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Very Low Adequacy of Micronutrient Intakes by Young Children and Women in Rural Bangladesh Is Primarily Explained by Low Food Intake and Limited Diversity[1–3]

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Abstract

Documentation of micronutrient intake inadequacies among developing country populations is important for planning interventions to control micronutrient deficiencies. The objective of this study was to quantify micronutrient intakes by young children and their primary female caregivers in rural Bangladesh. We measured 24-h dietary intakes on 2 nonconsecutive days in a representative sample of 480 children (ages 24–48 mo) and women in 2 subdistricts of northern Bangladesh by using 12-h weighed food records and subsequent 12-h recall in homes. We calculated the probability of adequacy (PA) of usual intakes of 11 micronutrients and an overall mean PA, and evaluated dietary diversity by counting the total number of 9 food groups consumed. The overall adequacy of micronutrient intakes was compared to dietary diversity scores using correlation and multivariate regression analyses. The overall mean prevalence of adequacy of micronutrient intakes for children was 43% and for women was 26%. For children, the prevalence of adequate intakes for each of the 11 micronutrients ranged from a mean of 0 for calcium to 95% for vitamin B-6 and was <50% for iron, calcium, riboflavin, folate, and vitamin B-12. For women, mean or median adequacy was <50% for all nutrients except vitamin B-6 and niacin and was <1% for calcium, vitamin A, riboflavin, folate, and vitamin B-12. The mean PA (MPA) was correlated with energy intake and dietary diversity, and multivariate models including these variables explained 71–76% of the variance in MPA. The degree of micronutrient inadequacy among young children and women in rural Bangladesh is alarming and is primarily explained by diets low in energy and little diversity of foods. J. Nutr. 143: 197–203, 2013.

Introduction

Deficiencies of selected micronutrients, including vitamin A, folate, iron, and zinc, are prevalent among young children and women of childbearing age residing in developing countries and are linked to a wide range of adverse health outcomes, such as birth defects, growth restriction, impaired cognition, and increased morbidity and mortality (1). Inadequate micronutrient intakes are primarily responsible for these deficiencies and are attributed to poor-quality, monotonous diets. A published review of micronutrient intake adequacy among women living in resource-poor countries revealed high levels of inadequacy of multiple micronutrients; however, the authors found few studies that assessed intakes of micronutrients other than vitamin A, folate, iron, and zinc or that adjusted micronutrient intake distributions for intra-individual variation to more accurately estimate usual intake distributions of the population (2).

Accurate knowledge of population dietary intakes is important to inform the selection and design of proper strategies to reduce micronutrient deficiencies. Although supplementation can effectively reduce micronutrient deficiencies, program coverage is often low and other strategies such as fortification, biofortification, and other food-based interventions may be more sustainable. Measuring the quantities of foods and nutrients consumed by the population is critical for designing food-based programs, and the availability of quantitative dietary data prior to

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[3] Supplemental Tables 1–3 are available from the ''Online Supporting Material'' link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.
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a program's implementation allows for more accurate estimation of its potential impacts (3).

The purpose of the present study was to assess micronutrient intakes of young children and their primary female caregivers in rural communities in Bangladesh. In addition, we examined relationships between micronutrient intake adequacy and energy intakes (as a marker of total food intakes) and dietary diversity. Previously, we reported data on zinc intakes in this population and the potential impacts of zinc-biofortified rice (4). In the present study, we include zinc as 1 of 11 micronutrients incorporated into an overall micronutrient adequacy score. The study community was not exposed to biofortified or fortified foods at the time of the study.

Participants and Methods

Study design and population. The study was a cross-sectional, representative, sample survey of dietary intakes of children 24–48 mo of age and their primary female caregivers in 2 rural, agricultural subdistricts in northern Bangladesh: Trishal Upazila in Mymengsingh District and Pirgacha Upazila in Rangpur District. The study design was previously described in detail (4). In brief, the population was selected using a multi-stage cluster sampling design. In each of the 2 subdistricts, we selected 24 clusters and 10 households/cluster for a total sample size of 480 households with a child 24–48 mo of age. Informed consent was obtained by the study personnel. The study was approved by the ethical review committees at the University of California, Davis and the International Centre for Diarrheal Disease Research, Bangladesh.

Field procedures. Data were collected beginning in October 2007 and ending in June 2008. Field workers visited the households in each cluster within a 1- to 2-wk period to assess dietary intakes, perform anthropometry, and administer demographic questionnaires.

The children were weighed nude or in light clothing on an infant balance (±5 g; Seca model 727). The women were weighed on an electronic scale (±0.1 kg; Seca 840 Digital Floor Scale). Heights of both children and women were measured to 0.1-cm precision using a ShorrBoard measuring board (Shorr Productions).

Dietary intakes of the children and their female caregivers were assessed by direct observation in the homes by trained local research assistants, using 12-h weighed food records and recall of any foods consumed during the subsequent 12-h period. The children were present in the home during data collection. Dietary data were collected regardless of reported symptoms of illness in order to capture intakes reflective of the typical situation whereby some members of the population are experiencing illness at any given time. Two nonconsecutive days of dietary information were obtained during 1 wk, with 1 d on a weekend for 50% of households. During the 12-h observation period, all food items, recipe ingredients, prepared recipes, and beverages served to the child and any uneaten portions were weighed to 1-g precision using electronic balances (MyWeigh KD7000). Amounts of foods consumed during the subsequent 12-h were assessed by recall using 2-dimensional plates and local cups and utensils to estimate portion sizes. For mixed dishes consumed during the recall period where the recipe information had not been observed during the previous 12-h observation, the caregiver was asked to recall the amounts of ingredients and the total recipe weight was imputed from average recipe information from other households or an average recipe from other households was used. Breastmilk intake was estimated by the test weighing procedure during the 12-h observation and 24-h intakes were calculated as previously described (4).

Data analysis. Anthropometric Z-scores were calculated for the children using the 2006 WHO growth standards and SAS macros provided by WHO (5,6). The BMIs of the women were calculated (kg/m^2) and classified according to WHO guidelines (7).

Foods consumed were converted to nutrients using a food composition database compiled for the study; the sources of nutrient data for foods and breastmilk were previously described in detail (4). Daily nutrient intakes were calculated using SAS (version 9.2). Dietary data were available for 463 children, because data from 17 children were excluded due to missing or implausible breastmilk data, and for 478 female caregivers (one caregiver was a male and the data from one household were lost).

The prevalence of adequate nutrient intakes was assessed with 2 d of dietary observation and the Institute of Medicine (IOM)[10] probability approach (8), using STATA 12.0 software (StatCorp). First, nutrient intakes, which are typically skewed, were transformed using a Box-Cox transformation. Then, using the transformed intake variables, we calculated within- and between-person variances and the best linear unbiased predictor (BLUP) of usual intake for each nutrient for each women and child. The BLUPs were used to calculate the probability of adequacy for each nutrient. Adequacy was assessed using the IOM Estimated Average Requirements (EARs) for calcium, vitamins A, C, B-6, and B-12, folate, thiamin, riboflavin, and niacin (9,10). For zinc, we used the International Zinc Nutrition Consultative Group EAR for a mixed or refined diet assuming 34% bioavailability (11). For iron, because EARs cannot be estimated due to skewed requirements for young children and nonpregnant, nonlactating women, we used tables from the IOM (12) that provide ranges of usual iron intakes associated with probabilities of adequacy and adapted the iron values for 10% bioavailability. For the women, we used specific requirements for age and lactation status. The SD of requirements was calculated using the CV of requirements and the EAR; the CVs were 12.5% for zinc (11), 20% for vitamin A, 15% for niacin, and 10% for vitamins C, B-6, and B-12, thiamin, riboflavin, niacin, and folate (9). The CV for calcium is 20% for children and 10% for women (10). The probability of adequacy (PA) was calculated for each nutrient, ranging from 0 to 1, and an overall mean PA (MPA) was calculated by averaging the PA across the 11 nutrients for each individual. When the probabilities of individuals are averaged, this is equivalent to the population prevalence of adequacy expressed as a percent (8). Henceforth, PA or MPA refers to individual level adequacy (i.e., in regression analyses) and the term prevalence refers to proportion of the population with adequate intakes. Values in the text are mean ± SD.

Dietary diversity scores (DDSs) were calculated using 9 food group indicators (13). The 9 food groups included starchy staples (e.g., rice, etc.), legumes and nuts, dairy, organ meats, eggs, flesh foods (meat, fish, or poultry), vitamin A-rich dark green leafy vegetables, other vitamin A-rich fruits and vegetables, and other fruits and vegetables. Vitamin A-rich foods were defined as including ≥60 retinol activity equivalents (RAE)/100 g. DDSs were calculated by summing the number of food groups consumed on each day and averaging the 2 d. We calculated 2 different scores based on minimum amounts of foods consumed, one using a 1-g minimum and a second using a more restrictive minimum amount consumed of 10 g for children (14) and 15 g for women (13). The mean DDSs for the 2 d are denoted as MDDS (1-g minimum) and MDDS-R (10- or 15-g minimum). Breastmilk was not included in the DDS, because the diet diversity food groups represent complementary foods and allow for comparison of DDS among children and women.

The percentage contributions of each of the 9 food groups to total nutrient intakes were calculated by dividing the sum of the nutrient intakes from each food group for all person-days by the sum of the total nutrient intakes for all person-days.

Differences in the PA of individual nutrients between children who were and were not breastfeeding and between women who were and were not lactating were assessed using nonparametric tests due to the skewness of the data. Pearson correlations were obtained to describe relationships between MPA and DDS. Separate correlations were obtained with and without controlling for energy intake. Correlation analyses used the transformed value of MPA and the BLUP of energy intake. Linear regression analyses were conducted to examine determinants of MPA using the SURVEYREG procedure in SAS to account for the clustered survey design. Covariates that may impact micronutrient

[10] Abbreviations used: BLUP, best linear unbiased predictor; DDS, dietary diversity score; EAR, Estimated Average Requirement; IOM, Institute of Medicine; MDDS, mean dietary diversity score; MDDS-R, mean dietary diversity score - restricted; MPA, mean probability of adequacy; NTD, neural tube defect; PA, probability of adequacy.

intake adequacy were included in separate multivariate models for children and women, including age of the individual, breastfeeding status, height status (height for women and stunting for children), weight status (wasting for children and BMI categories for women), district of residence, season, housing quality as a proxy of socioeconomic status, and MDDS-R. Seasons were defined in accordance with rice harvests: pre-Aman harvest (Oct-Nov); post-Aman harvest (Dec-Mar); and Aus and Boro harvests (Apr-Jun). Separate regressions were conducted for children and women and with and without control for energy intake.

Results

The characteristics of the study population were previously described (4). In brief, the mean age of the children was 35.5 ± 7.1 mo and 50% of the children were still breastfeeding. Overall, 56% of the children were stunted (height-for-age Z-score <−2) and 12% of children were wasted (weight-for-height Z-score < −2). The primary female caregivers of the children had a mean age of 27.9 ± 8.0 y and a mean BMI of 19.7 ± 2.6 and 37% of the women were underweight (BMI <18.5).

The overall mean prevalence of intake adequacy (for the 11 micronutrients) children was 43 ± 16% (**Table 1**). The mean prevalence of adequacy for each of the 11 individual micronutrients ranged from 0 for calcium to 95% for vitamin B-6 and was <50% for iron, calcium, riboflavin, folate, and vitamin B-12. Nonbreastfeeding children had a higher mean energy intake and prevalence of adequacy for thiamin, niacin, vitamin B-6, iron, and zinc ($P < 0.05$) than children who were breastfeeding. The prevalence of adequacy for children residing in Pirgacha was 48% compared with 39% for children in Trishal ($P < 0.0001$).

The overall mean prevalence of micronutrient intake adequacy of women was 26 ± 10% (**Table 2**). The women's mean or median prevalence was <50% for all nutrients except vitamin B-6 and niacin and was <1% for calcium, vitamin A, riboflavin, folate, and vitamin B-12. The energy intakes of lactating and nonlactating women were similar. The overall mean prevalence of adequacy for the 11 micronutrients and the prevalence of adequacy for vitamin A, vitamin C, thiamin, riboflavin, vitamin B-6, and zinc were lower for lactating women than for nonlactating women ($P < 0.05$) due to the greater nutrient requirements during lactation. The prevalence of adequacy for women residing in Pirgacha was 28 compared with 24% for women in Trishal ($P < 0.0001$).

The MDDS of the children ranged from 1.5 to 7 and the mean was 4.2. Using the more restrictive minimum of 10 g consumed, the MDDS-R was 2.9 (**Table 3**). The MDDS of the women ranged from 2 to 7 and the mean MDDS and MDDS-R were 4.3 and 3.4, respectively. The DDSs were similar on the 2 d.

Starchy staples (mainly rice) were the children's primary source of energy, zinc, iron, thiamin, niacin, and vitamin B-6 (**Supplemental Table 1**). Eggs were also a good source of zinc, iron, riboflavin, and vitamin B-12 in the children's diets. For the women, starchy staples contributed 84% of energy and were the primary sources of the same nutrients as for the children plus riboflavin. Vitamin A-rich vegetables and fruits provided the majority of the vitamin A in the women's diets (78%), but the children consumed more than one-half of their daily vitamin A intake from other sources, including eggs, dairy, and flesh foods. Although legumes provided only 2–3% of energy to the diets of the children and women, legumes were good sources of iron, zinc, and folate.

MPA was highly correlated with energy intake in both children and women. MPA was also significantly correlated with MDDS and MDDS-R (**Supplemental Table 2**). When energy was controlled for, the correlations between MPA and DDSs were slightly attenuated. The correlations between MPA and MDDS or MDDS-R were higher for children than for women; controlling for energy, the correlation between MPA and MDDS-R was 0.63 for children and 0.18 for women. The children's DDSs and

TABLE 1 Mean daily energy and micronutrient intakes of the children and prevalence of adequate micronutrient intakes[1]

	Requirements[2]		All children (*n* = 463)		Nonbreastfeeding (*n* = 237)		Breastfeeding (*n* = 226)	
	EAR	SD	Intake of nutrient	Prevalence of adequacy, %	Intake of nutrient	Prevalence of adequacy, %	Intake of nutrient	Prevalence of adequacy, %
Energy, *kcal*	–	–	886 ± 158 (881)	–	964 ± 169 (953)	–	805 ± 145 (807)	–
Vitamin A, *μg RAE*	210	42	117 ± 71 (87)	7 ± 19 (0.2)	124 ± 78 (80)	8 ± 22 (0.1)	111 ± 62 (89)	5 ± 16 (0.2)
Vitamin C, *mg*	13	1.3	30 ± 15 (24)	80 ± 37 (100)	32 ± 16 (24)	75 ± 41 (100)	29 ± 13 (23)	86 ± 32 (100)
Thiamin, *mg*	0.4	0.04	0.4 ± 0.1 (0.4)	58 ± 41 (75)	0.5 ± 0.1 (0.5)	73 ± 35 (91)	0.4 ± 0.1 (0.4)	43 ± 42 (24)
Riboflavin, *mg*	0.4	0.04	0.3 ± 0.1 (0.3)	22 ± 37 (0.1)	0.3 ± 0.1 (0.3)	23 ± 37 (0.1)	0.3 ± 0.1 (0.3)	22 ± 37 (0.1)
Niacin, *mg*	5	0.75	9 ± 2 (9)	89 ± 26 (100)	10 ± 2 (10)	96 ± 15 (100)	7 ± 2 (8)	82 ± 32 (100)
Vitamin B-6, *mg*	0.4	0.04	0.9 ± 0.2 (0.9)	95 ± 19 (100)	1.0 ± 0.2 (1.0)	99 ± 10 (100)	0.8 ± 0.2 (0.8)	92 ± 24 (100)
Folate, *μg*	120	12	65 ± 27 (59)	3 ± 14 (0)	66 ± 27 (61)	3 ± 14 (0)	64 ± 26 (56)	3 ± 14 (0)
Vitamin B-12, *μg*	0.7	0.07	0.8 ± 0.5 (0.5)	28 ± 42 (0)	0.8 ± 0.6 (0.5)	27 ± 42 (0)	0.8 ± 0.5 (0.5)	29 ± 43 (0)
Iron, *mg*	–[3]	–	3.6 ± 1.0 (3.3)	22 ± 18 (15)	4.1 ± 1.0 (3.9)	27 ± 19 (25)	3.2 ± 1.0 (3.0)	17 ± 16 (15)
Zinc, *mg*	2.0	0.25	2.5 ± 0.6 (2.5)	72 ± 37 (97)	2.8 ± 0.6 (2.8)	84 ± 29 (100)	2.2 ± 0.6 (2.1)	59 ± 41 (72)
Calcium, *mg*	500	100	145 ± 56 (120)	0 ± 0 (0)	142 ± 54 (107)	0 ± 0 (0)	148 ± 57 (131)	0 ± 0 (0)
Overall prevalence of adequacy[4]	–			43 ± 16 (44)		47 ± 14 (47)		40 ± 17 (39)

[1] Values are mean ± SD (median); the mean is the overall mean of each individual's 2-d mean or the 1-d intake for children with only one observation day; the SD of intake is the intra-individual SD. EAR, estimated average requirement; IOM, Institute of Medicine; RAE, retinol activity equivalents.
[2] The EARs for calcium, vitamins A, C, B-6, and B-12, and folate, thiamin, riboflavin, and niacin were from the IOM (9,10); the EAR for zinc was from International Zinc Nutrition Consultative Group for a mixed or refined diet assuming 34% bioavailability (11); the SD of requirements was calculated using the CV of requirements and the EAR; the CVs are 12.5% for zinc (11), 20% for vitamin A, 15% for niacin, and 10% for vitamins C, B-6, and B-12 and thiamin, riboflavin, niacin, and folate (9). The CV for calcium is 20% (10).
[3] The EAR for iron cannot be estimated due to skewed requirements for the young children tables from IOM (12) were used, which provide ranges of usual iron intakes and associated probabilities of adequacy, assuming 10% bioavailability.
[4] The overall prevalence of adequacy is the average of the adequacies of the 11 micronutrients.

TABLE 2 Mean daily energy and micronutrient intakes of the study women and prevalence of adequate micronutrient intakes[1]

	Requirements[2]		All women (n = 478)		Nonlactating (n = 235)		Lactating (n = 243)	
	EAR	SD	Intake	Prevalence of adequacy, %	Intake	Prevalence of adequacy, %	Intake	Prevalence of adequacy, %
Energy, *kcal*	–	–	1877 ± 326 (1820)	–	1855 ± 322 (1830)	–	1898 ± 330 (1820)	–
Vitamin A, *μg RAE*	500	100	228 ± 167 (143)	3 ± 15 (0)	239 ± 167 (136)	6 ± 20 (0)	218 ± 166 (146)	0 ± 1 (0)
Vitamin C, *mg*	60	6	60 ± 26 (52)	19 ± 35 (0)	60 ± 27 (52)	33 ± 42 (3)	59 ± 25 (53)	6 ± 20 (0)
Thiamin, *mg*	0.9	0.09	0.9 ± 0.2 (0.9)	34 ± 38 (16)	0.9 ± 0.2 (0.9)	52 ± 38 (54)	1.0 ± 0.2 (0.9)	16 ± 27 (1)
Riboflavin, *mg*	0.9	0.09	0.5 ± 0.1 (0.4)	0.4 ± 5 (0)	0.5 ± 0.1 (0.4)	1 ± 6 (0)	0.5 ± 0.1 (0.4)	0 ± 0 (0)
Niacin, *mg*	11	1.65	23 ± 4 (23)	99 ± 8 (100)	23 ± 4 (23)	99 ± 9 (100)	24 ± 4 (23)	98 ± 8 (100)
Vitamin B-6, *mg*	1.1	0.11	2.3 ± 0.4 (2.2)	93 ± 20 (100)	2.2 ± 0.4 (2.2)	99 ± 11 (100)	2.3 ± 0.4 (2.2)	87 ± 25 (100)
Folate, *μg*	320	32	96 ± 34 (89)	0 ± 0 (0)	94 ± 34 (91)	0 ± 0 (0)	97 ± 33 (88)	0 ± 0 (0)
Vitamin B-12, *μg*	2.0	0.2	0.6 ± 0.5 (0.4)	1 ± 10 (0)	0.7 ± 0.5 (0.4)	2 ± 13 (0)	0.6 ± 0.5 (0.4)	0.5 ± 6 (0)
Iron, *mg*	–[3]	–	8.6 ± 2.1 (8.2)	16 ± 20 (7)	8.3 ± 2.0 (8.1)	8 ± 13 (0)	8.8 ± 2.1 (8.3)	24 ± 23 (16)
Zinc, *mg*	6.0	0.75	5.5 ± 1.1 (5.2)	22 ± 30 (6)	5.4 ± 1.1 (5.2)	30 ± 33 (13)	5.5 ± 1.1 (5.2)	14 ± 24 (2)
Calcium, *mg*	800	80	192 ± 88 (164)	0 ± 0 (0)	194 ± 86 (168)	0 ± 0 (0)	190 ± 89 (160)	0 ± 0 (0)
Overall prevalence of adequacy[4]	–			26 ± 10 (23)		30 ± 11 (28)		22 ± 8 (20)

[1] Values are mean ± SD (median); the mean is the overall mean of each individual's 2-d mean or the 1-d intake for children with only one observation day; SD of intake is the intra-individual SD. EAR, Estimated Average Requirement; IOM, Institute of Medicine; RAE, retinol activity equivalents.
[2] The EARs in the table are for nonpregnant, nonlactating women; however, appropriate EARs for adolescents and lactating women were also used; the EAR for calcium, vitamins A, C, B-6, and B-12 and folate, thiamin, riboflavin, and niacin were from the IOM (9,10); the EAR for zinc was from IZiNCG for a mixed or refined diet assuming 34% bioavailability (11); the SD of requirements was calculated using the CV of requirements and the EAR; the CVs were 12.5% for zinc (11), 20% for vitamin A, 15% for niacin, and 10% for vitamins C, B-6, and B-12 and thiamin, riboflavin, niacin, and folate (9). The CV for calcium is 10% (10).
[3] The EAR for iron cannot be estimated due to skewed requirements for the nonpregnant, nonlactating women tables from IOM (12) were used, which provide ranges of usual iron intakes and associated probabilities of adequacy, assuming 10% bioavailability, using specific requirements for age and lactation status
[4] The overall prevalence of adequacy is the mean of the adequacies of the 11 micronutrients.

MPA were correlated with the results for their primary caregivers: MDDS (r = 0.52; P < 0.0001), MDDS-R (r = 0.41; P < 0.0001), and MPA (r = 0.25; P < 0.0001).

In a multivariate model, MPA among children was positively associated with energy intake, MDDS-R, child age, and district of residence (**Table 4**). The model explained 71% of the variance in MPA. In a multivariate model for women that explained 76% of the variance in MPA, MPA was positively associated with energy intake, MDDS-R, not lactating, and the Aus and Boro rice-growing seasons (**Table 5**).

Further analysis was conducted to determine which of the 9 food groups were predictive of MPA (**Supplemental Table 3**). For children, dairy and eggs were the most important predictors of MPA, explaining the most variation in MPA of all of the food groups, followed by other meats and vitamin A-rich green leafy vegetables and vitamin A-rich fruits and vegetables. Starchy staples and consumption of legumes on only 1 d were not significant predictors of MPA. For women, vitamin A-rich leafy greens and vitamin A-rich fruits and vegetables were the only food groups significantly predictive of MPA.

Discussion

The overall prevalence of micronutrient intake adequacy was low in both children (43%) and women (26%) in these rural Bangladeshi subdistricts. Adequacy of intake was particularly low for some specific micronutrients. For example, none of the children had adequate intakes of calcium and only 3 and 7% had adequate folate and vitamin A intakes, respectively. Few of the women (0–3%) had adequate intakes of calcium, folate, riboflavin, vitamin B-12, and vitamin A. Iron intakes were also low, with just 22% of children and 16% of women having adequate intakes. Low food energy intakes and poor dietary diversity explained much of the low micronutrient adequacy.

Prior to the present study, little recent information was available on food and micronutrient intakes in Bangladeshi preschool children. The latest national survey data from Bangladesh indicate that fewer than one-third of children <24 mo of age fulfill the recommended Infant and Young Child Feeding practices, which include consuming foods from 4 or more food groups, appropriate meal frequency, and milk

TABLE 3 DDSs and percentage of children and women consuming each of the 9 food groups on at least 1 of 2 d of dietary intake[1]

	Children (n = 463)		Women (n = 478)	
	MDDS	MDDS-R	MDDS	MDDS-R
Mean	4.2	2.9	4.3	3.4
SD	0.9	0.9	0.9	0.8
Median	4	3	4	3.5
Minimum	1.5	0.5	2	1.5
Maximum	7	5.5	7	6.5
Consumption, %				
Starchy staples	100	100	100	100
Legumes and nuts	71	17	64	44
Dairy products	48	41	22	18
Organ meats	2	1	0	0
Other meats/flesh foods	67	37	84	54
Eggs	46	34	30	18
Vitamin A-rich leafy green vegetables	46	28	71	61
Vitamin A-rich fruits and vegetables	48	37	52	35
Other fruits and vegetables	99	85	100	97

[1] DDS, dietary diversity score; MDDS, mean 2-d dietary diversity score calculated based on a minimum amount consumed of 1 g; MDDS-R, mean 2-d dietary diversity score calculated based on a minimum amount consumed of 10 and 15 g for children and women, respectively.

TABLE 4 Determinants of MPA of micronutrient intakes of children[1]

	Univariate models[2]				Multivariate model[3]		
	R^2	β-Coefficient	SE	P	β-Coefficient	SE	P
Energy, kcal	0.51	0.0004	<0.001	<0.0001	0.0003	<0.001	<0.0001
MDDS-R	0.44	0.101	0.005	<0.0001	0.068	0.005	<0.0001
Age, mo	0.09	0.006	0.001	<0.0001	0.0004	0.001	0.44
Breastfeeding	0.04						
Yes		−0.056	0.014	0.0002	–	–	–
No		Referent					
Stunted	0.02						
Yes		−0.041	0.015	0.008	–	–	–
No		Referent					
Wasted	0.02						
Yes		−0.054	0.022	0.02	–	–	–
No		Referent					
District	0.09						
Pirgacha		0.082	0.013	<0.0001	0.023	0.008	0.005
Trishal		Referent			Referent		
Season	0.005						
Oct-Nov		−0.018	0.013	0.19	–	–	–
Dec-Mar		Referent	0.019	0.42			
Apr-Jun		0.016					
Housing quality	0.03	0.042	0.011	0.0002	–	–	–
Intercept	–	–	–	–	−1.044	0.020	<0.0001
R^2	–	–	–	–	0.71	–	–

[1] Models included 445 children who had anthropometric measures. Dash signifies the variable was not included in the model due to insignificance. MDDS-R, mean 2-d dietary diversity score calculated based on a minimum amount consumed of 10 g; MPA, mean probability of adequacy.
[2] Linear regression models using SAS survey procedures (ProcSurveyreg) with overall mean prevalence of adequacy as the dependent variable and one independent variable.
[3] Linear regression model with overall meal prevalence of adequacy as the dependent variable and the independent variables that remained significant, $P < 0.05$.

products if nonbreastfeeding (15). Although one-half of the 24- to 48-mo-old children in our study were still breastfeeding, the majority of their energy intake was from nonbreastmilk sources. Only 41% of all children consumed at least 10 g of dairy foods on either of the 2 d, contributing to very low calcium intakes. Rickets was documented in children in Bangladesh and is thought to be due to deficiency of calcium rather than vitamin D (16,17). Folate intakes were also very low. Although folate-containing lentils and green leafy vegetables were present in the diets of the children, the quantities consumed were very small. For example, 71% of children consumed some legumes or nuts on at least 1 of the 2 d, but only 17% consumed at least 10 g/d. More than one-half of the children did not consume any vitamin A-rich leafy green vegetables or other vitamin A-rich fruits or vegetables on either observation day, contributing to the low prevalence of adequate vitamin A intakes.

Children who were still breastfeeding at 24–48 mo of age had lower total energy intakes and lower micronutrient adequacy than children who were not breastfeeding. Breastfeeding children consumed an average of 11% of their energy intake from breastmilk. Breastfeeding children consumed ~250 kcal/d less from nonbreastmilk sources than nonbreastfeeding children, the majority of which was attributed to lower rice intakes (4). Although breast-fed children were younger than nonbreastfeeding children, age alone should not explain such differences in energy intakes and micronutrient intake adequacy. It is possible that breast-fed children were from poorer households; however, we did not find differences in household indicators of socio-economic status such as possessions or housing quality.

The micronutrient intake adequacy of the women was lower than that of the children for most nutrients, possibly because the women consumed a greater proportion of their daily energy intakes from white rice, which is relatively low in micronutrients (84 vs. 58% of energy from rice for women and children, respectively) (4). Women also tended to consume fewer of the nutrient-rich dairy products and eggs than children. Low consumption of dairy products by women also contributed to the low adequacy of their riboflavin and calcium intakes. More of the women consumed vitamin-A rich fruits and vegetables than children, but only 3% of women had adequate vitamin A intakes due to the small quantities consumed and their higher requirements. Fish, the most commonly consumed flesh food, was eaten more frequently by women than children; however, the quantities consumed were very small. Whereas 84% of women consumed a flesh food on at least 1 of the 2 d, only 54% consumed at least 10 g/d. Of particular concern for these women of childbearing age is the widespread lack of folate in their diets, given the association between inadequate folate intake and neural tube defects (NTDs) (18). The prevalence of NTD in Bangladesh is not known; however, a study in a district of India with the lowest ranking in socio-economic factors found that the incidence of NTD was 6.6−8.2/1000 live births (19).

The women's DDSs were similar to those previously reported in Bangladeshi women as well as in women in other developing countries using the same definition of dietary diversity (13). Dietary diversity was strongly correlated with overall micronutrient intake adequacy in the children, but the correlations were not as strong among the women. Arimond et al. (13)

TABLE 5 Determinants of MPA of micronutrient intakes of women[1]

	Univariate models[2]				Multivariate model[3]		
	R^2	β-Coefficient	SE	*P*	β-Coefficient	SE	*P*
Energy, kcal	0.59	0.0003	<0.001	<0.0001	0.0003	<0.001	<0.0001
MDDS-R[4]	0.10	0.076	0.010	<0.0001	0.027	0.006	0.0001
Age, y	0.03	−0.004	0.001	0.01	–	–	–
Lactating							
Yes	0.12	−0.139	0.015	<0.0001	−0.154	0.010	<0.0001
No		Referent			Referent		
Height, cm	0.02	0.005	0.002	0.008	–	–	–
BMI							
<18.5	0.03	−0.067	0.021	0.002	–	–	–
18.5–24.9		Referent	0.042	0.13			
≥25		0.065					
District							
Pirgacha	0.06	0.094	0.019	<0.0001	–	–	–
Trishal		Referent					
Season							
Oct-Nov	0.02	−0.110	0.025	<0.0001	0.016	0.019	0.40
Dec-Mar		Referent	0.023	0.63	Referent	0.011	0.008
Apr-Jun		−0.011			0.030		
Housing quality	0.001	0.014	0.017	0.42	–	–	–
Intercept					−1.77	0.031	<0.0001
R^2					0.76	–	–

[1] Models included 471 women who had anthropometric measures. Dash signifies the variable was not included in the model due to insignificance. MDDS-R, mean 2-d dietary diversity score calculated based on a minimum amount consumed of 15 g; MPA, mean probability of adequacy.
[2] Linear regression models using SAS survey procedures (ProcSurveyreg) with overall mean prevalence of adequacy as the dependent variable and one independent variable.
[3] Linear regression model with overall mean prevalence of adequacy as the dependent variable and the independent variables that remained significant, $P < 0.05$.
[4] MDDS-R is calculated based on a minimum amount consumed of 15 g.

reported correlation coefficients for Bangladeshi women of 0.46 ($P < 0.001$) for nonlactating women and 0.35 ($P < 0.001$) for lactating women using the restricted DDS and controlling for energy intake. It is unclear why the correlations between MPA and DDS among women in our study were lower than that those in Bangladeshi women found by Arimond et al. (13). Vitamin A-rich fruits and vegetables appeared to be the only food groups that were predictive of MPA of the women; therefore, the inclusion of other food groups in the diets of women who were not consuming vitamin A-rich foods did not appear to improve the overall micronutrient adequacy of their diets due to the small quantities of these other foods consumed.

Dietary diversity was a stronger predictor of MPA for children than for women. The lactating status of the women was highly predictive of their MPA, but breastfeeding was not a predictor of MPA in the multivariate model for children. This is likely due to the fact that the children were older and consuming very small amounts of breastmilk (providing only 11% of the total energy intake of breast-fed children). By using the EARs for lactating women, we may have overestimated the women's micronutrient inadequacy, because the actual requirements of women who are breastfeeding older children in small amounts are probably not as high as for women breastfeeding children in the first year of life. Also, dietary diversity may be more influential in meeting nutrient requirements in children due to their ability to achieve adequacy with smaller quantities of foods. For example, one medium egg containing 0.5 mg of zinc provides ~25% of the child's EAR but only 7–8% of the EAR for women. More of the individual food groups were predictive of MPA for children than for women.

Energy intakes were a strong predictor of MPA, as expected due to the increased intake of micronutrients with higher energy intakes. The adequacy of energy intakes of the study population cannot be precisely assessed due to lack of information on activity levels; however, energy intakes were likely to be inadequate for many of the children and women based on the high rates of wasting (12%) in the children and underweight (37%) in the women. It is also noteworthy that the second highest contributor of energy to the diets of both children and women was the group of "other" foods not counted in the DDS (including cookies, cake, candy, sugar, and oil), which contribute few micronutrients.

Our study shows that young children and women in Bangladesh consume diets that lack sufficient nutrient-dense foods to achieve micronutrient adequacy. Poor dietary diversity has been associated with low food expenditures, particularly nonstarchy foods that are nutrient-dense but expensive, such as meat, eggs, and dairy products (20). In Bangladesh, lentils are consumed almost daily in dal, but it is prepared like a soup with very small amounts of lentils, which are also perceived as expensive. The children were able to achieve higher micronutrient adequacy than the women by consuming small amounts of nutrient-dense foods, but they consumed them in insufficient quantities and frequency to prevent inadequacy.

Our study had some limitations that must be acknowledged. Although we weighed foods prepared and consumed by the women and children during a 12-h daytime period, a portion of their daily intakes was assessed by recall. The proportion of daily intakes obtained by recall was higher for the women (22% of energy) than for the children (8%), because the women often ate their last meal of the day later than the children and after the field worker had left the home; however, compared on a meal basis, the estimated intakes of energy were similar between the recalled and observed meals.

In conclusion, the degree of micronutrient adequacy among young children and women in rural Bangladesh is alarmingly low and is primarily explained by low total intakes of diets lacking in diversity. In addition to the micronutrients known to be deficient among these vulnerable population groups (iron, zinc, vitamin A, and folate), dietary inadequacies of other important micronutrients, such as calcium, riboflavin, and vitamin B-12, were widespread. Increasing dietary diversity, particularly with nutrient-rich foods such as vitamin A-rich fruits and vegetables, eggs, dairy, and meats, as well as other strategies such as multiple micronutrient supplementation, fortification, or biofortification of foods are warranted in this population.

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