	0	
No education	31	68	1	0.006
Primary	25	73	1	
Secondary	22	76	2	
Tertiary	25	74	1	

China	Percent low	Percent acceptable	Percent high	P-value[b]
2–4 years	30	69	1	0.000
5–9 years	22	77	2	
10–14 years	25	74	1	
15–19 years	31	69	1	
20–49 years	20	79	1	
50+ years	17	82	1	
Underweight	14	83	3	0.000
Normal weight	17	82	2	
Overweight	22	77	1	
Obese	31	69	0	
No diet	24	75	1	0.023
Diet for weight gain	20	77	3	
Diet for weight loss	37	62	1	

[a] Low reporters: energy intake < 0.9 * basal metabolic rate (BMR); acceptable reporters: energy intake 0.9 - 3.0 * BMR; high reporters: energy intake > 3.0 * BMR.

[b] Pearson's chi-squared was computed then corrected for survey design and converted into an F-statistic.

In Mexico, high energy intake reporting was slightly more common for children 2–9 years of age and markedly more common for underweight individuals. Conversely, low energy intake reporting increased markedly with age, reaching one in three for individuals 50 years and older. Low energy intake reporting also increased markedly with BMI, with one quarter of overweight individuals and more than a third of obese individuals reporting low energy intakes. Energy intake reporting was less strongly associated with education level.

In China, high energy intake reporting was rare. As in Mexico, low energy intake reporting increased markedly with BMI, and in the case of China it was also high among children 6–17 years[10] who reported that they were on a weight-loss diet. The pattern of low energy intake reporting by age differed from that of Mexico, with the highest prevalence for young children (2–4 years of age) and older adolescents (15–19 years of age).

In summary, low energy intake reporting was associated with several characteristics, as has been reported elsewhere. However, it is not possible to determine the extent of under-reporting vs. true low intakes, whether due to dieting, poverty, or other causes. It is likely that some low energy intake reporting is false, thereby falsely depressing PAs and MPAs for certain groups and potentially differentially affecting associations with indicators.

COMPARISON OF TWO SETS OF NUTRIENT REFERENCE VALUES FOR WOMEN OF REPRODUCTIVE AGE

For our analyses we primarily used a set of recently proposed harmonised nutrient reference values (NRVs), intended for global use (23). However, we also aimed to compare

[10] Data on dieting were not available for other age groups.

our results for indicator performance to results from the Women's Dietary Diversity Project (WDDP) analyses undertaken during development of the MDD-W (5). To assess whether the selection of NRVs could have an impact on overall judgments of indicator performance, we performed a sensitivity analyses for women of reproductive age (WRA, 15–49 years) only, using both sets of NRVs.

To assess impacts on judgements of indicator performance, we compare the following analyses using the two sets of NRVs:

- Assessment of PA and MPA under the two sets of NRVs
- Correlations between FGDS and MPA, with and without controlling for total energy intake
- AUC from ROC analyses
- Judgements of best food group score cut-offs based on sensitivity, specificity and misclassification

These sensitivity analyses use a different age grouping than the main results reported above. To align with the WDDP-II analyses, older adolescent girls 15–19 years of age are grouped with women 20–49 years of age for analysis.

Table A1-6 shows PA for individual micronutrients as well as MPA for WRA using each set of NRVs.

Table A1-6. Probability of nutrient adequacy for women of reproductive age under two sets of nutrient reference values

Mexico	**Harmonised NRVs[a]**		**NRVs as in WDDP[a]**	
	Probability of adequacy		**Probability of adequacy**	
Nutrient	**Mean**	**Median**	**Mean**	**Median**
Thiamine (mg/d)	0.33	0.10	0.33	0.10
Riboflavin (mg/d)	0.18	0.00	0.53	0.58
Niacin (mg/d)	0.33	0.09	0.32	0.08
Vitamin B6 (mg/d)	0.18	0.00	0.30	0.01
Folate (µg/d)	0.18	0.00	0.08	0.00
Vitamin B12 (µg/d)	0.36	0.02	0.36	0.00
Vitamin C (mg/d)	0.32	0.00	0.56	0.96
Vitamin A (RE/d)	0.14	0.00	0.63	0.87
Calcium (mg/d)	0.36	0.15	0.31	0.09
Iron (mg/d)	0.21	0.15	0.21	0.15
Zinc (mg/d)	0.26	0.03	0.46	0.32
MPA	0.26	0.20	0.37	0.35

China	Harmonised NRVs[a]		NRVs as in WDDP[a]	
	Probability of adequacy		Probability of adequacy	
Nutrient	**Mean**	**Median**	**Mean**	**Median**
Thiamine (mg/d)	0.29	0.03	0.29	0.03
Riboflavin (mg/d)	0.05	0.00	0.23	0.01
Niacin (mg/d)	0.60	0.77	0.59	0.75
Vitamin B6 (mg/d)	0.13	0.00	0.21	0.00
Folate (µg/d)	0.30	0.08	0.12	0.00
Vitamin B12 (µg/d)	0.35	0.01	0.34	0.00
Vitamin C (mg/d)	0.37	0.03	0.79	1.00
Vitamin A (RE/d)	0.29	0.01	0.77	1.00
Calcium (mg/d)	0.04	0.00	0.03	0.00
Iron (mg/d)	0.43	0.35	0.43	0.35
Zinc (mg/d)	0.48	0.45	0.71	0.97
MPA	0.30	0.26	0.41	0.40

[a] NRV = nutrient reference value. Harmonised NRVs are from Allen et al. (23), except for iron. NRVs as in the WDDP analysis are from the Women's Dietary Diversity Working Project Study Group (5); see Annex 3 for details of NRVs.

The newer, harmonised NRVs are higher for several nutrients, resulting in a lower estimate for some individual nutrient PAs and for the summary, MPA; however, the harmonised NRV for folate is lower and for this nutrient PA is higher using these NRVs. Differences in PA were largest for riboflavin, folate, vitamin A, vitamin C, and zinc. In both countries, the point estimate for mean MPA was 0.11 lower using the harmonised NRVs.

Correlation coefficients describing the relationship between FGDS and MPA are somewhat higher when using the WDDP NRVs as compared to the harmonised NRVs ($P < 0.001$ for all correlations):

Not controlling for total energy intake:

	Mexico	**China**
Harmonised NRVs:	0.46	0.40
WDDP NRVs:	0.51	0.43

Controlling for energy intake:

	Mexico	**China**
Harmonised NRVs:	0.28	0.41
WDDP NRVs:	0.36	0.45

Regressions controlling for age, height, pregnancy/lactation status as well as total energy intake were similar, with slightly larger regression coefficients for FGDS when the WDDP NRVs were used to estimate MPA.

Figure A1-1 shows MPA changes with increases in the FGDS score, for each set of NRVs. At any given level of food group diversity, MPA is higher when the WDDP NRVs are used to estimate it.

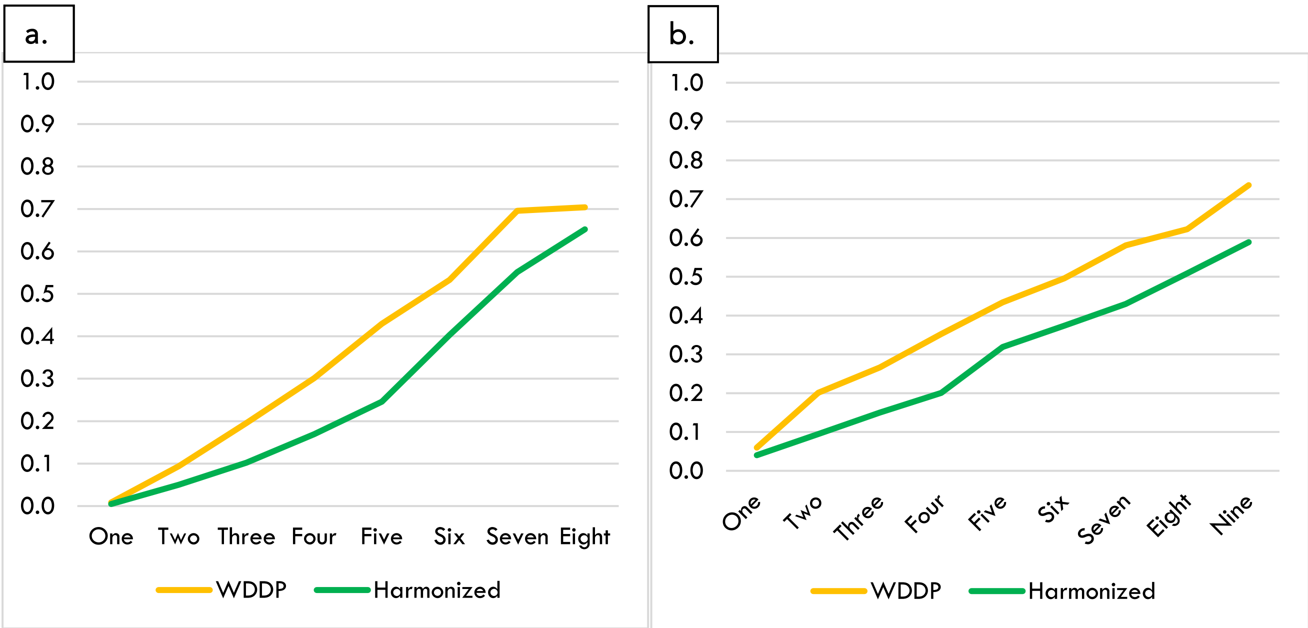

Figure A1-1: Increase in MPA by FGDS score for WRA. MPA = Mean Probability of Adequacy; WRA = women of reproductive age, 15–49 years. (a) Mexico; (b) China. Data points representing fewer than 5 observations are not shown.

Next, we assessed AUC for the FGDS indicator, under both sets of NRVs. Consistent with the higher mean MPA when estimated with the WDDP NRVs, the percent of WRA above each MPA cut-off was also higher for the WDDP NRVs, roughly double the percent than when using the harmonised NRVs (Table A1-7).

Table A1-7. Percent of observation days above selected cut-offs for Mean Probability of Adequacy among women of reproductive age (15–49 years)

	Mexico		**China**	
	Harmonised NRV	**WDDP NRV**	**Harmonised NRV**	**WDDP NRV**
	Percent	**Percent**	**Percent**	**Percent**
MPA > 50%	17	30	21	33
MPA > 60%	10	21	11	22
MPA > 70%	6	13	6	12
MPA > 80%	2	4	3	6

Considering these same four MPA cut-offs, for Mexico AUC are all significantly different from 0.50 ($P < 0.001$) and all are above 0.70. Point estimates of AUC are slightly higher when the harmonised NRVs are used to estimate MPA. However, the 95% confidence intervals for the AUC all overlap substantially. For China, all AUC are significantly different from 0.50 ($P < 0.001$) for both sets of NRVs. When the WDDP II NRVs are used to estimate MPA, all AUC are over the criterion value of 0.70. When using the harmonised NRVs, AUC at several MPA cut-offs fall just below 0.70. However, differences are small (for example, 0.69 vs. 0.71) and confidence intervals overlap.

Next, we examined sensitivity, specificity, and misclassification under both sets of NRVs, to assess whether judgments of best cut-offs would differ. Table A1-8 provides a summary of cut-offs providing the best balance between sensitivity and specificity.

Table A1-8. Food group cut-offs with the best balance between sensitivity and specificity for girls and women of reproductive age (15-49 years), using two sets of nutrient reference values[a]

Mexico	**MPA > 0.5**	**MPA > 0.6**	**MPA > 0.7**	**MPA > 0.8**
NRVs as in WDDP	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
Harmonised NRVs	**≥ 5**	**≥ 5**	**≥ 5**	**≥ 5**
China	**MPA > 0.5**	**MPA > 0.6**	**MPA > 0.7**	**MPA > 0.8**
NRVs as in WDDP	≥ 5	**	≥ 6	≥ 6
Harmonised NRVs	**	≥ 6	≥ 6	**≥ 6**

[a] Cells are shaded in grey when the best food group cut-off matches the MDD-W cut-off of 5 or more food groups. Amber-shaded cells indicate a higher food-group cut-off performed better.
Cut-offs are bolded when both sensitivity and specificity were at or above 60% and in red font when one of these was more than 50% but less than 60%.
A '—' indicates that there were no combinations with sensitivity and specificity both above 50%.
A "**" indicates that misclassification was > 40%, which exceeds our criterion.

For Mexico, under both NRV scenarios the MDD-W food group cut-off of five or more food groups provided the best balance between sensitivity and specificity. For China, the food group cut-off of five or more groups provided the best balance for the MPA cut-off of 0.50, and a cut-off of six or more groups provided the best balance at MPA cut-offs of 0.70 and 0.80. For the MPA cut-off of 0.60, the five-group cut-off was best when using the WDDP-II NRVs (however, with 42% misclassification) and the six-group cut-off was best when using the harmonised NRVs.

These results are consistent with the original WDDP-II analyses, where the MPA cut-off of 0.60 was used. In both Mexico and China, use of the WDDP NRVs yielded the same best FGDS cut-off of 5 or more food groups. While misclassification was high for China, this was also true for some data sets during development of MDD-W. The selected cut-off of five or more food groups was the one that performed best across all data sets, but it did not perform best in each.

In summary, use of the harmonised NRVs resulted in lower estimates of PA and MPA. AUC results do not indicate that selection of NRVs creates important differences in predictive power of FGDS. With one exception in China, use of the two sets of NRVs resulted in selection of the same FGDS cut-off as providing the best balance of sensitivity and specificity. When using the WDDP NRVs at an MPA cut-off of 0.60 (that is, replicating the analysis (34)) the MDD-W cut-off of five or more food groups would be selected, albeit with very high misclassification in China.

CONSIDERATION OF AN ALTERNATIVE INDICATOR WITH LOWER QUANTITY CONSTRAINT

MDD-W was developed for contexts where the simplest, lowest-cost approaches are needed and where collection of quantitative or semi-quantitative dietary recall data is infeasible. Yet, based on analyses during development of MDD-W, exclusion of trivial quantities (< 15g/day, or ~1 tablespoon, for many foods) strengthened associations to MPA. This cut-off was tested in analyses during development of MDD-W with the idea that exclusion of trivial quantities might be feasible even in simple surveys.

However, operationalising this in non-quantitative surveys has remained a challenge. The suggested approach was to categorise certain items likely to be consumed in trivial quantities into a 'condiments and flavourings' category, which would not count in any food group in the score (6). These items included fresh and dried herbs, spices, garlic, ginger, sauces and pastes (e.g., tomato products) added as flavourings, and others.

This approach was taken with the current data sets, and items in the condiments and flavourings categories were not counted in any food group. As a sensitivity analysis, we examined how well exclusion of these items succeeded in eliminating trivial quantities of consumption, for each food group. To do this, we first coded items as described above, so that condiments and flavourings would not count. We note that doing so *ex post* with quantitative data does not perfectly mimic data collected in simple non-quantitative surveys, as the recall methods are very different, particularly with regard to accounting for mixed dishes. We then duplicated the analysis in the main body of this report with assessment of an FGI indicator where any amount ≥ 1 g could 'count' in the food group score. Here, we report how this impacted prevalence of consumption for each food group and the mean and median FGI scores.

Mexico

For Mexico, *a priori* exclusion of condiments and flavourings failed in eliminating items consumed in trivial quantities (< 15 g/day), particularly for three food groups: pulses, 'other' vegetables, and 'other' vitamin A-rich fruits and vegetables. Starchy staples were nearly universally consumed and estimates of prevalence of consumption were very similar whether the 1 g or the 15 g cut-off was applied. Estimates were also similar for rarely consumed food groups (nuts and seeds, and dark green leafy vegetables).

China

For China, there were few reports of trivial consumption (< 15 g) for any food group. This could be due to the dietary methods employed and/or to the *a priori* exclusion of condiments and flavourings. The largest impact was for children aged 2–4 years, but all differences were small even for this age group (maximum of 5 percentage points).

Differences for all food groups are shown in Table A1-9, for both countries.

Table A1-9. Differences in estimation of prevalence of consumption of food groups, when 1-gram or 15-gram minima are applied

	Mexico	China

	Range of differences[a]	Mean[a]	Range of differences[a]	Mean[a]
	Percentage point differences			
Grains, white roots and tubers, and plantains	0 - 3	1	0	0
Pulses (beans, peas, and lentils)	18 - 25	22	0-5	1
Nuts and seeds	1 - 2	2	0-1	0
Dairy	3 - 7	5	0	0
Meat, poultry, and fish	1 - 6	3	0-3	1
Eggs	3 - 7	5	0-1	0
Dark green leafy vegetables	1 - 3	2	0-1	0
Other vitamin A-rich fruits and vegetables	8 - 13	9	0-2	1
Other vegetables	11 - 22	16	0-4	1
Other fruits	3 - 8	5	0	0

[a] Range of differences in estimates of prevalence of consumption across 10 age/sex groups. The mean is the simple unweighted average of the differences across the age/sex groups.

Table A1-10 shows the impact of these differences on mean and median FGDS scores, by age/sex group. For Mexico, median food group scores were increased by one point for each age/sex group, and differences in means were also similar across groups (0.6–0.8). For China, median scores were the same for all but one age/sex group, and mean scores were either the same or differed by only 0.1.

Table A1-10. Differences in FGI scores when a 1 g or a 15 g minimum is applied for counting each food group, Mexico

		Mexico		China	
		Mean	Median	Mean	Median
Children 2–4 years	1 g	5.0	5.0	4.8	5.0
	15 g	4.2	4.0	4.7	5.0
Children 5–9 years	1 g	5.1	5.0	4.8	5.0
	15 g	4.3	4.0	4.7	5.0
Girls 10–14 years	1 g	4.9	5.0	4.8	5.0
	15 g	4.2	4.0	4.7	5.0
Boys 10–14 years	1 g	5.0	5.0	4.8	5.0
	15 g	4.4	4.0	4.8	5.0
Girls 15–19 years	1 g	4.8	5.0	4.8	5.0
	15 g	4.1	4.0	4.8	5.0
Boys 15–19 years	1 g	5.0	5.0	4.7	5.0
	15 g	4.3	4.0	4.7	5.0
Women 20–49 years	1 g	5.0	5.0	4.7	5.0
	15 g	4.3	4.0	4.7	5.0
Men 20–49 years	1 g	5.0	5.0	4.6	5.0
	15 g	4.4	4.0	4.5	5.0
Women 50+ years	1 g	5.0	5.0	4.6	5.0
	15 g	4.3	4.0	4.5	4.0
Men 50+ years	1 g	5.0	5.0	4.5	4.0
	15 g	4.3	4.0	4.5	4.0

ANNEX 2: STATISTICAL METHODS

ESTIMATING PROBABILITY OF ADEQUACY AND MEAN PROBABILITY OF ADEQUACY

Estimating probability of adequacy for each of the eleven micronutrients followed the same approach as in the two phases of the Women's Dietary Diversity Project (5,22). In brief, this involves the following steps:

1. Transform nutrient intakes: Nutrient intakes are nearly always skewed; intake distributions need to be adjusted to approximate normal. We use a Box-Cox transformation (a power transformation) for energy and each micronutrient;
2. Calculate individual and population means for intakes of each nutrient, using the transformed variables;
3. Calculate within- and between-person variances for the transformed intake variables;
4. Using these variances, calculate the best linear unbiased predictor (BLUP) of the usual intake for each nutrient, for each individual;
5. Using the BLUPs, calculate the probability of adequacy for iron from IOM tables for all population groups except for pregnant and lactating women;
6. With the exception of iron for population groups other than pregnant and lactating women, information on the distribution of requirements (CV/SD) is available and distributions are assumed to be approximately normal;

   For these remaining nutrients and for iron for pregnant and lactating women, we transform the requirement distributions using the same power transformation as selected above for each nutrient. This is accomplished through generating a random normal variable (with n = 1000) to simulate each requirement distribution; this distribution is then transformed;
7. The probability of adequacy (PA) for each nutrient (excluding iron for all groups other than pregnant and lactating women) can now be calculated. Then all PA, including iron, are averaged to form MPA.

GENERAL NOTES ON STATISTICAL METHODS

1. For all statistical tests, P-values < 0.05 were considered significant.
2. To test the association between categorical variables, Pearson's chi-squared was computed for the hypothesis that the rows and columns in a cross-tabulation of the variables are independent. This test statistic was then corrected for the survey design (considering sampling weights, if available, primary sampling units, and strata) and converted into an F-statistic in Stata to derive the P-value.
3. To test for differences in MPA by a categorical variable (such as sex or being below/at or above a certain food group cut-off), median MPA was determined and a new dichotomous variable was created with values of zero if MPA ≤ median MPA,

and values of one if MPA> median MPA. This new variable was then tested against the categorical variable by means of a cross-tabulation, as described above.

4. For each age/sex group, MPA was transformed to approximate normality, and transformed MPA was used in regressions and correlations (using Pearson's correlation coefficient) to satisfy the requirement of approximately normally distributed variables. For the same reason, the BLUP of energy intake was used to control for energy intakes in correlations and regressions, and the BLUPs of micronutrient intakes were used in correlations with the food group indicator.

5. For some descriptive results (e.g., food group indicators, food group patterns) results are presented using data from a single day. This is because data are not available from all individuals for multiple days. All results related to probability of adequacy and BLUPs of energy and nutrient intakes, however, reflect the contribution of information from multiple recall days.

6. Sampling weights were not applied when examining the associations of indicators (correlations, regressions, ROC, and sensitivity-specificity analyses), but they were used when generating descriptive statistics, such as prevalence rates, mean and median values (this was only done for Mexico because sampling weights are not available for the CHNS data).

ANNEX 3: NUTRIENT REFERENCE VALUES

For the development of the MDD-W, the WHO/FAO nutrient reference values were used to assess PA for vitamins, the U.S. Institute of Medicine (IOM) values were used for calcium and iron, and the International Zinc Nutrition Consultative Group (IZiNCG) values were used for zinc. For iron and zinc, reference values were adjusted for bioavailability based on population-level assumptions (see details in Table A3-1, below). Recently, harmonised nutrient reference values were proposed for certain global applications (23) (see details in Table A3-2). For the current analysis, these harmonised values were used in the main analyses, except for iron.

For iron, IOM tables were used to estimate PA. The proposed harmonised values do not address estimation of PA for iron, where it is known that the distribution of requirements is strongly skewed for some population sub-groups, and for which standard methods for estimating probability of adequacy cannot be employed. IOM tables provide PA for various levels of iron intakes, using an iron bioavailability of 18%. Based on those figures, the PA for various levels of absorbed iron has been calculated, and the intake ranges have been adjusted for a bioavailability of 10 percent, following the same approach as in the WDDP (5,22). IOM Tables I-5, I-6, and I-7 were used (35), assuming that females 15–49 years were menstruating and did not use oral contraceptives. However, for comparative purposes, for women of reproductive age only, results were also generated using the WHO/FAO/IOM/IZiNCG set of reference values, to illustrate the impact of selection of reference values on overall results; these sensitivity analyses are presented in Annex 1, above.

Table A3-1. NRVs as in WDDP: EAR used for assessing Probability of Adequacy [a, b]

	Females 19-65 years		Females 15-18 years		Pregnant women		Lactating women	
	EAR	SD[c]	EAR	SD[c]	EAR	SD[c]	EAR	SD[c]
Vit A (RE/d) [d]	270 [e]	54	365 [e]	73	370[e]	74	450 [e]	90
Vit C (mg/d)	38 [e]	3.3	33 [e]	3.3	46 [e]	4.6	58 [e]	5.8
Thiamine (mg/d)	0.9 [f]	0.09	0.9 [f]	0.09	1.2 [f]	0.12	1.2 [f]	0.12
Riboflavin (mg/d)	0.9 [f]	0.09	0.8 [f]	0.08	1.2 [f]	0.12	1.3 [f]	0.13
Niacin (mg/d)	11 [f]	1.65	12 [f]	2	14 [f]	2.1	13 [f]	1.95
Vit B_6 (mg/d)	1.1 [f]	0.11	1.0 [f]	0.1	1.6 [f]	0.16	1.7 [f]	0.17
Folate (µg/d)	320 [e]	32	330 [e]	33	520 [e]	52	450 [e]	45
Vit B12 (µg/d)	2.0 [e]	0.2	2.0 [e]	0.2	2.2 [e]	0.22	2.4 [e]	0.24
Calcium (mg/d) [g]	800	100	1100	100	800	100	800	100
Iron (mg/d) [h]	See text	-	See text	-	20% bioavail: 24.9[i]	2.34	10% bioavail: 11.7[j]	3.51
Zinc (mg/d) [k]	34% bioavail: 6.0	0.75	34% bioavail: 7.0	0.88	34% bioavail: 8.0	1.00	44% bioavail: 7.0	0.88

[a] All values are taken from WHO/FAO (2004) unless otherwise stated.

[b] Values for EAR are adjusted for an assumed bioavailability (WHO/FAO, 2004). Thus, EAR refers to intake of the nutrients and not the physiological need for the absorbed nutrient.

[c] All SDs were calculated based on EAR and CV (SD=CV*EAR). CV is assumed to be 10% for all micronutrients except 15% for niacin (IOM, 2000), 20% for vitamin A (IOM, 2000), 12.5% for zinc (WHO/FAO 2004), 9.4% and 30% for iron, for pregnant and lactating women respectively (IOM, 2000), 12.5% and 9% for calcium, for adult women and adolescent girls respectively (IOM, 2011).

[d] One µg retinol equivalent (RE) is equal to 1 µg all-trans-retinol, 6 µg β-carotene and 12 µg α-carotene or β-cryptoxanthin (WHO/FAO 2004). Note also the EAR for vitamin A refers to intake adequate to prevent the appearance of deficiency-related syndromes (WHO/FAO 2004).

[e] EAR taken from WHO/FAO (2004).

[f] EAR back-calculated from RNI (Recommended Nutrient Intake) (WHO/FAO, 2004).

[g] EAR taken from IOM (2011).

[h] Gives EAR on iron for two levels of absorption. According to WHO/FAO (2004, p.270), either a very low (5%) or low (10%) absorption level can be assumed in a developing country setting. For both Mexico and China, an iron absorption level of 10% is assumed.

[i] EAR was back-calculated. First, the quantity of absorbed iron was calculated from IOM (2000), based on the IOM assumptions about absorption. An EAR was then calculated based on WHO/FAO (2004) statements regarding absorption during pregnancy (p. 265). WHO/FAO state absorption increases by about 50% in the second trimester and by 'up to about four times the norm' in the third trimester. Assuming the 10% absorption for non-pregnant women, we used an average for pregnancy based on a 50% increase in absorption in the second trimester (i.e. to 15%) and a 250% increase in absorption in the third trimester (i.e. to 25%), giving an average of 20%.

[j] EAR based on IOM (2000).

[k] As suggested by IZiNCG (2004), two sets of requirements (one for both NPNL and pregnant women and one for lactating women) should be used depending on dietary patterns: 34%/44% for mixed diets or refined vegetarian diets; 25%/35% for unrefined cereal-based diets. For both Mexico and China, zinc requirements for unrefined cereal–based diets were selected.

Sources:

IOM (Institute of Medicine, USA). 2000. Dietary reference intakes. Applications in dietary assessment. Washington DC, USA, National Academies Press.

IOM (Institute of Medicine, USA). 2011. Dietary reference intakes for calcium and vitamin D. Washington, DC, USA, National Academies Press.

IZiNCG (International Zinc Nutrition Consultative Group). 2004. Assessment of the risk of zinc deficiency in populations and options for its control. Technical document no. 1. Food and Nutrition Bulletin 25(1) (Suppl. 2): 91-203.

WHO/FAO. 2004. Second edition. Human vitamin and mineral requirements. Report of a joint FAO and WHO expert consultation held in Bangkok, Thailand, 21-30 September1998. Geneva, Switzerland, World Health Organization.

Table A3-2. Harmonised NRVs used for main analysis [a]

Population group	Vitamin A (mcg RAE)		Vitamin C (mg)		Thiamine (mg)		Riboflavin (mg)		Niacin (mg)		Vitamin B6 (mg)		Folate (mcg DFE)		Vitamin B12 (mcg)		Calcium (mg)		Iron[b] (mg) 10% absorption		Iron[b] (mg) 5% absorption		Zinc[c] (mg) Refined		Zinc[c] (mg) Semi-refined		Zinc[c] (mg) Semi-unrefined		Zinc[c] (mg) Unrefined	
	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	EAR	SD[d]	EAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR	SD[d]	HAR[e]	SD[d]
Children																														
1–3 y	205	31	15	1,5	0,4	0,04	0,5	0,05	5	0,75	0,5	0,05	90	14	0,7	0,07	390	39									3,6	0,36		
4–6 y	245	37	25	2,5	0,5	0,05	0,6	0,06	6	0,90	0,6	0,06	110	17	1,0	0,10	680	68									4,6	0,46		
7–10 y	320	48	40	4,0	0,5	0,05	0,8	0,08	6	0,90	0,9	0,09	160	24	1,0	0,10	680	68									6,2	0,62		
Males																														
11–14 y	480	72	60	6,0	0,7	0,07	1,1	0,11	9	1,35	1,2	0,12	210	32	1,5	0,15	960	96									8,9	0,89		
15–17 y	580	87	85	8,5	1,0	0,10	1,4	0,14	12	1,80	1,5	0,15	250	38	2,0	0,20	960	96									11,8	1,18		
18–24 y	570	86	90	9,0	1,0	0,10	1,3	0,13	12	1,80	1,5	0,15	250	38	2,0	0,20	860	86					7,5	0,95	9,3	1,20	11,0	1,50	12,7	1,80
≥25 y	570	86	90	9,0	1,0	0,10	1,3	0,13	12	1,80	1,5	0,15	250	38	2,0	0,20	750	100					7,5	0,95	9,3	1,20	11,0	1,50	12,7	1,80
Females																														
11–14 y	480	72	60	6,0	0,7	0,07	1,1	0,11	9	1,35	1,2	0,12	210	32	1,5	0,15	960	96									8,9	0,89		
15–17 y	490	74	75	7,5	0,9	0,09	1,4	0,14	11	1,65	1,3	0,13	250	38	2,0	0,20	960	96									9,9	0,99		
18–24 y	490	74	80	8,0	0,9	0,09	1,3	0,13	11	1,65	1,3	0,13	250	38	2,0	0,20	860	86					6,2	0,65	7,6	0,85	8,9	1,05	10,2	1,25
≥25 y	490	74	80	8,0	0,9	0,09	1,3	0,13	11	1,65	1,3	0,13	250	38	2,0	0,20	750	100					6,2	0,65	7,6	0,85	8,9	1,05	10,2	1,25
Pregnancy[f]																														
≤18 y	540	81	75	7,5	1,2	0,12	1,5	0,15	14	2,10	1,5	0,15	520	78	2,2	0,22	860	86	24,9	2,34	49,9	4,69	7,5	0,80	8,9	1,00	10,2	1,20	11,5	1,40
19–24 y	540	81	80	8,0	1,2	0,12	1,5	0,15	14	2,10	1,5	0,15	520	78	2,2	0,22	860	86	24,9	2,34	49,9	4,69	7,5	0,80	8,9	1,00	10,2	1,20	11,5	1,40
25–50 y	540	81	80	8,0	1,2	0,12	1,5	0,15	14	2,10	1,5	0,15	520	78	2,2	0,22	750	100	24,9	2,34	49,9	4,69	7,5	0,80	8,9	1,00	10,2	1,20	11,5	1,40
Lactation[f]																														
≤18 y	1020	153	145	14,5	1,2	0,12	1,7	0,17	13	1,95	1,4	0,14	380	57	2,4	0,24	860	86	11,7	3,51	23,4	7,02	8,6	0,90	10,0	1,10	11,3	1,30	12,6	1,50
19–24 y	1020	153	145	14,5	1,2	0,12	1,7	0,17	13	1,95	1,4	0,14	380	57	2,4	0,24	860	86	11,7	3,51	23,4	7,02	8,6	0,90	10,0	1,10	11,3	1,30	12,6	1,50
25–50 y	1020	153	145	14,5	1,2	0,12	1,7	0,17	13	1,95	1,4	0,14	380	57	2,4	0,24	750	100	11,7	3,51	23,4	7,02	8,6	0,90	10,0	1,10	11,3	1,30	12,6	1,50

[a] All values are taken from Allen et al. (2020) unless otherwise stated.

[b] Iron values for pregnant and lactating women were back-calculated from IOM (2001) and are taken from Martin-Prével et al. (2015). For all other population groups, PA tables from IOM (2001) are used, with iron intakes adjusted for a bioavailability of 10%. For both Mexico and China, an iron absorption level of 10% is assumed.

[c] Allen et al. (2020) present zinc requirements for four types of diets for adults 18+ years, assuming 300 mg phytate/day (refined diet, 43-44% absorption), 600 mg phytate/day (semi-refined diet, 35% absorption), 900 mg phytate/day (semi-unrefined diet, 30% absorption), and 1200 mg phytate/day (unrefined diet, 26% absorption). For children 1-17 years, EFSA (2014b) assumes a mixed diet with 30% absorption, with no adjustment for phytate intakes (shown as "semi-unrefined diet"). For both Mexico and China, zinc requirements for a semi-unrefined diet were selected.

[d] All SDs were calculated based on EAR and CV (SD=CV*EAR). CV is assumed to be 10% for thiamine (IOM 1998), riboflavin (EFSA 2017b), vitamin B6 (EFSA 2016), vitamin B12 (IOM 1998), and vitamin C (EFSA 2013), and 15% for niacin (IOM 1998), folate (EFSA 2014a), and vitamin A (EFSA 2015b). CV is assumed to be 10% for calcium (EFSA 2015a) except 13.3% for adults 25+ years, back-calculated from the average requirement (AR) and population reference intake (PRI) in EFSA (2015a). CV is assumed to be 9.4% and 30% for iron, for pregnant and lactating women respectively (IOM 2001). CV is assumed to be 10% for zinc for children 1-17 years (EFSA 2014b), and 10.5-14.2% for adults 18+ years, depending on absorption level and population group, back-calculated from ARs and PRIs in EFSA (2014b).

[e] Values for lactating women were adjusted based on EFSA (2017a).

[f] Age ranges for pregnant and lactating women were adjusted based on EFSA (2015a).

ANNEX 4: TREATMENT OF SUPPLEMENTS AND FORTIFIED FOODS

In the analyses underlying development of MDD-W, fortified foods were not considered because they were not consumed and/or were not in food composition databases in most of the resource-poor settings that were included (Burkina Faso, Mali, Mozambique, Uganda, Bangladesh, and the Philippines). For consistency with this approach, and because it is of interest to assess the association of diverse unfortified foods to micronutrient adequacy, similar unfortified foods/products were substituted for fortified foods/products in the China and Mexico data sets. This is also consistent with FAO guidance. Eighty-four food items were substituted in Mexico, and 70 food items were substituted in China.

In Mexico, the fortified foods that were replaced belonged to the following categories: grain-based staples (flours, breads, tortillas, and pasta) (20), breakfast cereals (44), milk and milk powder (9), baked sweets (9), and sugar-sweetened drinks (2). In China, the fortified foods that were substituted included grain-based staples (flours and pasta) (8), milk and milk powder (26), other dairy products (10), baked sweets (16), and salty snacks (2).

For certain specialised products fortified with a wide range of micronutrients, there are no appropriate substitutions. These items include commercial infant formula and certain caloric supplements for older children or adults in food or beverage form, such as micronutrient-fortified shakes to support weight control, or special micronutrient-fortified drinks for older adults to increase energy and muscle mass. These highly fortified products dilute relationships between dietary diversity and micronutrient adequacy. When there is a sufficiently large group consuming these products, analyses can be done separately for consumers and non-consumers. However, in the China and Mexico data sets, these products were very rarely consumed, and the observation days concerned were therefore excluded from the analyses (103 observation days in Mexico and 147 observation days in China).

Non-caloric micronutrient supplements (pills or powders) were dropped from the data set and are not reflected in intake values. However, individuals who consumed these items were not excluded.

ANNEX 5: SUPPLEMENTARY TABLES

Tables A5-1 through A5-10: Probability of adequacy for eleven micronutrients, and mean probability of adequacy, by age/sex group, Mexico.

Table A5-1. Sample sizes for two survey data sets[a]

Age/sex group	China 2011			Mexico 2012	
	Day 1	Day 2	Day 3	Day 1	Day 2
Children 2–4 years	449	447	447	1,629	130
Children 5–9 years	772	769	772	1,996	185
Adolescent girls 10–14 years	329	329	328	768	78
Adolescent boys 10–14 years	355	355	354	814	77
Adolescent girls 15–19 years	192	191	189	653	50
Adolescent boys 15–19 years	209	209	208	584	44
Women 20–49 years	3241	323	3223	1105	108
Men 20–49 years	2795	2787	2777	704	52
Women 50+ years	3505	3494	3499	753	59
Men 50+ years	3172	3164	3167	646	54
Total	**15019**	**14975**	**14964**	**9652**	**837**

[a] Excluded: implausible food records; infants and young children under two years of age; food records for individuals who consumed infant formula or food or beverage-based nutritional supplements; repeat recalls without day 1 observations.

Additional descriptive tables and figures for Mexico are followed by same for China

Table A5-2. Description of sample, children 2–14 years, Mexico

	Children 2–4 yr		Children 5–9 yr		Girls 10–14 yr		Boys 10–14 yr	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (yr)	3.1	1.3	7.1	2.1	11.9	2.1	11.8	2.0
Height (cm)	96.7	12.8	122.0	14.8	147.5	14.4	149.4	17.7
Weight (kg)	15.4	5.3	25.9	10.8	45.4	17.9	46.4	24.1
BMI (z-score)	0.5	1.7	0.5	1.7	0.5	1.9	0.7	2.0
% Underweight	1.1		0.7		3.5		1.2	
% Normal weight	69.6		68.2		60.2		57.0	
% Overweight	21.3		19.6		25.6		22.5	
% Obese	8.0		11.4		10.8		19.3	

Table A5-3. Description of sample, adolescent girls and women, Mexico

	Girls 15–19 yr		Women 20–49 yr		Women 50+ yr	
	Mean	SD	Mean	SD	Mean	SD
Age (yr)	16.9	2.3	33.9	12.4	63.0	15.5
Height (cm)	155.9	10.5	154.4	10.7	149.7	11.1
Weight (kg)	58.1	18.9	68.2	19.8	66.0	23.6
BMI (z-score)	0.6	1.5				
BMI			28.6	7.4	29.3	8.5
% Lactating	5.9		4.1		0.0	
% Pregnant	2.7		3.5		0.0	
% Living in urban areas	72.2		73.4		78.1	
% Indigenous[a]	12.1		10.5		10.3	

	Girls 15–19 yr		Women 20–49 yr		Women 50+ yr	
	Mean	SD	Mean	SD	Mean	SD
% No education			4.0		22.0	
% Primary education			28.6		57.0	
% Secondary education			52.5		15.4	
% Tertiary education			14.9		5.6	
% Underweight	1.1		1.3		0.6	
% Normal weight	63.9		26.2		21.7	
% Overweight	24.5		37.1		38.5	
% Obese	10.6		35.4		39.3	

[a] Definition: Population that is part of a household where the head, spouse or any of the ancestors declares to be an indigenous language speaker.

Table A5-4. Description of sample, adolescent boys and men, Mexico

	Boys 15–19 yr		Men 20–49 yr		Men 50+ yr	
	Mean	SD	Mean	SD	Mean	SD
Age (yr)	17.0	1.9	33.5	13.6	62.9	14.4
Height (cm)	167.9	9.7	166.6	9.9	163.6	14.1
Weight (kg)	64.7	18.4	75.0	20.3	73.4	24.4
BMI (z-score)	0.3	1.8				
BMI			27.0	6.5	27.3	6.5
% Living in urban areas	73.6		73.7		71.1	
% Indigenous[a]	12.7		7.5		11.2	
% No education			3.1		20.6	
% Primary education			26.1		50.2	
% Secondary education			58.4		18.7	
% Tertiary education			12.3		10.4	
% Underweight	2.2		0.6		0.5	
% Normal weight	70.8		38.5		31.3	
% Overweight	15.1		35.8		45.4	
% Obese	11.9		25.1		22.8	

[a] Definition: Population that is part of a household where the head, spouse or any of the ancestors declares to be an indigenous language speaker.

Table A5-5. Probability of adequacy for eleven micronutrients, and mean probability of adequacy, by age/sex group, Mexico

Nutrient	Children 2–4yr	Children 5–9yr	Girls 10–14yr	Boys 10–14yr	Girls 15–19yr	Boys 15–19yr	Women 20–49yr	Men 20–49yr	Women 50+yr	Men 50+yr
Thiamine	0.73	0.86	0.74	0.84	0.31	0.51	0.33	0.52	0.26	0.46
Riboflavin	0.88	0.79	0.52	0.58	0.20	0.34	0.18	0.34	0.17	0.23
Niacin	0.57	0.70	0.52	0.66	0.32	0.45	0.33	0.47	0.21	0.33
Vitamin B6	0.74	0.61	0.31	0.36	0.18	0.23	0.18	0.25	0.14	0.11
Folate	0.66	0.59	0.34	0.44	0.15	0.28	0.18	0.33	0.19	0.32
Vitamin B12	0.88	0.79	0.62	0.70	0.37	0.55	0.36	0.50	0.24	0.35
Vitamin C	0.71	0.63	0.41	0.43	0.33	0.26	0.32	0.27	0.24	0.26
Vitamin A	0.64	0.53	0.20	0.26	0.15	0.11	0.13	0.10	0.16	0.07
Calcium	0.71	0.56	0.33	0.42	0.23	0.35	0.38	0.53	0.34	0.52
Iron	0.54	0.61	0.48	0.54	0.21	0.47	0.21	0.63	0.49	0.59
Zinc	0.81	0.71	0.37	0.52	0.19	0.26	0.27	0.31	0.19	0.18
MPA[a]	0.72	0.67	0.44	0.52	0.24	0.35	0.26	0.39	0.24	0.31

[a] MPA = Mean probability of adequacy across 11 micronutrients

Table A5-6. Percent and number of individuals exceeding various MPA cut-offs, Mexico

	Children 2–4 years		Children 5–9 years		Girls 10–14 years		Boys 10–14 years	
	Percent (number)		Percent (number)		Percent (number)		Percent (number)	
MPA > 0.50	80	(1305)	76	(1507)	41	(314)	54	(438)
MPA > 0.60	71	(1161)	66	(1323)	31	(240)	39	(319)
MPA > 0.70	61	(986)	52	(1043)	20	(152)	30	(244)
MPA > 0.80	49	(796)	39	(783)	12	(96)	20	(164)
MPA > 0.90	30	(481)	24	(475)	5.8	(44)	8.6	(70)
MPA = 1.00	1	(18)	1	(21)	0.8	(6)	0.3	(2)
	Girls 15–19 years		Boys 15–19 years		Women 20–49 years		Men 20–49 years	
	Percent (number)		Percent (number)		Percent (number)		Percent (number)	
MPA > 0.50	15	(100)	27	(156)	17	(186)	36	(250)
MPA > 0.60	12	(76)	19	(113)	10	(109)	23	(161)
MPA > 0.70	7	(48)	12	(68)	6	(62)	16	(109)
MPA > 0.80	3	(20)	6	(33)	2	(25)	7	(51)
MPA > 0.90	1	(4)	2	(12)	1	(10)	2	(17)
MPA = 1.00	0	(0)	0	(0)	0	(0)	0	(0)
	Women 50+ years		Men 50+ years					
	Percent (number)		Percent (number)					
MPA > 0.50	15	(110)	18	(116)				
MPA > 0.60	10	(76)	12	(80)				
MPA > 0.70	8	(59)	8	(48)				
MPA > 0.80	5	(34)	3	(19)				
MPA > 0.90	1	(8)	0.3	(2)				
MPA = 1.00	0	(0)	0.1	(1)				

Table A5-6. Percent and number of individuals exceeding various MPA cut-offs, Mexico

	Children 2–4 years		Children 5–9 years		Girls 10–14 years		Boys 10–14 years	
	Percent (number)		Percent (number)		Percent (number)		Percent (number)	
MPA > 0.50	80	(1305)	76	(1507)	41	(314)	54	(438)
MPA > 0.60	71	(1161)	66	(1323)	31	(240)	39	(319)
MPA > 0.70	61	(986)	52	(1043)	20	(152)	30	(244)
MPA > 0.80	49	(796)	39	(783)	12	(96)	20	(164)
MPA > 0.90	30	(481)	24	(475)	5.8	(44)	8.6	(70)
MPA = 1.00	1	(18)	1	(21)	0.8	(6)	0.3	(2)

	Girls 15–19 years Percent (number)		Boys 15–19 years Percent (number)		Women 20–49 years Percent (number)		Men 20–49 years Percent (number)	
MPA > 0.50	15	(100)	27	(156)	17	(186)	36	(250)
MPA > 0.60	12	(76)	19	(113)	10	(109)	23	(161)
MPA > 0.70	7	(48)	12	(68)	6	(62)	16	(109)
MPA > 0.80	3	(20)	6	(33)	2	(25)	7	(51)
MPA > 0.90	1	(4)	2	(12)	1	(10)	2	(17)
MPA = 1.00	0	(0)	0	(0)	0	(0)	0	(0)
	Women 50+ years Percent (number)		Men 50+ years Percent (number)					
MPA > 0.50	15	(110)	18	(116)				
MPA > 0.60	10	(76)	12	(80)				
MPA > 0.70	8	(59)	8	(48)				
MPA > 0.80	5	(34)	3	(19)				
MPA > 0.90	1	(8)	0.3	(2)				
MPA = 1.00	0	(0)	0.1	(1)				

Table A5-7a. Correlation between FGDS and estimated usual intakes of micronutrients, children 2–14 years, Mexico

Nutrients	Children 2–4 years		Children 5–9 years		Girls 10–14 years		Boys 10–14 years	
	Not controlling for energy	Controlling for energy	Not controlling for energy	Controlling for energy	Not controlling for energy	Controlling for energy	Not controlling for energy	Controlling for energy
Energy	0.43 ***		0.40 ***		0.39 ***		0.38 ***	
Thiamine	0.41 ***	0.15 ***	0.36 ***	0.09 ***	0.38 ***	0.14 ***	0.39 ***	0.18 ***
Riboflavin	0.43 ***	0.22 ***	0.47 ***	0.29 ***	0.46 ***	0.29 ***	0.45 ***	0.29 ***
Niacin	0.42 ***	0.20 ***	0.34 ***	0.09 ***	0.35 ***	0.13 ***	0.35 ***	0.14 ***
Vitamin B6	0.52 ***	0.36 ***	0.50 ***	0.33 ***	0.45 ***	0.29 ***	0.48 ***	0.34 ***
Folate	0.46 ***	0.31 ***	0.41 ***	0.26 ***	0.41 ***	0.28 ***	0.41 ***	0.28 ***
Vitamin B12	0.39 ***	0.27 ***	0.41 ***	0.29 ***	0.42 ***	0.30 ***	0.36 ***	0.25 ***
Vitamin C	0.39 ***	0.30 ***	0.40 ***	0.30 ***	0.32 ***	0.22 ***	0.34 ***	0.27 ***
Vitamin A	0.45 ***	0.31 ***	0.49 ***	0.37 ***	0.44 ***	0.32 ***	0.48 ***	0.39 ***
Calcium	0.33 ***	0.09 ***	0.37 ***	0.16 ***	0.37 ***	0.17 ***	0.36 ***	0.15 ***
Iron	0.40 ***	0.15 ***	0.34 ***	0.05 *	0.29 ***	-0.01	0.33 ***	0.05
Zinc	0.45 ***	0.21 ***	0.44 ***	0.21 ***	0.42 ***	0.20 ***	0.39 ***	0.16 ***

Table A5-7b. Correlation between FGDS and estimated usual intakes of micronutrients, adolescents and adults 15–49 years, Mexico

Nutrients	Girls 15–19 years		Boys 15–19 years		Women 20–49 years		Men 20–49 years	
	Not controlling for energy	Controlling for energy	Not controlling for energy	Controlling for energy	Not controlling for energy	Controlling for energy	Not controlling for energy	Controlling for energy
Energy	0.40 ***		0.33 ***		0.37 ***		0.35 ***	
Thiamine	0.39 ***	0.14 ***	0.23 ***	-0.03	0.33 ***	0.09 **	0.29 ***	0.04
Riboflavin	0.50 ***	0.33 ***	0.42 ***	0.29 ***	0.53 ***	0.41 ***	0.43 ***	0.29 ***
Niacin	0.36 ***	0.15 ***	0.21 ***	-0.02	0.33 ***	0.12 ***	0.26 ***	0.03
Vitamin B6	0.47 ***	0.32 ***	0.38 ***	0.22 ***	0.45 ***	0.31 ***	0.37 ***	0.21 ***
Folate	0.44 ***	0.30 ***	0.41 ***	0.31 ***	0.41 ***	0.29 ***	0.41 ***	0.31 ***
Vitamin B12	0.37 ***	0.24 ***	0.36 ***	0.25 ***	0.41 ***	0.32 ***	0.33 ***	0.23 ***
Vitamin C	0.31 ***	0.24 ***	0.38 ***	0.32 ***	0.39 ***	0.32 ***	0.39 ***	0.32 ***
Vitamin A	0.48 ***	0.36 ***	0.44 ***	0.36 ***	0.53 ***	0.45 ***	0.49 ***	0.41 ***
Calcium	0.36 ***	0.12 **	0.33 ***	0.16 ***	0.40 ***	0.23 ***	0.40 ***	0.24 ***
Iron	0.35 ***	0.09 *	0.25 ***	-0.02	0.30 ***	0.02	0.28 ***	0.03
Zinc	0.43 ***	0.20 ***	0.35 ***	0.15 ***	0.42 ***	0.23 ***	0.34 ***	0.11 **

Table A5-7c. Correlation between FGDS and estimated usual intakes of micronutrients, 50 years and older, Mexico

Nutrients	Women 50+ years				Men 50+ years			
	Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy	
Energy	0.41	***			0.40	***		
Thiamine	0.39	***	0.11	**	0.39	***	0.14	***
Riboflavin	0.53	***	0.37	***	0.56	***	0.43	***
Niacin	0.41	***	0.20	***	0.35	***	0.11	**
Vitamin B6	0.52	***	0.38	***	0.53	***	0.40	***
Folate	0.42	***	0.28	***	0.40	***	0.28	***
Vitamin B12	0.43	***	0.32	***	0.40	***	0.30	***
Vitamin C	0.47	***	0.40	***	0.49	***	0.40	***
Vitamin A	0.49	***	0.38	***	0.56	***	0.49	***
Calcium	0.40	***	0.18	***	0.44	***	0.25	***
Iron	0.30	***	0.00		0.28	***	-0.03	
Zinc	0.44	***	0.21	***	0.42	***	0.18	***

Table A5-8. Description of sample, children 2–14 years, China

	Children 2–4 yr		Children 5–9 yr		Girls 10–14 yr		Boys 10–14 yr	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (yr)	3.0	0.8	7.0	1.5	11.9	1.5	11.9	1.5
Height (cm)	97.9	10.6	123.3	12.9	149.8	13.2	152.3	14.6
Weight (kg)	16.6	6.1	25.3	9.6	41.1	13.6	44.4	14.8
BMI (z-score)[a]			0.1	1.9	-0.2	1.4	0.2	1.7
% Underweight			4.6		5.7		6.8	
% Normal weight			72.9		79.9		63.0	
% Overweight			12.1		9.7		18.0	
% Obese			10.4		4.7		12.1	

[a] BMI z-scores could not be computed for children under five years because age in months and the exact birth dates were not available in the published data.

Table A5-9. Description of sample, adolescent girls and women, China

	Girls 15–19 yr		Women 20–49 yr		Women 50+ yr	
	Mean	SD	Mean	SD	Mean	SD
Age (yr)	16.6	1.4	37.6	10.0	62.7	12.7
Height (cm)	159.0	8.3	158.2	10.8	154.2	12.1
Weight (kg)	52.0	10.2	58.5	15.4	57.9	18.5
BMI (z-score)	-0.3	0.9				
BMI			23.4	5.1	24.3	5.8
% Lactating	1.1		3.5		0.0	
% Pregnant	0.0		2.7		0.0	
% Living in urban areas	49.5		40.4		42.2	
% Ethnic minority[a]	13.6		9.3		9.4	
% No education			7.7		43.5	
% Primary education			14.9		17.7	
% Secondary education			49.7		30.1	
% Tertiary education			27.7		8.7	
% Underweight	3.5		6.0		4.9	
% Normal weight	87.3		66.5		56.8	
% Overweight	7.5		22.3		31.9	
% Obese	1.7		5.1		6.5	

[a] Definition: Population that does not belong to the ethnic majority group (Han Chinese).

Table A5-10. Description of sample, adolescent boys and men, China

	Boys 15–19 yr		Men 20–49 yr		Men 50+ yr	
	Mean	SD	Mean	SD	Mean	SD
Age (yr)	16.7	1.4	37.9	9.9	62.5	12.8
Height (cm)	170.7	7.6	169.5	11.5	165.6	12.3
Weight (kg)	61.5	12.0	69.6	19.9	65.6	21.7
BMI (z-score)	-0.1	1.2				
BMI			24.2	5.2	23.8	5.6
% Living in urban areas	41.6		39.7		42.6	
% Ethnic minority[a]	8.1		9.5		9.4	
% No education			4.5		19.9	
% Primary education			10.5		21.5	
% Secondary education			55.1		44.2	
% Tertiary education			29.9		14.4	
% Underweight	6.8		3.7		4.4	
% Normal weight	73.7		59.7		62.6	
% Overweight	16.3		30.9		28.6	
% Obese	3.2		5.7		4.4	

[a] Definition: Population that does not belong to the ethnic majority group (Han Chinese).

Table A5-11. Probability of adequacy for eleven micronutrients, and mean probability of adequacy, by age/sex group, China

Nutrient	Children 2–4yr	Children 5–9yr	Girls 10–14yr	Boys 10–14yr	Girls 15–19yr	Boys 15–19yr	Women 20–49yr	Men 20–49yr	Women 50+yr	Men 50+yr
Thiamine	0.52	0.59	0.46	0.65	0.23	0.32	0.29	0.39	0.28	0.32
Riboflavin	0.38	0.30	0.14	0.19	0.04	0.07	0.05	0.09	0.05	0.08
Niacin	0.68	0.80	0.71	0.81	0.60	0.66	0.60	0.72	0.54	0.62
Vitamin B6	0.29	0.27	0.11	0.17	0.08	0.09	0.13	0.13	0.12	0.09
Folate	0.56	0.52	0.34	0.46	0.23	0.33	0.30	0.39	0.31	0.37
Vitamin B12	0.63	0.57	0.52	0.57	0.38	0.51	0.34	0.46	0.29	0.37
Vitamin C	0.65	0.62	0.42	0.51	0.36	0.27	0.37	0.33	0.35	0.31
Vitamin A	0.53	0.47	0.27	0.35	0.28	0.24	0.29	0.25	0.27	0.23
Calcium	0.14	0.03	0.02	0.02	0.01	0.02	0.04	0.05	0.05	0.07
Iron	0.62	0.62	0.54	0.65	0.35	0.57	0.43	0.84	0.81	0.79
Zinc	0.70	0.65	0.44	0.59	0.32	0.37	0.49	0.50	0.45	0.40
MPA[a]	0.52	0.49	0.36	0.45	0.26	0.31	0.30	0.38	0.32	0.33

[a] MPA = Mean probability of adequacy across 11 micronutrients

.

Table A5-12. Percent and number of individuals exceeding various MPA cut-offs, China

	Children 2–4 years Percent (number)		Children 5–9 years Percent (number)		Girls 10–14 years Percent (number)		Boys 10–14 years Percent (number)	
MPA > 0.50	52	(235)	51	(390)	30	(97)	42	(150)
MPA > 0.60	43	(191)	38	(290)	20	(66)	29	(102)
MPA > 0.70	33	(147)	27	(206)	11	(36)	16	(57)
MPA > 0.80	23	(102)	17	(131)	5	(17)	11	(38)
MPA > 0.90	11	(50)	5	(37)	2	(6)	3	(10)
MPA = 1.00	2	(8)	0	(2)	0	(0)	0	(1)
	Girls 15–19 years Percent (number)		**Boys 15–19 years Percent (number)**		**Women 20–49 years Percent (number)**		**Men 20–49 years Percent (number)**	
MPA > 0.50	15	(28)	21	(44)	21	(686)	29	(813)
MPA > 0.60	7	(13)	12	(24)	12	(374)	18	(489)
MPA > 0.70	4	(7)	5	(11)	6	(207)	9	(251)
MPA > 0.80	1	(2)	3	(7)	3	(87)	4	(117)
MPA > 0.90	0	(0)	1	(1)	1	(28)	1	(35)
MPA = 1.00	0	(0)	0	(0)	0	(0)	0	(0)
	Women 50+ years Percent (number)		**Men 50+ years Percent (number)**					
MPA > 0.50	21	(736)	23	(713)				
MPA > 0.60	13	(447)	13	(424)				
MPA > 0.70	7	(249)	7	(231)				
MPA > 0.80	3	(120)	4	(120)				
MPA > 0.90	1	(47)	1	(45)				
MPA = 1.00	0	(2)	0	(4)				

Table A5-13a. Correlation between FGDS and estimated usual intakes of micronutrients, children 2–14 years, China

Nutrients	Children 2–4 years				Children 5–9 years				Girls 10–14 years				Boys 10–14 years			
	Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy	
Energy	0.32	***			0.29	***			0.24	***			0.31	***		
Thiamine	0.37	***	0.21	***	0.28	***	0.09	**	0.34	***	0.26	***	0.27	***	0.06	
Riboflavin	0.59	***	0.53	***	0.57	***	0.52	***	0.57	***	0.56	***	0.53	***	0.46	***
Niacin	0.42	***	0.28	***	0.38	***	0.26	***	0.37	***	0.29	***	0.43	***	0.32	***
Vitamin B6	0.48	***	0.38	***	0.46	***	0.38	***	0.37	***	0.30	***	0.42	***	0.33	***
Folate	0.50	***	0.41	***	0.48	***	0.40	***	0.41	***	0.35	***	0.41	***	0.29	***
Vitamin B12	0.61	***	0.55	***	0.58	***	0.53	***	0.56	***	0.52	***	0.57	***	0.51	***
Vitamin C	0.47	***	0.39	***	0.37	***	0.28	***	0.30	***	0.23	***	0.36	***	0.27	***
Vitamin A	0.50	***	0.42	***	0.45	***	0.38	***	0.44	***	0.40	***	0.42	***	0.35	***
Calcium	0.55	***	0.48	***	0.51	***	0.44	***	0.48	***	0.43	***	0.46	***	0.37	***
Iron	0.37	***	0.20	***	0.31	***	0.13	***	0.24	***	0.10		0.28	***	0.10	
Zinc	0.48	***	0.39	***	0.37	***	0.24	***	0.37	***	0.32	***	0.40	***	0.27	***

Table A5-13b. Correlation between FGDS and estimated usual intakes of micronutrients, adolescents and adults 15–49 years, China

Nutrients	Girls 15–19 years				Boys 15–19 years				Women 20–49 years				Men 20–49 years			
	Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy	
Energy	0.30	***			0.19	**			0.13	***			0.11	***		
Thiamine	0.42	***	0.31	***	0.18	*	0.05		0.21	***	0.17	***	0.18	***	0.14	***
Riboflavin	0.63	***	0.59	***	0.46	***	0.47	***	0.45	***	0.46	***	0.39	***	0.42	***
Niacin	0.41	***	0.30	***	0.36	***	0.32	***	0.29	***	0.27	***	0.28	***	0.27	***
Vitamin B6	0.43	***	0.34	***	0.39	***	0.35	***	0.37	***	0.36	***	0.30	***	0.29	***
Folate	0.49	***	0.40	***	0.36	***	0.31	***	0.37	***	0.36	***	0.34	***	0.33	***
Vitamin B12	0.60	***	0.55	***	0.56	***	0.54	***	0.49	***	0.48	***	0.45	***	0.44	***
Vitamin C	0.43	***	0.35	***	0.27	***	0.23	**	0.30	***	0.27	***	0.27	***	0.24	***
Vitamin A	0.47	***	0.41	***	0.29	***	0.24	***	0.37	***	0.35	***	0.35	***	0.34	***
Calcium	0.60	***	0.54	***	0.40	***	0.37	***	0.38	***	0.36	***	0.34	***	0.33	***
Iron	0.39	***	0.26	***	0.22	**	0.13		0.20	***	0.15	***	0.17	***	0.12	***
Zinc	0.46	***	0.38	***	0.30	***	0.26	***	0.29	***	0.29	***	0.25	***	0.25	***

Table A5-13c. Correlation between FGDS and estimated usual intakes of micronutrients, 50 years and older, China

Nutrients	Women 50+ years				Men 50+ years			
	Not controlling for energy		Controlling for energy		Not controlling for energy		Controlling for energy	
Energy	0.16	***			0.13	***		
Thiamine	0.22	***	0.16	***	0.20	***	0.16	***
Riboflavin	0.49	***	0.51	***	0.45	***	0.47	***
Niacin	0.32	***	0.29	***	0.29	***	0.26	***
Vitamin B6	0.38	***	0.35	***	0.38	***	0.36	***
Folate	0.36	***	0.33	***	0.33	***	0.31	***
Vitamin B12	0.53	***	0.51	***	0.48	***	0.47	***
Vitamin C	0.30	***	0.26	***	0.29	***	0.26	***
Vitamin A	0.38	***	0.36	***	0.36	***	0.34	***
Calcium	0.41	***	0.38	***	0.38	***	0.37	***
Iron	0.26	***	0.21	***	0.23	***	0.19	***
Zinc	0.31	***	0.29	***	0.28	***	0.28	***

Table A5-14. Sensitivity and specificity results for MPA > 0.60 by age and sex, Mexico

	Cut-off	Percent of observations ≥ cut-off	Sensitivity	Specificity	Estimated minus actual population prevalence	Percent of false positives	Percent of false negatives	Total percent mis-classified
Children 2-4 years	>=3	90.2	96.5	26.5	17.4	20.0	2.6	22.5
	>=4	**69.1**	**81.4**	**64.0**	**-3.8**	**9.8**	**13.6**	**23.3**
	>=5	40.1	51.5	90.3	-32.7	2.6	35.4	38.0
	>=6	14.7	19.7	98.6	-58.1	0.4	58.5	58.9
Children 5-9 years	>=3	90.3	96.7	20.6	27.4	29.5	2.1	31.5
	>=4	71.1	85.1	52.6	8.2	17.6	9.4	27.0
	>=5	42.5	56.8	81.6	-20.3	6.8	27.2	34.0
	>=6	17.2	25.0	96.0	-45.6	1.5	47.1	48.6
Girls 10-14 years	>=4	72.0	89.5	36.3	39.8	43.2	3.4	46.6
	>=5	**42.8**	**67.6**	**68.9**	**10.7**	**21.1**	**10.4**	**31.5**
	>=6	17.1	31.6	89.8	-15.1	6.9	22.0	28.9
	>=7	4.0	9.3	98.5	-28.1	1.0	29.2	30.2
Boys 10-14 years	>=4	72.7	90.1	38.6	33.2	37.1	3.9	41.0
	>=5	**44.8**	**67.1**	**69.7**	**5.3**	**18.3**	**13.0**	**31.3**
	>=6	20.1	37.3	91.1	-19.4	5.4	24.8	30.2
	>=7	4.9	9.9	98.4	-34.6	1.0	35.6	36.6
Girls 15-19 years	>=4	66.8	89.7	35.9	56.4	57.4	1.1	58.5
	>=5	**39.1**	**70.6**	**64.6**	**28.6**	**31.7**	**3.1**	**34.8**
	>=6	13.8	39.7	89.2	3.4	9.6	6.3	15.9
	>=7	3.1	14.7	98.3	-7.4	1.5	8.9	10.4
Boys 15-19 years	>=4	72.3	85.3	31.0	52.4	55.3	2.9	58.2
	>=5	**43.0**	**61.2**	**61.5**	**23.1**	**30.8**	**7.7**	**38.5**
	>=6	16.6	31.9	87.2	-3.3	10.3	13.5	23.8
	>=7	3.6	10.3	98.1	-16.3	1.5	17.8	19.3
Women 20-49 years	>=4	68.6	93.3	34.4	57.7	58.5	0.7	59.2
	>=5	**41.4**	**76.7**	**62.8**	**30.6**	**33.1**	**2.5**	**35.7**
	>=6	18.8	54.2	85.5	8.0	12.9	5.0	17.9
	>=7	4.6	18.3	97.1	-6.2	2.6	8.9	11.5
Men 20-49 years	>=4	73.7	87.3	30.4	50.3	53.3	3.0	56.3
	>=5	**42.8**	**63.6**	**63.6**	**19.3**	**27.8**	**8.5**	**36.4**
	>=6	16.5	31.5	88.1	-7.0	9.1	16.1	25.1
	>=7	5.1	10.9	96.7	-18.3	2.6	20.9	23.4
Women 50+ years	>=4	62.3	91.4	40.1	54.6	55.2	0.7	55.9
	>=5	**33.9**	**72.4**	**69.4**	**26.2**	**28.3**	**2.1**	**30.4**
	>=6	13.8	46.6	88.9	6.1	10.2	4.1	14.3
	>=7	3.9	19.0	97.4	-3.9	2.4	6.2	8.6
Men 50+ years	>=4	67.2	94.5	36.3	55.9	56.5	0.6	57.1
	>=5	**38.4**	**71.2**	**65.8**	**27.1**	**30.3**	**3.3**	**33.6**
	>=6	15.2	43.8	88.5	3.9	10.2	6.3	16.6
	>=7	3.9	16.4	97.7	-7.4	2.0	9.4	11.5

[a] Cells are shaded grey when the best food group cut-off matches the MDD-W cut-off of 5 or more food groups. Yellow-shaded cells indicate a lower food group cut-off performed better.

Cut-offs are bolded when both sensitivity and specificity were at or above 60% and in red font when one of these was more than 50% but less than 60%.

No cut-off was selected if there was no combination with sensitivity and specificity both above 50% or if misclassification was > 40%, which exceeds our criterion.

Table A5-15. Sensitivity and specificity results for MPA > 0.60 by age and sex, China

	Cut-off	Percent of observations ≥ cut-off	Sensitivity	Specificity	Estimated minus actual population prevalence	Percent of false positives	Percent of false negatives	Total percent mis-classified
Children 2–4 years	>=4	78.4	95.8	34.5	35.9	37.6	1.8	39.4
	>=5	**52.1**	**77.0**	**66.3**	**9.6**	**19.4**	**9.8**	**29.2**
	>=6	29.2	52.4	88.0	-13.4	6.9	20.3	27.2
	>=7	11.1	21.5	96.5	-31.4	2.0	33.4	35.4
Children 5–9 years	>=4	78.8	95.2	31.1	41.2	43.0	1.8	44.8
	>=5	**53.6**	**81.4**	**63.1**	**16.1**	**23.1**	**7.0**	**30.1**
	>=6	29.5	54.1	85.3	-8.0	9.2	17.2	26.4
	>=7	12.0	23.4	94.8	-25.5	3.2	28.8	32.0
Girls 10–14 years	>=4	77.5	97.0	27.4	57.4	58.1	0.6	58.7
	>=5	54.1	84.8	53.6	34.0	37.1	3.0	40.1
	>=6	28.9	51.5	76.8	8.8	18.5	9.7	28.3
	>=7	11.9	27.3	92.0	-8.2	6.4	14.6	21.0
Boys 10–14 years	>=4	78.9	96.1	28.1	50.1	51.3	1.1	52.4
	>=5	58.0	83.3	52.2	29.3	34.1	4.8	38.9
	>=6	31.3	52.0	77.1	2.5	16.3	13.8	30.1
	>=7	11.8	24.5	93.3	-16.9	4.8	21.7	26.5
Girls 15–19 years	>=4	79.7	100.0	21.8	72.9	72.9	0.0	72.9
	>=5	57.8	92.3	44.7	51.0	51.6	0.5	52.1
	>=6	**30.2**	**61.5**	**72.1**	**23.4**	**26.0**	**2.6**	**28.6**
	>=7	11.5	30.8	89.9	4.7	9.4	4.7	14.1
Boys 15–19 years	>=4	78.0	95.8	24.3	66.5	67.0	0.5	67.5
	>=5	54.1	87.5	50.3	42.6	44.0	1.4	45.5
	>=6	29.2	58.3	74.6	17.7	22.5	4.8	27.3
	>=7	10.0	25.0	91.9	-1.4	7.2	8.6	15.8
Women 20–49 years	>=4	79.3	93.3	22.5	67.8	68.6	0.8	69.3
	>=5	54.0	78.1	49.1	42.5	45.0	2.5	47.5
	>=6	25.9	50.8	77.4	14.3	20.0	5.7	25.7
	>=7	9.4	25.1	92.7	-2.2	6.5	8.6	15.1
Men 20–49 years	>=4	78.4	91.6	24.4	60.9	62.4	1.5	63.9
	>=5	51.5	74.0	53.3	34.0	38.6	4.5	43.1
	>=6	22.8	35.6	79.9	5.3	16.6	11.3	27.8
	>=7	6.7	13.7	94.8	-10.8	4.3	15.1	19.4
Women 50+ years	>=4	75.5	92.8	27.0	62.8	63.7	0.9	64.6
	>=5	49.3	78.5	55.0	36.5	39.3	2.7	42.0
	>=6	24.7	51.5	79.3	11.9	18.1	6.2	24.3
	>=7	9.1	27.3	93.6	-3.7	5.6	9.3	14.9
Men 50+ years	>=4	75.7	92.9	26.9	62.4	63.3	0.9	64.2
	>=5	48.7	75.9	55.5	35.3	38.6	3.2	41.8
	>=6	23.0	49.3	81.0	9.7	16.5	6.8	23.2
	>=7	8.1	22.9	94.2	-5.3	5.0	10.3	15.4

[a] Cells are shaded grey when the best food group cut-off matches the MDD-W cut-off of 5 or more food groups. Yellow-shaded cells indicate a higher food-group cut-off performed better.

Cut-offs are bolded when both sensitivity and specificity were at or above 60% and in red font when one of these was more than 50% but less than 60%.

No cut-off was selected if there was no combination with sensitivity and specificity both above 50% or if misclassification was > 40%, which exceeds our criterion.

Table A5-16. Sensitivity and specificity results for women of reproductive age for MPA > 0.60 under two sets of nutrient reference values

	Cut-off	Percent of observations ≥ cut-off	Sensitivity	Specificity	Estimated minus actual population prevalence	Percent of false positives	Percent of false negatives	Total percent mis-classified
Mexico								
Harmonised NRVs	>=4	67.9	92.0	35.0	57.2	58.1	0.9	58.9
	>=5	**40.6**	**74.5**	**63.5**	**29.9**	**32.6**	**2.7**	**35.3**
	>=6	17.0	48.9	86.9	6.3	11.7	5.5	17.2
	>=7	4.0	17.0	97.5	-6.7	2.2	8.9	11.1
WDDP NRVs	>=4	67.9	89.9	37.6	47.7	49.8	2.0	51.8
	>=5	**40.6**	**67.0**	**66.1**	**20.4**	**27.0**	**6.7**	**33.7**
	>=6	17.0	40.0	88.9	-3.2	8.9	12.1	21.0
	>=7	4.0	12.7	98.1	-16.2	1.5	17.6	19.1
China								
Harmonised NRVs	>=4	79.3	93.5	22.5	68.1	68.8	0.7	69.5
	>=5	54.2	78.6	48.9	43.0	45.4	2.4	47.8
	>=6	26.1	51.2	77.1	14.8	20.3	5.5	25.8
	>=7	9.5	25.3	92.5	-1.8	6.6	8.4	15.1
WDDP NRVs	>=4	79.3	93.2	24.4	57.9	59.3	1.5	60.8
	>=5	54.2	77.5	52.1	32.8	37.6	4.8	42.4
	>=6	26.1	47.2	79.7	4.6	16.0	11.3	27.3
	>=7	9.5	21.2	93.7	-12.0	5.0	16.9	21.9

[a] Cells are shaded grey when the best food group cut-off matches the MDD-W cut-off of 5 or more food groups. Yellow-shaded cells indicate a higher food-group cut-off performed better.

Cut-offs are bolded when both sensitivity and specificity were at or above 60% and in red font when one of these was more than 50% but less than 60%.

No cut-off was selected if there was no combination with sensitivity and specificity both above 50% or if misclassification was > 40%, which exceeds our criterion.