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Developing and Validating Simple Indicators of Complementary Food Intake and Nutrient Density for Breastfed Children in Developing Countries

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ACRONYMS

CF	Complementary foods
FAO	Food and Agriculture Organization
FGI-8	Food group index (8 food groups; no minimum amount criterion)
FGI-8R	Food group index-restricted (8 food groups; 10-gram minimum amount criterion)
HAZ	Height-for-age Z-scores
IOM	Institute of Medicine
MNDA	Mean nutrient density adequacy
NDA	Nutrient density adequacy
PAHO	Pan American Health Organization
RE	Retinol equivalents
RNI	Recommended nutrient intakes
Se	Sensitivity
Spe	Specificity
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
V+	Positive predictive value
WHO	World Health Organization
WHZ	Weight-for-height Z-scores

EXECUTIVE SUMMARY

Introduction

The overall goal of the research was to initiate a process of developing and validating indicators of diet "quality" and "quantity" from complementary foods during the first two years of life. In this first study, we used four data sets available at the University of California at Davis to validate indicators related to two aspects of complementary feeding: the nutrient density of complementary foods and the complementary food intake of breastfed infants 6-12 months of age. More specifically, the two main research questions addressed were the following:

1. How well can dietary diversity (sum of foods or food groups consumed over a reference period) or sentinel food group (selected nutrient-dense food groups) indicators predict the dietary quality[1] of complementary foods for breastfed infants in different populations with varying dietary patterns?
2. How well does the frequency of feeding of complementary foods predict energy intake – either from complementary foods or total energy intake – in different populations with varying dietary patterns?

Methods

Four data sets with information on dietary intake of breastfed children between the ages of 6-12 months were used for these analyses (from Peru, Bangladesh, Ghana, and Honduras). In total, 1866 child-days of dietary records were included. For each record, nutrient intake from complementary foods was calculated using the best available data on food composition. When converting food intake data into nutrient intake data, the estimated bioavailability of zinc, calcium, and iron from different foods was used to estimate the amount of each nutrient *absorbed*.

Two dietary diversity indexes were used in the analyses:

1) The *Food Group Index-8* (FGI-8): this index was based on consumption of foods from each of eight different food groups, with each group counted in the index if at least 1 gram was eaten:

   a) Grains, roots and tubers;
   b) Legumes and nuts;
   c) Dairy products;
   d) Flesh foods;
   e) Eggs;
   f) Vitamin A-rich fruits and vegetables;
   g) Other fruits and vegetables;
   h) Fats and oils.

[1] Dietary quality is defined in this report as "adequate nutrient density of complementary foods for 9 nutrients."

2) The Food Group Index-8 Restricted (FGI-8R): this index was similar to the first index (FGI-8), except that the child must have eaten at least 10 g from the food group (except fats and oils) for it to be counted as a point (range 0-8). For the "fats and oils" food group, the cutoff at least 1 g was used.

Dietary quality was defined based on how well the complementary food diet met nutrient density recommendations. Nutrient adequacy was based on *nutrient density* (amount per 100 kcal of complementary food), rather than absolute *nutrient intake*, because of the variability in breast-milk intake among individual children.

The desired nutrient densities were calculated by dividing the required amount of each nutrient from complementary food by the appropriate complementary food energy requirement (for each age group) and multiplying by 100. The percentage of the desired nutrient density fulfilled by the complementary foods consumed that day, termed the "nutrient density adequacy" (NDA) score, was calculated for each of nine "problem" nutrients (vitamins A, B6, and C, riboflavin, thiamin, folate, iron, zinc, and calcium). The overall "mean nutrient density adequacy" (MNDA) was calculated as the average of the nine individual NDA scores for that day, after each was capped at 100%. For all analyses, the unit of analysis was one child-day, corresponding to one 24-hour record of food intake.

Bivariate analyses (comparison of means and correlation coefficients) were carried out to test the association between dietary diversity indicators and MNDA for all four data sets. Sensitivity and specificity analysis was also used to compare the performance of the different dietary diversity indicators in differentiating cases with low and higher MNDA, and to identify best cutoff points. Two sets of analyses were completed, one using FGI-8 and the other using FGI-8R as the measure of dietary diversity. For each set of analyses, two cutoff points of MNDA were used, MNDA $< 50\%$ and $\geq 75\%$.

For the analysis of feeding frequency, three of the four datasets had sufficient information (all but Ghana). Two of these (Peru and Bangladesh) also had data on breast milk intake, which permitted calculation of total energy intake. Correlation analysis was used to test associations between total energy intake (Peru and Bangladesh) or energy from complementary foods (Peru, Bangladesh, and Honduras) and number of feeding episodes (feeding episodes (meals + snacks), or meals only, if feeding episodes were subdivided). Sensitivity and specificity analysis was also used to assess the performance of the feeding frequency indicators in differentiating children with total energy intake (or energy from complementary foods) above or below their age-specific requirements, and to identify best cutoff points.

Results

Dietary patterns in the sample populations

The diets of infants in the four studies (Peru, Honduras, Ghana, and Bangladesh) reflect a wide range of food intake patterns. The most commonly consumed foods were those categorized into the "grain products, roots and tubers" group, with at least one of these foods being recorded on 92-100% of child-days and consumption of at least 10 g from this food group on 78-99% of child-days.

There was great variability across sites in the consumption of the other food groups. Legumes and nuts were consumed commonly in Ghana (67-70%), occasionally in Bangladesh (18-30%), and rarely in Peru (4-5%) and Honduras (14%). By contrast, dairy products were infrequently consumed in Ghana (12-18%) and Bangladesh (10-21%), but commonly consumed in Peru (40-48%) and Honduras (53%). Flesh foods were consumed on 28-58% of child-days in Peru, Honduras, and Ghana, though these percentages dropped to 12-24% when imposing the 10-gram minimum. In Bangladesh, flesh foods were rarely consumed, and none of the infants consumed ≥ 10 g on a given day. Eggs were consumed on 42% of child-days in Honduras, but much less frequently in Peru (11-16%), Ghana (1-3%), and Bangladesh (1-4%). Vitamin A-rich fruits and vegetables were commonly consumed in Peru (60-66%), but infrequently consumed in Honduras (16%), Ghana (5-13%), and Bangladesh (4-12%). Other fruits and vegetables were consumed on half or more of child-days in Peru (49-69%) and Honduras (69%), but on less than half of child-days in Ghana (15-48%) and Bangladesh (27-31%). Fats and oils were consumed occasionally in Peru (13-30%), Honduras (19%) and Ghana (10-44%), but rarely in Bangladesh (4-6%).

Mean dietary diversity (using the eight-food group index with no quantity restriction (FGI-8)) was higher in Peru (3.0-3.7) and Honduras (3.3) than in Ghana (2.6-3.4) and Bangladesh (1.7-2.1). When considering only food groups from which at least 10 g were consumed (using the same index with a 10-gram minimum restriction for each food group except fats and oils (FGI-8R)), the mean diversity scores were lower: approximately 2-3 in Peru, Honduras and Ghana and < 2 in Bangladesh. Thus, the diets of most of the children included foods from less than three of the eight food groups on any given day.

Nutrient density of the complementary food diet was generally inadequate. The median percentage of desired nutrient density was particularly low for absorbed iron: 5-9% in Bangladesh, 6-10% in Peru, 8% in Honduras, and 13-36% in Ghana. Of the other nutrients, the median percentage of desired nutrient density was low (generally < 60%) in all sites for absorbed zinc and in several sites for absorbed calcium, vitamin A, riboflavin, vitamin B6 and vitamin C. Median nutrient density of folate and thiamin was generally > 60% of desired.

As a consequence of the generally low nutrient densities, the mean nutrient density adequacy (MNDA) of the complementary food diet (average of percent desired nutrient density, capped at 100%, for the nine nutrients) was low in all four sites, with means ranging from 35-49% in Bangladesh to 56-63% in Peru, depending on age. MNDA increased with age in the three sites that had more than one age group (i.e., 6-8.9 months and 9-11.9 months).

Mean feeding frequency was 3.0-3.6 per day at 6-8.9 months, with 7-24% receiving fewer than the minimum of two feedings per day stipulated for this age range in the Guiding Principles recommendations (PAHO/WHO 2003). At 9-11.9 months, mean feeding frequency was 3.9-4.8 per day, with 18-27% receiving fewer than the minimum of three feedings per day recommended for this age range. Feeding frequency was lower in Bangladesh than in Honduras and Peru for both age groups. Overall, the large majority of the infants in our three samples met the minimum feeding frequency guidelines.

The relationship between dietary diversity and mean nutrient density adequacy

Mean nutrient density adequacy (MNDA) was used in this study as our indicator of diet quality. Dietary diversity was positively associated with MNDA in all four countries, with MNDA generally 50-60% when only two food groups were consumed, increasing to ~60-70% when at least four food groups were consumed (regardless of the quantity consumed). If a 10-gram minimum quantity was imposed, MNDA generally rose to ~70-80% when at least four food groups were consumed. Thus, a larger number of food groups in the child's diet is associated with greater dietary quality. The correlations between dietary diversity and MNDA were significant in all sites and age groups, ranging from ~0.4 to ~0.7. Imposing a 10-gram minimum in counting the number of foods groups did not generally improve the correlation. In sensitivity/specificity analyses, imposing the 10-gram minimum did not generally result in reduced misclassification. Because a simple indicator is easier to implement in the field, it is preferable to choose one that does not require collecting information on quantities consumed, unless there is a clear advantage to doing so. Thus, we focus the discussion below on the results using the dietary diversity indicator with the 1-gram minimum amount.

Sensitivity/specificity analyses were performed in order to explore the ability of the food group diversity indicator to accurately identify children with low vs. higher MNDA. Findings from our four data sets suggest that to identify children with low nutrient density diet (MNDA < 50%), a cutoff point of ≤ 2 food groups results in the lowest percentage of misclassified children and an acceptable balance of sensitivity and specificity in all four data sets. With this cutoff (using FGI-8), sensitivity was 61-88%, specificity was 43-85%, and the percentage misclassified was 22-29%, depending on the country. The most consistent cutoff point of dietary diversity to identify children with a better nutrient density diet (MNDA ≥ 75%) was ≥ 4 food groups. In this situation (again using FGI-8), sensitivity was 50-81%, specificity was 61-96%, and the percentage misclassified was 7-36%.

While the values for sensitivity and specificity are not as high as one might like in some of the countries, the results indicate that the dietary diversity indicator holds promise at least at the population level, if not at the individual level. Results from analyses using additional data sets from other countries are needed before making conclusive statements about the best indicators of dietary quality.

"Sentinel" foods groups as predictors of mean nutrient density adequacy

In the sensitivity/specificity analyses using individual food groups as predictors of MNDA, the combined food group for animal source foods and the group for other fruits and vegetables were predictive of MNDA in all four countries. Dairy products were predictive of MNDA in three of the four countries. When compared with the results for dietary diversity (using a cutoff of ≤ 2 food groups for FGI-8 and the 50% MNDA cutoff), the ASF food group yielded similar or better results in three of the four sites (the exception being Peru, in which the dietary diversity indicator gave slightly better results). Sensitivity was 49-93%, specificity was 50-87% and the percentage misclassified was 20-26%, depending on the country.

The relationship between feeding frequency and energy intake

Feeding frequency was strongly correlated with energy intake from complementary foods, with correlation coefficients ranging from ~0.5 in Honduras and Bangladesh to 0.66-0.78 in Peru. In the two sites in which meal frequency was also recorded, the correlation with energy intake from complementary foods was higher for meal frequency than for feeding frequency in Bangladesh, but the opposite was true in Honduras. This suggests that there is no consistent advantage in distinguishing meals from snacks, in terms of predicting energy intake from complementary foods.

In the two sites in which total energy intake (including energy from breast milk) was measured (Peru and Bangladesh), the correlations with feeding frequency were lower for total energy intake than for energy intake from complementary foods. This is not surprising, given that there is usually a trade-off between energy intake from breast milk and energy intake from complementary foods. Thus, when evaluating indicators that are predictive of the adequacy of energy intake, it is preferable to use total energy intake as the yardstick, rather than energy intake from complementary foods. Otherwise, the risk of misclassification is high (e.g., concluding that a child with a low feeding frequency had low energy intake, when energy intake was actually adequate because of a relatively high breast milk intake). This is particularly true when the average breast milk intake in a given population deviates from the global average breast milk intake upon which the feeding frequency recommendations are based, which was certainly the case for Bangladesh. However, there may be circumstances when an indicator of energy intake from complementary foods may be of use.

We performed sensitivity/specificity analyses using both total energy intake and energy intake from complementary foods as the outcome. With the latter option, a cutoff of ≤ 3 feedings at 6-8.9 months yielded the best results when predicting low energy intake from complementary foods, with sensitivity of 79-87%, specificity of 55-80% and 15-28% of cases misclassified. At 9-11.9 months, a cutoff of ≤ 4 feedings yielded the best results, with sensitivity of 75-81%, specificity of 75% and 18-25% misclassified. With the former option (total energy intake as outcome), the results were not as good (as expected, given the lower correlations between feeding frequency and total energy intake than between feeding frequency and energy intake from complementary foods). The cutoffs that yielded the lowest percentage misclassified were the same as those identified when energy intake from complementary foods was the outcome, and sensitivity was comparable, but specificity was lower (35-59%) and the percentage misclassified was higher (25-35%). In other words, when using total energy intake as the outcome, there was an excess of "false positives," or children identified by the indicator as having low energy intake who, in fact, had adequate energy intake. Whether this is acceptable depends on the purposes and uses of the indicators.

Conclusions

With regard to the two main objectives of these analyses, we conclude the following:

1. **Dietary diversity as an indicator of diet quality:**
    a) Diet diversity was associated with diet quality in all samples, for all age groups: mean MNDA increased with increasing dietary diversity, although the relationship was not always linear. All correlation coefficients between dietary diversity and MNDA were statistically significant, and they ranged from 0.37 to 0.74, depending on the age group and country.

    b) The dietary diversity indicator that included a 10-g minimum restriction did not result in lower percentages of misclassified children or higher sensitivities or specificities than the simpler indicator based on a 1-g limit (for practical purposes, equivalent to "any or none" for consumption), and therefore the simpler one is recommended.

    c) Best cutoff points varied depending on the diversity indicator and the cutoff point for MNDA used. Additional analyses in other age groups and contexts are required to confirm whether universal cutoff points can be recommended.

    d) An indicator based on consumption of animal source foods (yes/no) performed as well as or better than the dietary diversity indicator as a predictor of adequacy of nutrient density of complementary foods (when using the MNDA cutoff point of $<50\%$). Again, further analyses are needed to determine if this holds true for other data sets.

2. **Feeding frequency as an indicator of energy intake:**
    a) Feeding frequency was associated with both total energy intake and energy from complementary foods.

    b) All correlation coefficients between frequency of feeding and energy from complementary foods were statistically significant and ranged from 0.48 to 0.78, depending on the age group and country.

    c) As expected, the association of feeding frequency with total energy intake (from breast milk and complementary foods combined) was weaker than the association with energy from complementary foods only. Statistically significant correlations ranged from 0.35 among older infants in Bangladesh to 0.51 among young infants in Peru. The association was not significant among younger infants in Bangladesh (correlation coefficient was 0.02).

Analyses with other data sets will allow further evaluation of the performance of feeding frequency indicators (and cutoff points) to predict total energy intake as well as energy intake from complementary foods. Depending on the results, the usefulness of feeding frequency for these purposes will be re-evaluated. Irrespective of the results, however, feeding frequency may still be a useful indicator of the adequacy of infant caregiving practices.

1. INTRODUCTION

A lack of simple indicators of complementary feeding practices has hampered progress in measuring and improving infant and young child feeding in developing countries. In response to this, the World Health Organization (WHO) and the Pan American Health Organization (PAHO) set in place a new initiative in 2002 to review and develop indicators of complementary feeding practices. The initiative was timely because the "Guiding Principles for Complementary Feeding of the Breastfed Child," which were being developed at the time, provided a useful framework for addressing the multidimensionality of complementary feeding practices (PAHO/WHO 2003).[2] The Guiding Principles provide guidance and scientific rationale for 10 different aspects of optimal complementary feeding practices.

Simple, yet valid and reliable population-level indicators of complementary feeding practices are needed globally for the following purposes: (1) *for assessment*: to make national and subnational comparisons and to describe trends over time; (2) *for screening*: to identify populations at risk, target interventions, and make policy decisions about resource allocation; and (3) *for monitoring and evaluation*: to monitor progress in achieving goals and to evaluate the impact of interventions.

The process required to develop and validate global indicators of complementary feeding practices involves a series of steps and activities, including analysis of existing data sets, field-testing of selected indicators, and technical meetings and workshops to promote inter-institutional dialogue and to reach consensus on best indicators. The research described in this report addresses the first step of the process. It used four existing data sets available at the University of California at Davis to validate indicators related to two aspects of complementary feeding: the nutrient density of complementary foods and complementary food intake (kilocalories) of infants 6-12 months of age. More specifically, the two main research questions addressed were the following:

1) How well can *dietary diversity* (sum of foods or food groups consumed over a reference period) or *sentinel food groups* (selected nutrient-dense food groups) indicators predict the *dietary quality*[3] of complementary foods for infants in different populations with varying dietary patterns?

2) How well do indicators of frequency of feeding of complementary foods predict energy intake – either from complementary foods or total energy intake (including breast milk and complementary foods) – in different populations with varying dietary patterns?

The overall goal of the research was to initiate the process of developing and validating indicators of diet "quality" and "quantity" from complementary foods during the first two years of life.

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[2] Note that similar guiding principles have been developed and are soon to be published for the non-breastfed child.

[3] Dietary quality is defined in this report as "adequate nutrient density of complementary foods for 9 nutrients."

2. METHODS

2.1 Data sets

Four data sets with information on dietary intake of breastfed children between the ages of 6-12 months were used for these analyses (from Peru, Bangladesh, Ghana, and Honduras). The data were originally collected for other purposes; we selected subsets of the data, covering the age range of interest. The data sets had to include the amounts of all non-breast milk foods and nutritive fluids consumed by each child for at least one 24-hour period, obtained either by maternal recall or by an observer in the home who weighed all items consumed. When a mixed food containing several ingredients was consumed, the data set had to include the specific recipe used or a generic recipe for that population. In addition, nutrient composition data for all foods consumed had to be available. The types of data available in each data set are shown in Table 1, and the maximum sample sizes are shown in Table 2.

Table 1. Types of data available in each data set

	Peru	Bangladesh	Ghana	Honduras
Breast milk intake				
(12 h daytime)	Yes	Yes	No	No
Complementary food intake				
Weighed intake (daytime)	Yes	Yes	Yes	No
Recall (daytime)	No	No	No	Yes
Recall (nighttime)	Yes	Yes	No foods eaten at night	Yes
Meal frequency				
Feeding episodes	Yes	Yes	No	Yes
Meals	No	Yes	No	Yes
Snacks (day)	No	Yes	No	Yes
Snacks (night)	No	No	No	Yes

Table 2. Maximum sample sizes (child-days and subjects), by country and age category

Country/age (months)	Child-days	Subjects
PERU		
6-9	365	108
9-12	274	97
BANGLADESH		
6-9	54	54
9-12	70	70
GHANA		
6-9	220	140
9-12	174	118
HONDURAS		
6-9	709	130

2.1.1 Peru

The data for Peru come from an infant nutrition study in Huascar, a peri-urban community on the outskirts of Lima (Lopez de Romana, Brown, and Black 1987; Creed de Kanashiro et al. 1990). Newborns with a birth weight > 2,500 g were recruited between July 1982 and June 1984. Intake of breast milk, other liquids, and complementary foods was measured multiple times during the first year of life. Breast milk intake was estimated by daytime 12-hour test-weighing and milk macronutrient concentrations were analyzed. The amounts of other foods and liquids consumed during the same 12-hour period were weighed by an observer in the home. The amounts of foods consumed at nighttime were obtained by maternal recall. Enumerators observed and noted each feeding episode, and snacks were not distinguished from meals. For each child, 3-4 days of records were available for each age interval in these analyses. Nearly all of the children were breastfed at 6 months, but some discontinued breastfeeding at some point during the study. The intake records (child-days) that did not include breast milk were excluded from these analyses (12.5% of all child-days).

2.1.2 Bangladesh

Dietary intake data were obtained in 1999 for infants who were between 6 and 12 months of age in nine rural villages in Matlab *Thana*, located 55 kilometers southeast of Dhaka (Kimmons et al. 2004). The Matlab Health and Demographic Surveillance System supplied information on the number of infants per village and which households included infants of the appropriate age. In these villages, most infants in the 6-to-12-month age range participated in the study, unless their parents refused (n = 2) or the infant was ill and the observations could not be rescheduled (n = 2). All infants were breastfed. Each child's intake of breast milk and complementary foods was weighed on a single day by an observer in the home during a 12-hour period, and nighttime intake was estimated by maternal recall. Meals were defined as any feeding episode during which at least 10 g of food was consumed, and snacks were defined as < 10 g of food.

2.1.3 Ghana

The data for Ghana come from a randomized intervention study conducted in 1994-1996 to evaluate the effects of four different "improved" complementary food blends: (1) a maize/soybean/peanut blend [Weanimix], (2) Weanimix plus fish powder, (3) traditional fermented maize porridge [*koko*] plus fish powder, and (4) Weanimix fortified with vitamins and minerals (Lartey et al. 1999). The fourth group was excluded from the analyses herein. Infants were recruited at ≤ 1 month of age from Maternal and Child Health centers run by the Techiman Ministry of Health. Selection criteria were as follows: birth weight ≥ 2500 g, breastfed, no congenital abnormalities, assigned a Maternal and Child Health card, and the child's mother was not planning to travel or move out of the study area (the town of Techiman and its surroundings) during the study period. The intervention period was from 6 to 12 months of age. Note that the infants in the intervention study had better growth status at 12 months than those in a cross-sectional comparison group (e.g., mean length-for-age Z-score was -0.63 vs. –1.27, respectively), presumably because of the provision of the improved complementary foods. The dietary data for these analyses are based on 12-hour weighed intakes of a randomly selected subsample of 50% of infants in the intervention study at each time point (at 6, 7, 8, 10, and 12 months). A trained observer weighed all the foods and beverages consumed by the infant during the daytime 12-hour period, and no infant consumed anything other than breast milk during the nighttime. All infants were breastfed at 6 months and all but two were breastfed at 12 months. Intake records for child-days when breast milk was not consumed were excluded from analysis. The data set does not include information on the number of meals, snacks, or feeding episodes.

2.1.4 Honduras

The dietary data for Honduras come from a randomized clinical trial designed to study the effects of iron supplementation on iron status during infancy (Domellof et al. 2001). Mother-infant pairs were recruited at birth from the public maternity hospital in the city of San Pedro Sula. The study took place in 1997. Selection criteria for entry into the iron intervention trial, which began at 4 months, were as follows: (1) gestational age > 37 weeks, (2) birth weight > 2,500 g, (3) no chronic illness, (4) maternal age > 16 years, (5) infant exclusively breastfed at 4 months (and did not receive more than 90 mL/d of formula during any period since birth), (6) mother intended to exclusively or nearly exclusively breastfeed until 6 months (i.e., ≤ 1 tablespoon/d of foods or fluids other than breast milk, and no iron-fortified foods), and (7) mother intended to continue breastfeeding to at least 9 months. All infants in the intervention trial were breastfed throughout the study. Complementary food intake between 6 and 9 months of age was estimated by a bi-weekly 24-hour recall. If the infant was ill on the previous day, the mother was asked to recall intake on the day before that, or on a "typical" day. Meals and snacks were self-defined by mothers.

2.2 Food composition data and nutrient bioavailability assumptions

For Peru, a country-specific food composition database was used that included phytate values. Values for vitamin B6 and folate were added to the original Peruvian food composition database using values from the WorldFood Dietary Assessment System[4] or the Food Processor for Windows[5] food composition database (which is based on United States Department of Agriculture [USDA] data). For Bangladesh, Ghana, and Honduras, Food Processor values were generally used. For Ghana, some foods were not listed in the Food Processor database, in which case values from the USDA online database,[5] WorldFood Dietary Assessment System, or a Ghanaian food composition database were used.

When converting food intake data into nutrient intake data, the estimated bioavailability of zinc, calcium, and iron from different foods was used to estimate the amount of each nutrient *absorbed*. Phytate values are used to estimate zinc bioavailability based on the phytate to zinc (P/Z) ratio (Hotz and Brown 2004). Phytate values were available for Peru but not for the other data sets because phytate is not included in the Food Processor database. For the other sites, phytate values were obtained from the researchers or from the World Food Programme, and the

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[4] The WorldFood Dietary Assessment System, version 2, is available at: http://www.fao.org/infoods/software_worldfood_en.stm.

[5] ESHA Research (1997) The Food Processor for Windows. Version 7.01. The database incorporated into the Food Processor software is the USDA Nutrient Database for Standard Reference, Release 14, is available at: http://www.nal.usda.gov/fnic/foodcomp/Data/SR14/sr14.html

P/Z ratio was calculated. Zinc absorption was estimated as 30% for P/Z ≤ 18 and 22% for P/Z > 18 (Hotz and Brown 2004). Absorption of calcium was assumed to be 25% for legumes, roots/tubers, and grains, 5% for foods with high oxalate content (e.g., spinach), 45% for other fruits and vegetables, and 32% for all other foods (including dairy products) (Weaver, Proulx, and Heaney 1999). Absorption of iron was assumed to be 6% from plant source foods and 11% from animal source foods (including milk, which has lower iron bioavailability than meats). These are rough estimates based on reported values for absorption of iron from complementary foods (Hurrell 2003; Lynch and Stoltzfus 2003).

The food composition databases use a ratio of 6:1 for the conversion of beta-carotene to retinol equivalents (RE), but recent data indicate that a ratio of 12:1 is more appropriate, and this ratio was used in calculating the new Dietary Reference Intakes (IOM 2000). We adjusted for this by dividing all the plant-based food vitamin A values by 2. The exception was red palm oil, which has a conversion ratio of 2:1.[6] Thus, for red palm oil we multiplied the vitamin A value in the food composition database by 3.

2.3 Dietary diversity indicators

After examining several different options for grouping foods and calculating a dietary diversity index, the food groups shown in Table 3 were selected. Foods such as sweets, spices, etc., that do not provide nutrients other than energy were not included in the food groups (although they were included when calculating energy intake). The following diet diversity indexes were used in the analyses:

1) The *Food Group Index-8* (FGI-8): this index was based on consumption of food from each of the eight food groups listed in Table 3, with each food group coded "yes" if at least 1 g was consumed (range 0-8);

2) The *Food Group Index-8 Restricted* (FGI-8R): this index was similar to the first index (FGI-8), except that it used a restriction of 10 g from the food group (except fats and oils) to be considered as having been consumed by the child (range 0-8). The cutoff of 10 g is based on inspection of the individual dietary records. For the "fats and oils" food group, the cutoff of ≥ 1 g was used.

[6] See conversion factors suggested by the International Vitamin A Consultative Group (http://ivacg.ilsi.org/file/webBookmark.pdf; accessed March 21, 2005).

Table 3. Food groupings used to derive the dietary diversity indexes[a]

Major food groups	Foods
1. Grains, roots and tubers	Grains a) grain products (porridge, bread, tortilla, pasta, etc.) b) cookies, cake, etc. Roots and tubers (except sweet potatoes) a) vitamin C rich b) others
2. Legumes and nuts	a) beans and peas b) soybeans and soy products c) nuts and seeds (include peanuts)
3. Dairy products	a) milk b) cheese c) other - yogurt, puddings, ice cream d) cream, sour cream
4. Flesh foods	a) meat b) fish c) poultry d) liver and other organ meat
5. Eggs	
6. Vitamin A-rich fruits and vegetables (> 130 RE of vitamin A per 100 g)	a) dark green leafy vegetables b) other vitamin A rich vegetables and juices (including sweet potatoes) c) vitamin A rich fruits and juices
7. Other fruits and vegetables	a) vitamin C rich vegetables and juices (> 18 mg vitamin C per100 g) b) other vegetables (not rich in either vitamin A or vitamin C) c) vitamin C rich fruits and juices d) other fruits (not rich in either vitamin A or vitamin C) e) starchy fruits (bananas, plantains) f) other juices (not rich in either vitamin A or vitamin C)
8. Fats and oils	a) general (oil, butter, margarine, lard, "crisco," mayonnaise) b) red palm oil

[a] The following foods and condiments are not included in the above groups: sodas and other sweet beverages, candy, honey, chocolate, and condiments or spices that provide little other than energy.

2.4 Definition of nutrient adequacy of complementary foods (gold standard used for validation)

The nutrient adequacy of complementary foods was defined based on how well the complementary food diet met nutrient density recommendations. Nutrient adequacy was based on *nutrient density* (amount per 100 kcal of complementary food), rather than absolute *nutrient intake*, because of the variability in breast milk intake among individual children. Without measuring breast milk intake (which would not be practical in large-scale surveys), it would be difficult to judge whether the absolute amounts of nutrients from complementary foods consumed were sufficient.

Nutrient density recommendations vary not only by age group (6-8.9, 9-11.9, and 12-23.9 months), but also by level of breast milk intake (WHO) 1998), because the amount of each nutrient needed depends on how much is provided by breast milk. Following a set of preliminary analyses, described in Annex 1, we used the 50th percentile value (from WHO 1998), or "average" breast milk intake to calculate the amount required from complementary foods for each of nine "problem" nutrients identified in Dewey and Brown (2003), for each of the two age groups. The nine problem nutrients are: vitamins A, B6, and C, riboflavin, thiamin, folate, iron, zinc, and calcium.

The estimated amount of each of these nutrients contributed by breast milk (based on breast milk concentrations published in WHO 1998) was subtracted from the Recommended Nutrient Intake (RNI) for each nutrient. RNI values from FAO/WHO were used for all of the vitamins (Joint FAO/WHO Expert Consultation 2002). For the minerals, the recommended amount *absorbed* was the basis for the calculation. For calcium, the total recommended amount absorbed was estimated as 30% of the Dietary Reference Intake (IOM 1997): 81 mg/d at 6-11.9 months (.3 x 270 mg/d) and 150 mg/d at 12-23.9 months (.3 x 500 mg/d). The percentage of calcium absorbed from breast milk was estimated as 30%. For iron, the total recommended amount absorbed was estimated as 10% of the FAO/WHO (2002) RNI: 0.93 mg/d at 6-11.9 months (.1 x 9.3 mg/d) and 0.58 mg/d at 12-23.9 months (.1 x 5.8 mg/d). The percentage of iron absorbed from breast milk was estimated as 20% (Domellof et al. 2001). For zinc, the total recommended amount absorbed was based on the Dietary Reference Intake calculations (IOM 2000): 0.836 mg/d + 20% = 1 mg/d. The percentage of zinc absorbed from breast milk was estimated as 50% (IOM 2000).

The desired nutrient densities were then calculated by dividing the required amount of the nutrient from complementary food by the complementary food energy requirement for infants with average breast milk intake, and multiplying by 100. For example, for a 6-8.9 month infant with average breast milk intake, the calculation of the desired nutrient density for vitamin A would be:

> [Vit A RNI **-** (Vit A concentration in breast milk × "average" breast milk intake volume)**/** Energy needed from complementary foods when breast milk intake is "average"] × 100;

or

> [400 ug RE **-** (500 ug RE/L × .674 L)/202 kcal] × 100 = 31.2 ug RE per100 kcal.

Table 4 shows the nutrient needs from complementary foods, and Table 5 shows the desired nutrient densities used for these calculations.

On the level of the child-day, the desired nutrient density for each nutrient was used to determine the percentage of the desired nutrient density fulfilled by the complementary foods consumed that day (termed the "nutrient density adequacy" (NDA) score). See Box 1 for an example of calculation of nutrient density adequacy for folate for one child-day of observation.

After calculating the individual nutrient density adequacy for each of the nine "problem" nutrients, the overall "mean nutrient density adequacy" (MNDA) was calculated as the average of the nine individual NDA scores for that day, after each was capped at 100%.

Table 4. Energy and nutrient needs from complementary foods for breastfed children with average breast milk intake[a]

	Age group	
Energy and nutrients per day	**6-8.9 months**	**9-11.9 months**
Total energy (kcal)	615	686
Average breast milk intake (L)	0.674	0.616
Average breast milk energy (kcal)	413	379
Nutrient needs from complementary foods		
Energy (kcal)	202	307
Vitamin A (RE)	63	92
Thiamin (mg)	0.16	0.17
Riboflavin (mg)	0.16	0.18
Vitamin B6 (mg)	0.24	0.24
Folate (ug)	23	28
Vitamin C (mg)	3	5
Calcium (mg)	81	98
Absorbed calcium (mg)	24	29
Iron (mg)	9.1	9.1
Absorbed iron (mg)	0.89	0.89
Zinc (mg)	2.2	2.3
Absorbed zinc (mg)	0.60	0.63

[a] RNI values: Vitamin A, 6-24 mo - 400 RE; thiamin, 6-12 mo - 0.3 mg, 12-24 mo - 0.5 mg; riboflavin, 6-12 mo - 0.4 mg, 12-24 mo - 0.5 mg; vitamin B6, 6-12 mo - 0.3 mg, 12-24 mo - 0.5 mg; folate, 6-12 mo - 80 ug, 12-24 mo - 160 ug; vitamin C, 6-24 mo - 30 mg; calcium (absorbed), 6-12 mo - 270 mg (81 mg), 12-24 mo - 500 mg (150 mg); iron (absorbed), 6-12 mo - 9.3 mg (0.93 mg), 12-24 mo - 5.8 mg (0.58 mg); zinc (absorbed), 6-24 mo - 3 mg (1 mg). RNI values from FAO/WHO (2002) were used for all of the vitamins. For the minerals, the recommended amount *absorbed* was the basis for the calculation (see text). Average breast milk intake = 50th percentile of breast milk intake (WHO 1998).

Table 5. Desired nutrient densities[a] for infants with average breast milk intake

Nutrient	**6-8.9 months**	**9-11.9 months**
Vitamin A (RE)	31.2	30.0
Riboflavin (mg)	0.08	0.06
Thiamin (mg)	0.08	0.06
Vitamin B_6 (mg)	0.12	0.08
Vitamin C (mg)	1.50	1.75
Folate (ug)	11.2	9.0
Calcium (mg)		
Absorbed calcium (mg)	12.1	9.5
Iron (mg)		
Absorbed iron (mg)	0.44	0.29
Zinc (mg)		
Absorbed zinc (mg)	0.29	0.21

[a] Amount per 100 kcal of complementary food, based on the following RNI values: vitamin A, 6-24 mo - 400 RE; thiamin, 6-12 mo - 0.3 mg, 12-24 mo - 0.5 mg; riboflavin, 6-12 mo - 0.4 mg, 12-24 mo - 0.5 mg; vitamin B6, 6-12 mo - 0.3 mg, 12-24 mo - 0.5 mg; folate, 6-12 mo - 80 ug, 12-24 mo - 160 ug; vitamin C, 6-24 mo - 30 mg; calcium (absorbed), 6-12 mo – 270 mg (81 mg), 12-24 mo - 500 mg (150 mg); iron (absorbed), 6-12 mo - 9.3 mg (0.93 mg), 12-24 mo - 5.8 mg (0.58 mg); zinc (absorbed), 6-24 mo - 3 mg (1 mg). RNI values from FAO/WHO (2002) were used for all of the vitamins. For the minerals, the recommended amount *absorbed* was the basis for the calculation (see text).

Box 1. Example of nutrient density adequacy calculation for folate

If intake of folate from complementary foods for a 6-8.9 month old was 20 ug, and complementary food energy intake was 150 kcal, then that day's percentage of the desired nutrient density for folate would be calculated as:

$$[((20 \text{ ug}/150 \text{ kcal}) \times 100)/11.2] \times 100 = 149\% .$$

If that same child ate 250 kcal that day, then the corresponding calculation would be:

$$[((20 \text{ ug}/250\text{kcal}) \times 100/11.2] \times 100 = 71\% .$$

2.5 Analytical methods

For all analyses, the unit of analysis was one child-day, corresponding to one 24-hour record of food intake. In all data sets except Bangladesh, there were multiple child-days per child. For any analyses that included the food group categories or dietary diversity indexes, child-days on which the child consumed a specially fortified product (infant formula or fortified infant cereal) were excluded. These products were rarely consumed but have the potential to greatly influence nutrient adequacy and thus distort the usual relationship between dietary diversity and nutrient adequacy. The percentage of child-days excluded for this reason was < 1% (0.8% in Honduras, 0.7% in Peru, 0.6% in Ghana, and 0.5% in Bangladesh).

2.5.1 Association between dietary diversity and nutrient density adequacy

The association between dietary diversity and nutrient density adequacy was first assessed by simple bivariate analyses such as comparison of mean values and correlation coefficients. Simple regression models were used to test if relationships between dietary diversity and nutrient density adequacy were linear.[7] Next, for each of the four data sets, sensitivity and specificity analyses were done to compare the performance of indicators in correctly differentiating cases with low and higher MNDA. Sensitivity and specificity analyses were used to identify the cutoff points for dietary diversity (i.e., number of food groups consumed) that best differentiated cases with MNDA below 50% ("poor" dietary quality) or at or above 75% ("better" dietary quality).[8]

[7] That is, the square of the number of food groups was included as an independent variable in the equation. A significant coefficient for this quadratic term was taken to indicate that the relationship was not linear.

[8] In conversations among collaborating researchers, there was consensus that an MNDA below 50% could be called low and is very likely to represent an inadequate diet. There was far less consensus surrounding the idea of selecting of a cutoff for a positive indicator. Children with an MNDA ≥ 75% could still be consuming far too little of one or more nutrients. However, for these analyses, use of a higher MNDA cutoff proved to be problematic. In two of the four data sets analyzed here, very few children had MNDA ≥ 75%; this makes it difficult to assess the relationship with any other measure (e.g., dietary diversity). For the purposes of this document, the indicator created by use of a 75% cutoff will be referred to as "better" MNDA; above this cutoff, diets are more likely to be closer to adequate. We also emphasize that the work is primarily aimed towards developing indicators for use at population level, and not at the level of the individual child. We acknowledge that discussions on this issue should continue.

Two sets of analyses were completed, one using FGI-8 and the other using FGI-8R as the measure of dietary diversity.

2.5.2 Association between individual food group consumption and nutrient adequacy

For each of the four data sets, sensitivity and specificity were also calculated to identify which of the eight food groups were most predictive of whether each of the nine individual NDA scores fell above or below a certain "adequacy" cutoff. For these purposes, the cutoff for an inadequate nutrient density was defined as < 60% of desired for all nutrients except iron.[9] This cutoff could not be used for iron density because it was exceedingly rare for iron density to be ≥ 60% of desired; therefore, a cutoff of < 10% of desired was used to define inadequate iron density. These analyses were done both with and without imposing the 10-gram minimum when coding consumption from a given food group as "yes." In addition, sensitivity and specificity were calculated to test whether selected "sentinel" food groups (yes/no for consumption) could be useful to differentiate cases with MNDA below 50% or above 75%. This was completed both with and without the 10-gram minimum restriction.

2.5.3 Association between feeding frequency and energy intake

These analyses included the following:

1) Correlation analysis was used to test the associations between total energy intake (Peru and Bangladesh) or energy from complementary foods (Peru, Bangladesh, and Honduras) and number of feeding episodes (meals + snacks, or meals only, if feeding episodes were subdivided). As before, simple regression models were used to test if relationships between energy and number of feeding episodes were linear.[10] For the latter analyses, three "outliers" in Honduras were excluded (because of very high feeding frequency or high energy intake, all due to a high consumption of cow's milk).

2) Sensitivity and specificity were calculated from 2 x 2 tables to assess which cutoff points for frequency of feeding complementary foods (meals + snacks, or meals only) best differentiated cases with total energy intake above or below total energy requirements (Peru and Bangladesh), or with energy intake from complementary foods above or below the expected level (based on average breast milk intake) at each age (Peru, Bangladesh, and Honduras).

[9] Cutoffs of 60% (and 10% for iron) were chosen based on the distribution of densities, and the need to have sufficient numbers of child-days above the cutoff to conduct the analysis.

[10] That is, the square of the number of meals (or feeding episodes) was included as an independent variable in the equation. A significant coefficient for this quadratic term was taken to indicate that the relationship was not linear.

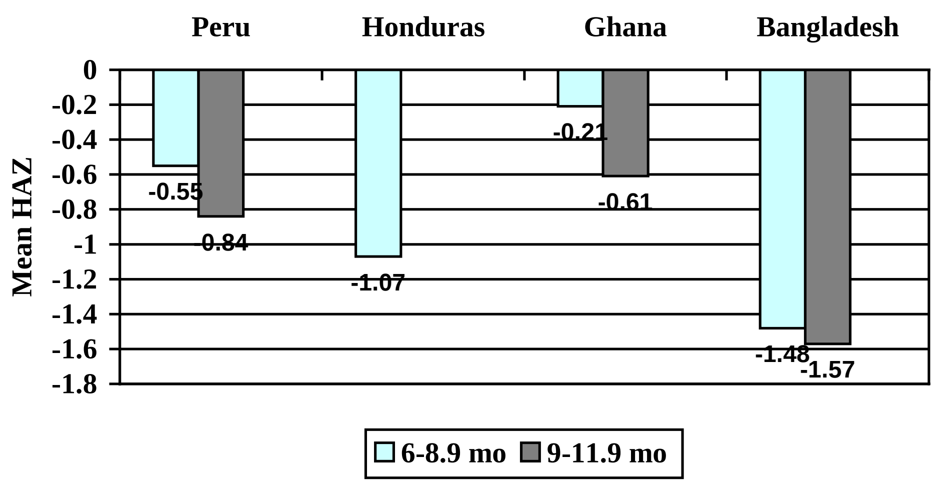
3. RESULTS

This section presents the results of our analysis of four data sets. Descriptive information is presented first on the nutritional status, breastfeeding patterns, and complementary feeding practices of the sampled infants. Section 3.4 presents the findings of the validation of dietary diversity indicators to predict the nutrient density adequacy of complementary foods. It is followed in Section 3.5 by an analysis of selected nutrient-dense "sentinel" food groups and their performance in predicting the nutrient density of complementary foods. Section 3.6 addresses the second objective of the research, i.e., to test whether simple indicators of feeding frequency accurately predict energy intake from complementary foods.

3.1 Characteristics of samples: Anthropometry

Figure 1 and Table 6 provide information on the nutritional status of children in the samples. As is usually observed, mean height-for-age Z-scores (HAZ) decrease with age, and conversely, the prevalence of stunting (low height-for-age) increases. With the exception of Bangladesh, very few children have low weight-for-height. Favorable indicators in Ghana presumably reflect the effect of the complementary food intervention (see methods).

Figure 1. Mean height-for-age Z-score (HAZ), by country and by age group



3.2 Characteristics of samples: Breastfeeding

Data on both breastfeeding frequency and breast milk intake are available only for Peru and Bangladesh. Table 7 summarizes the information on breast milk intake and frequency of feeding for children in these two samples. The frequency of breastfeeding is much lower in Peru than in Bangladesh for all age groups, and within each country, the frequency changes only slightly across the two age groups. In contrast, breast milk intake decreases markedly across age groups in Peru, while this is not the case in Bangladesh. In these data sets, there is not a clear and consistent relationship between breastfeeding frequency and breast milk intake. Table 7 also shows that more children in Bangladesh exceed the age-specific global average for breast milk intake than in Peru.

Table 6. Percent of child-days when children were stunted or wasted, by country and by age group

Country/age group	n	Percent stunted HAZ < -2	Percent wasted WHZ < -2
Peru			
6-8.9 months	318	4	1
9-11.9 months	254	8	1
Honduras			
6-8.9 months	495	15	0
Ghana			
6-8.9 months	209	0	3
9-11.9 months	172	3	5
Bangladesh			
6-8.9 months	48	40	25
9-11.9 months	65	29	20

3.3 Characteristics of the sample: Complementary feeding

3.3.1 Frequency of feeding

As noted earlier, definitions of frequency of feeding differed between the samples, and no data are available for Ghana. In Peru, enumerators observed and noted each feeding episode, and snacks were not distinguished from meals; in Honduras, meals and snacks were self-defined by mothers; in Bangladesh, meals were defined as any feeding episode during which the child consumed at least 10 grams of food, and snacks were defined as feeding episodes when the child ate less than 10 grams.

Recently updated guidance for complementary feeding of the breastfed child recommends that children aged 6-8.9 months be fed meals of complementary food at least 2-3 times per day along with additional snacks, as desired. Older infants and children (9-23.9 months) should be fed meals at least 3-4 times per day, with additional snacks (PAHO/WHO 2003).[11]

Table 8 shows the mean frequency of feeding episodes (Peru), and meals and snacks (Honduras and Bangladesh), and also shows the proportion of children who ate at least the minimum recommended number of meals the previous day.[12]

[11] The lower frequencies (two meals for the younger age group and three meals for the older) assume breast milk intake at a level that is average in developing countries, whereas the higher frequencies (three meals for the younger and four meals for the older) assume low breast milk intake. These recommendations also assume that complementary foods meet a criterion for minimum energy density of 0.8 kcal/g, and that infants eat to gastric capacity at each meal.

[12] Tables A1 and A2 in the annex provide the distribution (number and percent) of child-days falling into each frequency of feeding category.

Table 7. Frequency of breastfeeding and breast milk intake, by country and by age group

Country/age group	Number of observations	Mean 12-hour breastfeeding frequency (SD)	Mean 12-hour breast milk intake (g) (SD)	Mean 24-hour breastfeeding frequency (SD)	Mean 24-hour breast milk intake (g) (SD)	Global average[a]	Percent of observations above global average[b]
Peru							
6-8.9 months	365	4.6 (1.6)	356 (140)	n/a[b]	658 (210)	674	51
9-11.9 months	274	4.1 (1.8)	305 (136)		582 (212)	616	47
Bangladesh							
6-8.9 months	54	8.5 (2.2)	373 (124)	12.0 (2.8)	703 (235)	As above	57
9-11.9 months	70	8.0 (1.8)	388 (109)	11.6 (2.3)	732 (206)		71

[a] (WHO 1998).

[b] Mean 24-hour breastfeeding frequencies are not available for Peru.

Table 8. Frequency of meals and snacks, by country and by age group

Country/age group	Mean meal frequency (SD)	Mean snack frequency (SD)	Mean total frequency of feeding episodes (SD)	Percent fed fewer than minimum recommended meals: Meals	Percent fed fewer than minimum recommended meals: Feeding episodes[a]
Peru					
6-8.9 months			3.6 (2.4)		20
9-11.9 months	n/a[b]	n/a	4.8 (2.7)	n/a	18
Honduras					
6-8.9 months	2.5 (0.7)	0.7 (0.9)	3.2 (1.2)	11	7
Bangladesh					
6-8.9 months	2.2 (1.7)	0.8 (1.1)	3.0 (1.7)	39	24
9-11.9 months	3.0 (2.0)	0.9 (1.0)	3.9 (2.1)	40	27

[a] The guideline refers to meals; data are shown here both for meals and with "feeding episodes" considered as meals, for comparison.
[b] n/a: data not available.

In Honduras, only one in ten infants was fed too infrequently; low frequency of feeding appears to be a more common problem in Peru and particularly in Bangladesh, where nearly half the children (four in ten) were fed less frequently than the minimum recommendation.

3.3.2 Food groups consumed and dietary diversity

Tables 9 and 10 show the proportion of child-days each food group was consumed. The first table shows the proportions when 1 gram was the minimum amount used to define consumption. The second table shows the proportions when a 10-gram minimum was applied to each food group (i.e., the child was not considered to have eaten that food group on that day unless he/she ate a minimum of 10 grams, except for fats and oils).

Table 9. Percent of child-days various food groups were consumed, by country and by age group (1-gram minimum)

	Grains, roots, tubers	Legumes and nuts	Dairy	Flesh foods	Eggs	Vitamin A -rich fruits and vegetables	Other fruits and vegetables	Fats and oils
Peru								
6-8.9 months	92	4	40	28	11	60	49	13
9-11.9 months	99	5	48	38	16	66	69	30
Honduras								
6-8.9 months	95	14	53	28	42	16	69	19
Ghana								
6-8.9 months	100	67	18	43	3	5	15	10
9-11.9 months	99	70	12	58	1	13	48	44
Bangladesh								
6-8.9 months	96	18	10	2	4	4	27	4
9-11.9 months	99	30	21	9	1	12	31	6

Table 10. Percent of child-days various food groups were consumed, by country and by age group (10-gram minimum)

	Grains, roots, tubers	Legumes and nuts	Dairy	Flesh foods	Eggs	Vitamin A - rich fruits and vegetables	Other fruits and vegetables
Peru							
6-8.9 months	79	1	35	14	4	26	22
9-11.9 months	98	3	42	20	9	34	41
Honduras							
6-8.9 months	80	3	27	13	30	5	60
Ghana							
6-8.9 months	99	56	15	12	1	3	8
9-11.9 months	99	61	12	24	1	6	34
Bangladesh							
6-8.9 months	78	8	8	0	4	4	20
9-11.9 months	84	22	21	0	1	7	21

Patterns of food groups consumed vary substantially between the data sets. For example, legumes were consumed by very few infants in Peru or Honduras, but in Ghana, two-thirds of the infants had at least a taste and more than half had 10 grams or more. Conversely, dairy foods were widely consumed only in Peru and Honduras, and eggs were widely consumed only in Honduras. Flesh foods were consumed by a substantial proportion of infants (28-58%) everywhere except Bangladesh. However, even in the three countries where infants commonly had at least a taste, it appears that amounts were generally small, and only 12-24% of the infants consumed 10 grams or more of these foods. Vitamin A-rich fruits and vegetables were commonly eaten in Peru, but not elsewhere.

In general, applying the 10-gram minimum makes a marked difference in the estimates of the proportion of children who consumed foods from the different groups. This is less true for staple foods (grains/roots/tubers), which were eaten on most child-days, and for dairy products (except in Honduras). Also, when food groups are rarely consumed (e.g., eggs in Ghana and Bangladesh), there is little difference in the proportions. For most food groups in most countries, however, using the 10-gram restriction on the amount of food consumed resulted in large differences in the estimated proportions of children who had consumed that food group.

Annexes 2-5 show the mean and median amounts (grams) and energy (kcal) consumed from each food group both for the sample overall, and for child-days when the food group was consumed.

Figures 2 and 3 show mean food group diversity for our two diversity indexes—the FGI-8 (1-gram minimum) and the FGI-8R (10-gram minimum)—by country and age group. As would be expected, mean food group diversity is considerably lower when the 10-gram minimum is applied. Scores for the FGI-8R are generally 30-40% lower than when no minimum is applied (FGI-8). Regardless of which score is used, however, cross-country comparisons are similar, with Bangladesh showing the lowest diversity, followed by Ghana, and the highest diversity found in the Latin American samples. Also as would be expected, mean diversity increases markedly with age. Tables 11 and 12 show frequency distributions for the two diversity indexes, by country, and present a similar picture.

Figure 2. Mean food group diversity, by country and by age group (FGI-8: range 0-8, 1-gram minimum)

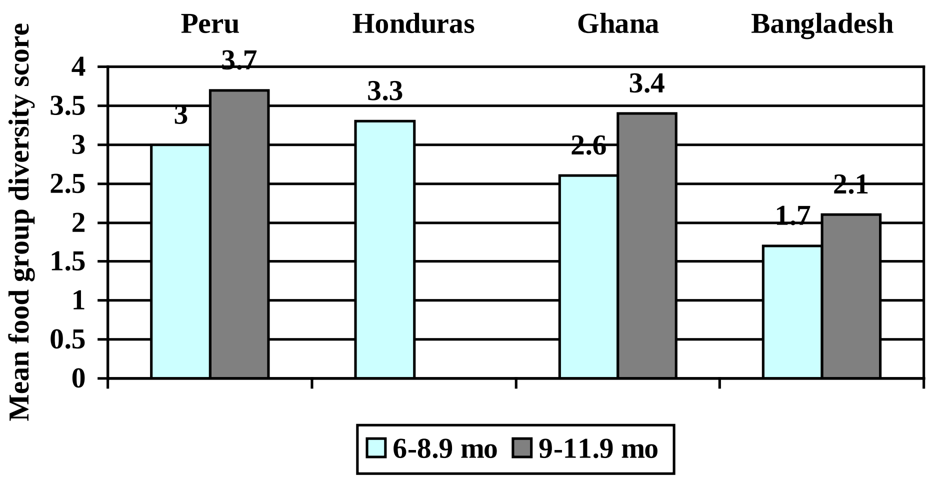


Figure 3. Mean food group diversity, by country and by age group (FGI-8R: range 0-8, 10-gram minimum)

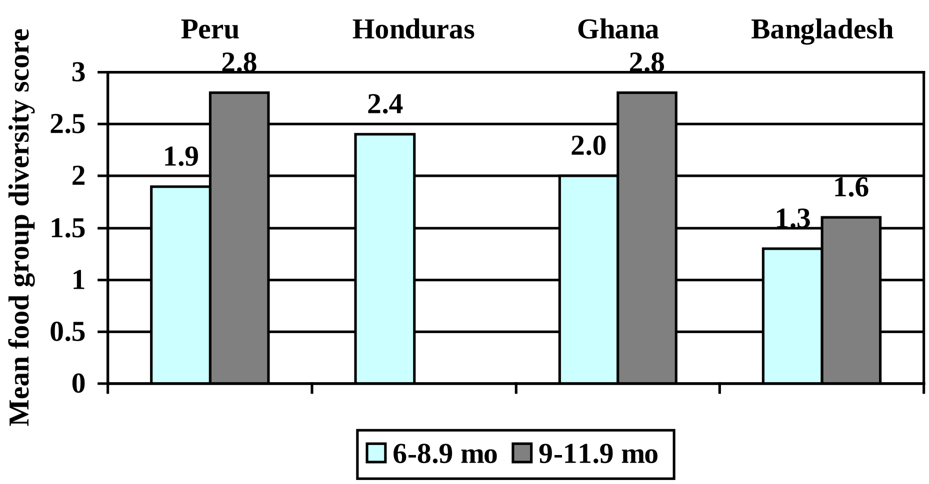


Table 11. Percent of child-days at each food group diversity score, by country (FGI-8: 1-gram minimum)

Number of food groups	Peru	Honduras	Ghana	Bangladesh
1	12	10	8	41
2	16	21	36	34
3	25	25	25	17
4	28	22	16	6
5	13	14	10	1
6	5	6	4	0
7	1	1	1	0
8	0	0	0	0

Table 12. Percent of child-days at each food group diversity score, by country (FGI-8R; 10-gram minimum)

Number of food groups	Peru	Honduras	Ghana	Bangladesh
0	4	5	1	12
1	28	22	20	44
2	27	29	41	32
3	22	26	22	9
4	13	12	13	2
5	4	5	3	1
6	1	1	1	0
7	0	0	0	0
8	0	0	0	0

Table 13 shows an example from Peru of how diet patterns change as dietary diversity increases. The example uses the FGI-8; results for all four countries are shown in Annexes 6-9.

Table 13. Peru: Percentage of child-days on which different food groups were consumed, by FGI-8 score (infants 6-11.9 months)

	FGI-8 score (number of food groups)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Percent (number) of child-days at each diversity score	12% (71)	16% (91)	25% (146)	28% (160)	13% (74)	5% (26)	1% (5)	0% (0)
Food groups	Percent of child-days on which each food group was consumed							
Grains, roots, tubers	72	96	98	99	100	100	100	
Legumes and nuts	0	0	1	8	9	15	20	
Dairy	18	29	38	48	65	92	100	
Flesh foods	0	14	24	48	53	73	100	
Eggs	3	4	9	15	23	46	80	
Vitamin A-rich fruits and vegetables	3	36	71	77	96	92	100	
Other fruits & vegetables	4	20	51	83	97	100	100	
Fats and oil	0	1	8	23	57	81	100	

In Peru, children whose diet includes only one food group are most likely to receive foods from the grains/roots/tubers group. The second most commonly consumed foods among those who had only one food group are dairy products. Fruits and vegetables and flesh foods become more common at diversity scores of 4 or higher, while eggs, legumes, and fats and oil are rare until diversity scores are 6-7. Patterns differ across countries (see Annexes 6-9).

3.3.3 Energy and nutrient intakes, and nutrient density adequacy of complementary foods

Desired energy and nutrient intakes from complementary foods for various age groups were calculated from the RNIs described in the methods section, assuming average breast milk intake (WHO 1998). Using these desired intakes, we calculated the percent of desired levels for each child-day in the four country samples. Complete information about desired intakes, actual intakes, and percent of desired intakes is given in Annex 10.

Table 14 provides information on the median percent of desired intake, by country and age, in order to identify which nutrients were most problematic in these samples. Table 15 shows results for the median percentage of desired nutrient densities.

Tables 14 and 15 illustrate that iron was a problematic nutrient in all four countries, with the median percent of desired absorbed iron density being only 5-13% at 6-8.9 months and 9-36% at 9-11.9 months. Median vitamin A density was very low in Bangladesh (0-1% of desired) and Ghana (0-31% of desired), but higher in Honduras (82% of desired) and Peru (65-92% of desired). Median absorbed zinc density was low during both age intervals and across countries (22-63% of desired at 6-8.9 months, 42-57% of desired at 9-11.9 months). Median absorbed calcium and vitamin B6 density was low (< 60% of desired) in Peru and Bangladesh at 6-8.9 months, and in Bangladesh at 9-11.9 months. Median riboflavin density was generally low in Bangladesh and Ghana, but close to or more than adequate in Peru and Honduras, while median thiamin density tended to be low in Peru and Bangladesh but more adequate in Honduras and Ghana. Median folate density was low in Bangladesh and Ghana at 6-8.9 months, but was otherwise > 60% of desired. Median vitamin C density was very low in Ghana and Bangladesh but more than adequate in Peru and Honduras.

As described previously, the individual nutrient density adequacy (NDA) for each of nine “problem” nutrients was calculated for each day of intake. The overall mean nutrient density adequacy (MNDA) was calculated as the average of the nine individual nutrient density adequacy scores for that day, after each was capped at 100%. Figure 4 compares this summary MNDA across countries and age groups.

Table 14. Median percent desired energy and nutrient intake from complementary foods, by country and by age group

Energy and nutrients	Peru	Honduras	Ghana	Bangladesh
	Percent desired intake[a]			
6-8.9 months				
Energy	56	78	78	39
Vitamin A	67	69	0	0
Thiamin	30	72	61	24
Riboflavin	49	87	38	22
Vitamin B6	39	58	51	7
Folate	56	82	49	29
Vitamin C	85	234	7	0
Absorbed calcium	22	63	49	13
Absorbed iron	4	6	14	2
Absorbed zinc	20	23	49	9
9-11.9 months				
Energy	80	n/a[b]	90	37
Vitamin A	52		48	0
Thiamin	53		88	33
Riboflavin	90		53	24
Vitamin B6	61		82	18
Folate	80		69	41
Vitamin C	93		37	7
Absorbed calcium	43		126	19
Absorbed iron	9		32	3
Absorbed zinc	36		52	17

[a] *Desired intake calculated based on average breast milk intake (WHO 1998).*
[b] *n/a = no data for this age group.*

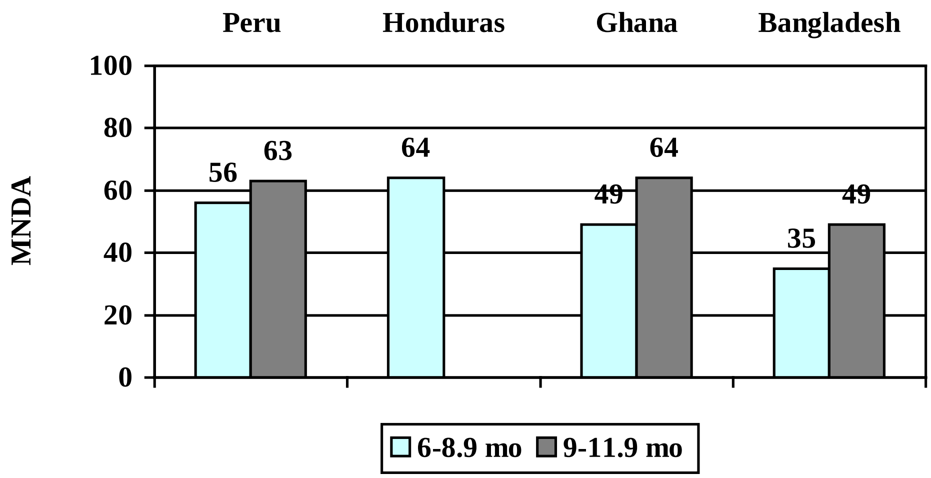
Table 15. Median percent desired nutrient density of complementary foods[a], by country and by age group

Nutrients	Peru	Honduras	Ghana	Bangladesh
	Percent desired nutrient density of complementary foods			
6-8.9 months				
Vitamin A	92	82	0	0
Thiamin	49	89	75	58
Riboflavin	92	95	50	53
Vitamin B6	59	74	64	15
Folate	74	89	60	54
Vitamin C	157	261	11	0
Absorbed calcium	52	80	63	28
Absorbed iron	6	8	13	5
Absorbed zinc	37	30	63	22
9-11.9 months				
Vitamin A	65	n/a[b]	31	1
Thiamin	62		97	82
Riboflavin	115		60	81
Vitamin B6	83		93	36
Folate	87		77	116
Vitamin C	130		35	19
Absorbed calcium	69		167	48
Absorbed iron	10		36	9
Absorbed zinc	49		57	42

[a] See methods for calculations.
[b] *n/a = no data for this age group.*

Figure 4 shows that the MNDA increases with age, in a pattern similar to the increases in dietary diversity illustrated in Figures 2 and 3. Also as with diversity, the MNDA is highest in the two Latin American countries, intermediate in Ghana, and lowest in Bangladesh.

Figure 4. Mean Nutrient Density Adequacy (MNDA), by country and by age group



In order to better understand how patterns of food group consumption relate to differences in nutrient intake and density, we examined the contribution of each food group to energy and nutrient intakes from complementary foods (see Tables 16-19). Just as patterns of food group intake vary between countries, food groups vary considerably in their overall contribution to energy and nutrient intakes. The proportion of energy intake (kcal) from grains/roots/tubers varies from 33% in Honduras to 76% in Bangladesh.[13] Other food groups providing at least 10% of energy vary by country and include: dairy products in Peru; dairy products, eggs, and "other" fruits and vegetables in Honduras; and legumes in Ghana (no other food group provides more than 6% of energy in Bangladesh).

Contributions of food groups to other nutrients also reflect diet patterns. For example, because dairy products are rich in many nutrients and because they were eaten on nearly one-half of all observed days in Peru, this food group contributes a substantial proportion of many nutrients in Peru. Similarly, eggs were commonly consumed in Honduras, and contributed ~20% of the intake of several key nutrients such as iron, zinc, riboflavin, and vitamin A. Conversely, vitamin A-rich fruits and vegetables could not contribute substantial proportions to vitamin A intake in three of the four countries because they were not eaten on the majority of child-days.

[13] Note that the Honduran sample includes only infants 6-8.9 months, whereas the other samples all include older infants.

Table 16. Peru: Percent contribution of food groups to intake (from complementary foods) of energy and selected "problem" nutrients (children 6-11.9 months)[a]

	Food group (%)							
Nutrients	**Grains, roots, tubers**	**Legumes and nuts**	**Dairy**	**Flesh foods**	**Eggs**	**Vitamin A-rich fruits and vegetables**	**Other fruits and vegetables**	**Fats and oil**
Energy	51	1	16	5	2	3	6	2
Vitamin A	2	0	24	13	5	37	8	0
Thiamin	56	2	16	7	3	6	10	0
Riboflavin	38	1	31	13	3	5	8	0
Vitamin B6	46	1	15	9	3	11	15	0
Folate	40	3	15	11	3	14	13	0
Vitamin C	38	1	3	6	0	20	22	0
Absorbed calcium	29	1	35	4	3	12	11	0
Absorbed iron	43	2	14	16	4	8	10	0
Absorbed zinc	49	2	22	13	3	5	5	0

[a] Row percents do not total 100 because certain foods were not included in any group (e.g., sweets).

Table 17. Honduras: Percent contribution of food groups to intake (from complementary foods) of energy and selected "problem" nutrients (infants 6-8.9 months)[a]

	Food group (%)							
Nutrients	**Grains, roots, tubers**	**Legumes and nuts**	**Dairy**	**Flesh foods**	**Eggs**	**Vitamin A-rich fruits and vegetables**	**Other fruits and vegetables**	**Fats and oil**
Energy	33	1	10	5	10	1	21	3
Vitamin A	9	0	21	6	25	7	22	2
Thiamin	40	1	8	4	6	1	22	0
Riboflavin	19	1	17	7	20	1	22	0
Vitamin B6	38	1	7	6	12	2	31	0
Folate	26	4	8	4	18	2	34	0
Vitamin C	18	2	6	1	0	5	58	0
Absorbed calcium	24	1	24	2	11	2	21	0
Absorbed iron	39	2	3	9	20	2	15	0
Absorbed zinc	30	2	15	11	18	1	13	0

[a] Row percents do not total 100 because certain foods were not included in any group (e.g., sweets).

Table 18. Ghana: Percent contribution of food groups to intake (from complementary foods) of energy and selected "problem" nutrients (infants 6-11.9 months)[a]

	Food group (%)							
Nutrients	**Grains, roots, tubers**	**Legumes and nuts**	**Dairy**	**Flesh foods**	**Eggs**	**Vitamin A-rich fruits and vegetables**	**Other fruits and vegetables**	**Fats and oil**
Energy	56	12	2	6	0	1	1	6
Vitamin A	2	35	14	1	1	7	15	4
Thiamin	66	25	4	15	0	0	2	0
Riboflavin	51	29	8	4	1	1	3	0
Vitamin B6	73	11	2	10	0	1	3	0
Folate	57	24	3	8	1	1	7	0
Vitamin C	11	38	10	0	0	2	20	0
Absorbed calcium	22	21	8	44	1	1	3	0
Absorbed iron	36	17	2	41	0	1	1	0
Absorbed zinc	58	19	3	18	1	0	1	0

[a] Row percents do not total 100 because certain foods were not included in any group (e.g., sweets).

Table 19. Bangladesh: Percent contribution of food groups to intake (from complementary foods) of energy and selected "problem" nutrients (children aged 6-11.9 months)[a]

	Food group (%)							
Nutrients	**Grains, roots, tubers**	**Legumes and nuts**	**Dairy**	**Flesh foods**	**Eggs**	**Vitamin A-rich fruits and vegetables**	**Other fruits and vegetables**	**Fats and oil**
Energy	76	3	5	0	1	1	6	1
Vitamin A	2	16	16	0	2	8	16	0
Thiamin	71	10	7	1	1	3	7	0
Riboflavin	64	6	12	0	2	4	10	0
Vitamin B6	58	12	9	1	1	3	16	0
Folate	59	18	6	0	1	4	10	0
Vitamin C	3	16	13	0	0	6	22	0
Absorbed calcium	71	3	14	0	1	2	7	0
Absorbed iron	69	13	3	0	2	4	6	0
Absorbed zinc	72	9	9	0	1	2	6	0

[a] Row percents do not total 100 because certain foods were not included in any group (e.g., sweets).

3.4 Association between dietary diversity and nutrient density adequacy of complementary foods

This section presents the results of analyses done to test how well dietary diversity indicators could predict dietary quality of complementary foods. As indicated earlier, dietary quality is defined here as the mean nutrient density adequacy (MNDA) of complementary foods. The MNDA summarizes nutrient density of the diet relative to desirable nutrient density for nine problem nutrients, assuming average breast milk intake.

3.4.1 Comparison of means

Figures 5-12 summarize the relationships between dietary diversity (using both FGI-8 and FGI-8R) and the MNDA. In all four countries and for all age groups, the mean nutrient density adequacy (MNDA) of complementary foods increases as dietary diversity increases, although the association is not consistently linear.

Figure 5. Peru: Mean Nutrient Density Adequacy score (MNDA), by dietary diversity index and child age: for FGI-8 (1-gram minimum)

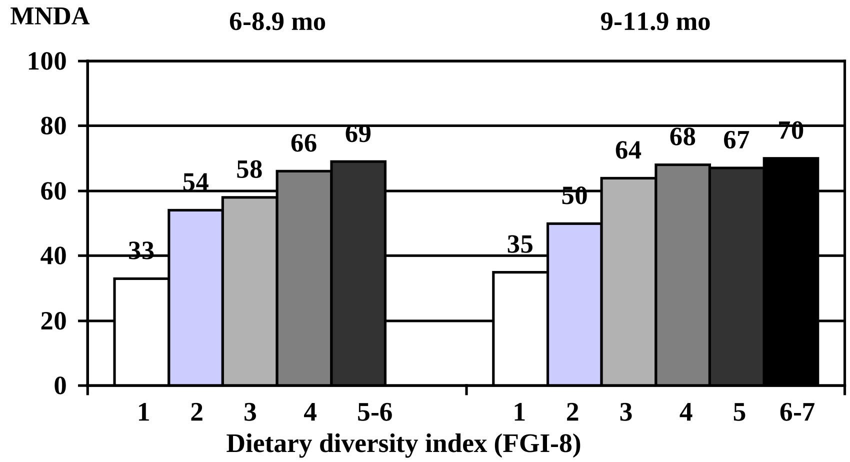


Figure 6. Peru: Mean Nutrient Density Adequacy score (MNDA), by dietary diversity index and child age: for FGI-8R (10-gram minimum)

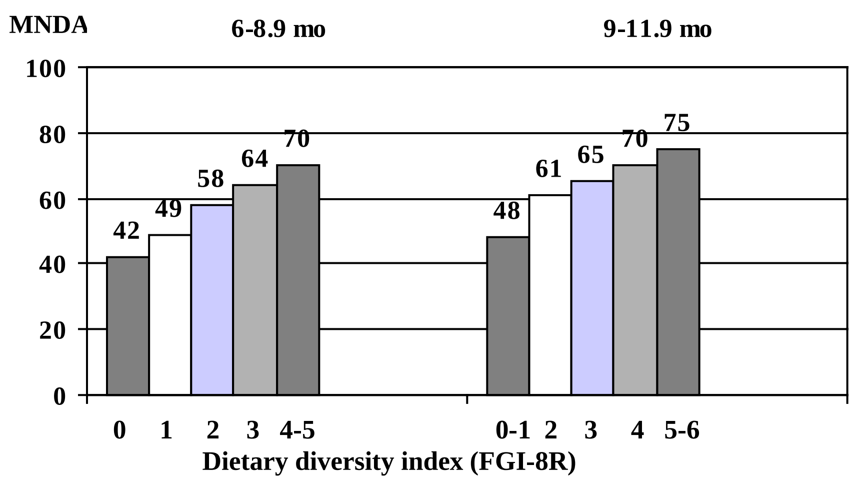


Figure 7. <u>Honduras</u>: Mean Nutrient Density Adequacy (MNDA), by dietary diversity index and child age: <u>for FGI-8</u> (1-gram minimum)

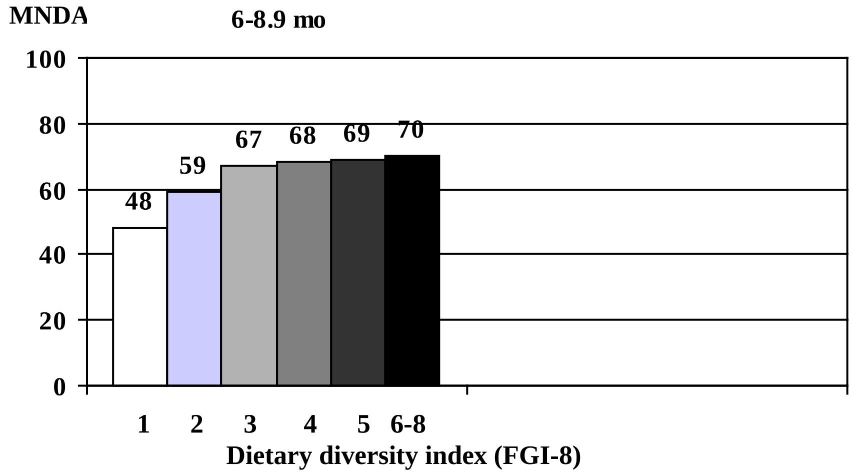


Figure 8. <u>Honduras</u>: Mean Nutrient Density Adequacy (MNDA) by dietary diversity index and child age: <u>for FGI-8R</u> (10-gram minimum)

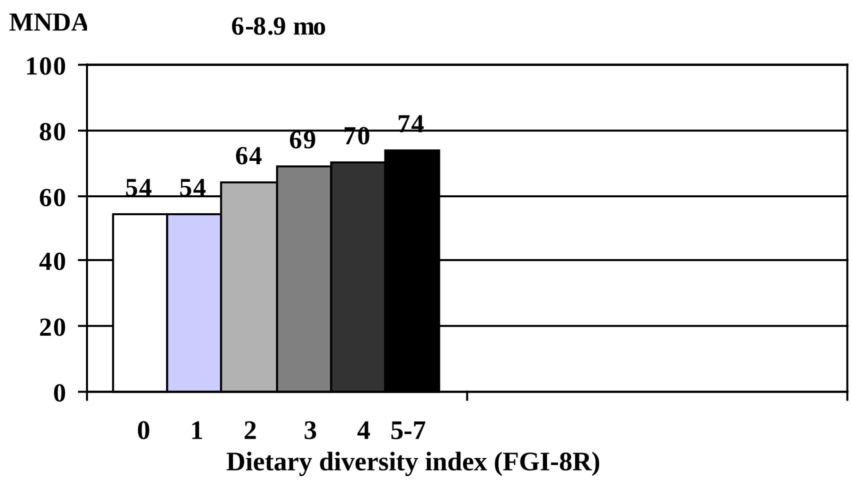


Figure 9. Ghana: Mean Nutrient Density Adequacy (MNDA), by dietary diversity index and child age: for FGI-8 (1-gram minimum)

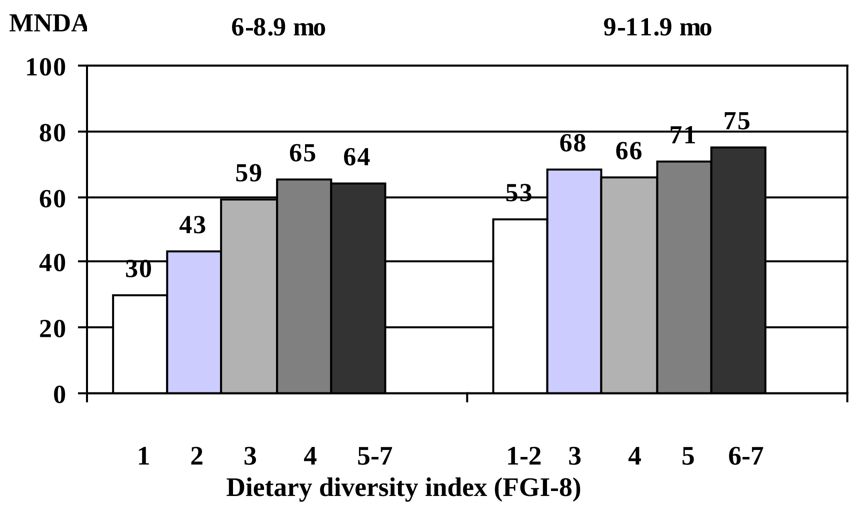


Figure 10. Ghana: Mean Nutrient Density Adequacy (MNDA) score, by dietary diversity index and child age: for FGI-8R (10-gram minimum)

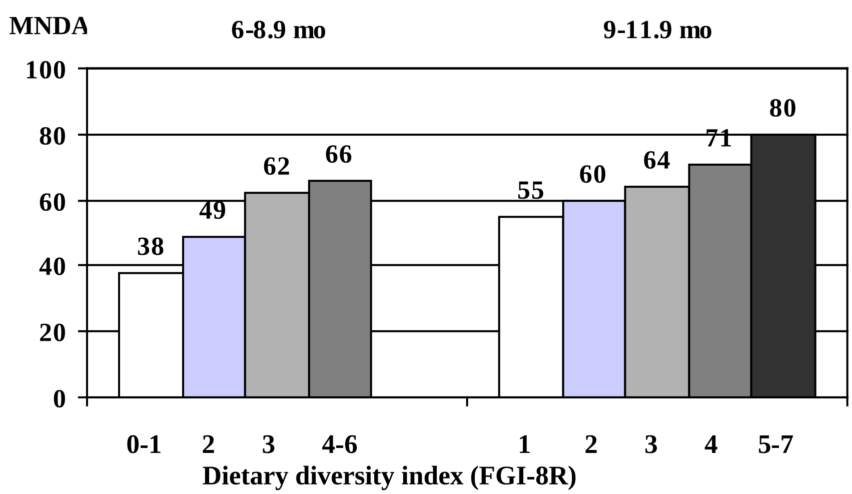


Figure 11. <u>Bangladesh</u>: Mean Nutrient Density Adequacy (MNDA), by dietary diversity index and child age: <u>for FGI-8</u> (1-gram minimum)

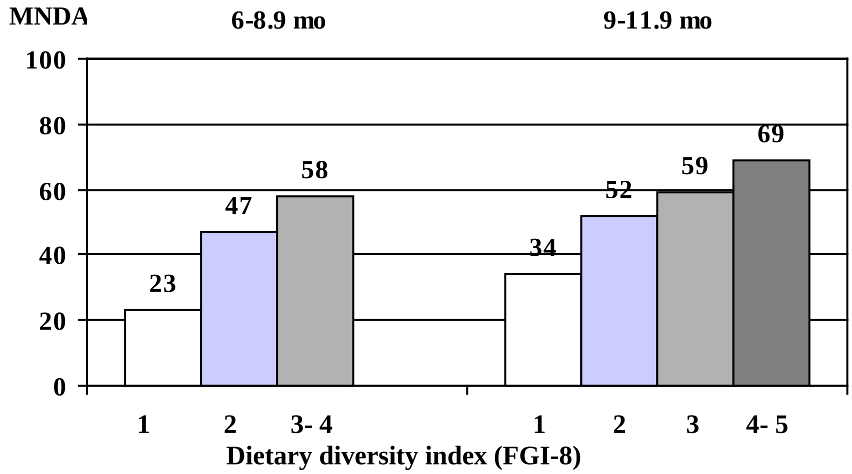
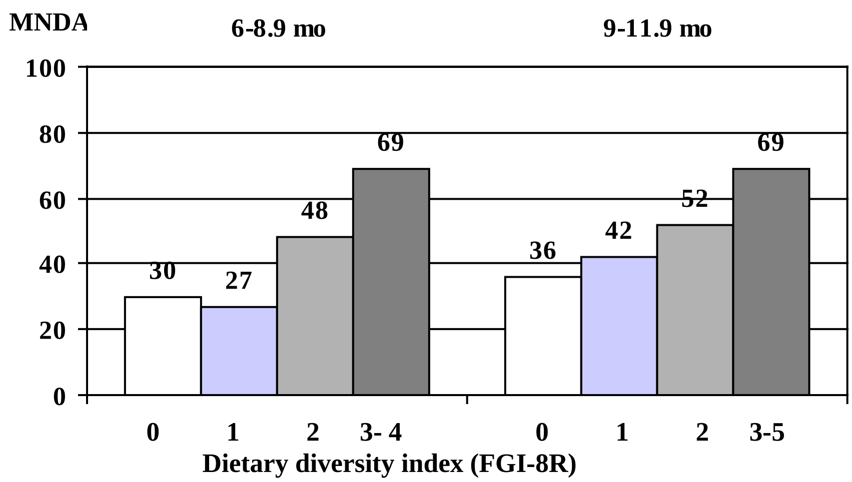


Figure 12. <u>Bangladesh</u>: Mean Nutrient Density Adequacy (MNDA), by dietary diversity index and child age: <u>for FGI-8R</u> (10-gram minimum)



3.4.2 Correlation analysis

Tables 20 and 21 show the correlation coefficients between MNDA and the two dietary diversity indexes, FGI-8 and FGI-8R, respectively. All correlations are statistically significant and, in general, moderate, ranging from 0.37 to 0.74 when the 1-gram minimum criterion is applied (FGI-8), and from 0.41 to 0.64 when the 10-gram minimum is applied (FGI-8R). Correlations are strongest in Bangladesh and Ghana.

Table 20. Relationship between mean nutrient density adequacy (MNDA) and dietary diversity (FGI-8), by country and by age group

	MNDA (mean)	FGI-8 (mean)	Correlation coefficient[a]	Test for linear trend[b]
Peru				
6-8.9 months	56	3.0	0.56	Not linear
9-11.9 months	63	3.7	0.44	Not linear
Honduras				
6-8.9 months	64	3.3	0.37	Not linear
Ghana				
6-8.9 months	49	2.8	0.70	Not Linear
9-11.9 months	64	3.4	0.44	Not Linear
Bangladesh				
6-8.9 months	35	1.7	0.74	Linear
9-11.9 months	49	2.1	0.70	Linear

[a] All correlations are significant ($p < 0.05$).
[b] Tests for linearity were performed using SAS PROC REG by adding a quadratic term to the equation; a significant quadratic term was taken to indicate a non-linear relationship.

Table 21. Relationship between mean nutrient density adequacy (MNDA) and dietary diversity (FGI-8R), by country and by age group

	MNDA (mean)	FGI-8 (mean)	Correlation with MNDA[a]	Test for linear trend[b]
Peru				
6-8.9 months	56	1.9	0.41	Linear
9-11.9 months	63	2.8	0.47	Not linear
Honduras				
6-8.9 months	64	2.4	0.42	Not linear
Ghana				
6-8.9 months	49	2.0	0.61	Linear
9-11.9 months	64	2.8	0.41	Linear
Bangladesh				
6-8.9 months	35	1.3	0.62	Linear
9-11.9 months	49	1.6	0.64	Linear

[a] All correlations are significant ($p < 0.05$).
[b] Tests for linearity were performed using SAS PROC REG by adding a quadratic term to the equation; a significant quadratic term was taken to indicate a non-linear relationship.

3.4.3 Sensitivity and specificity analysis

To assess the performance of the different dietary diversity indexes in predicting the mean nutrient density adequacy (MNDA) of complementary foods, we conducted sensitivity and specificity analyses. As described earlier (pages 10-11), for each country, we used two cutoff points: < 50% MNDA and ≥ 75% MNDA. Box 2 defines some of the terminology used in the sensitivity/specificity analysis and presents some general considerations in selecting indicators and cutoff points for different purposes.

The analysis was conducted with both indexes of dietary diversity (FGI-8 and FGI-8R), for each country and for each of the MNDA cutoff points (< 50% and ≥ 75%). To ensure reasonable cell sizes, analyses were done with all age groups combined.

Results using the 50% MNDA cutoff point are presented in Tables 22 and 23 and Figures 13-16. The tables show that for the 50% MNDA cutoff, the best combinations of sensitivity/specificity were generally achieved at a cutoff point of ≤ 2 for the FGI-8 index and at a cutoff point of ≤ 1 for the FGI-8R. The index that included a 10-gram minimum restriction (FGI-8R, using a cutoff of ≤ 1) performed somewhat better than the simpler FGI-8 (using a cutoff of ≤ 2) in Honduras and Bangladesh, but the opposite was true in Peru and Ghana.

Using the <50% cutoff point for MNDA and ≤ 2 for the FGI-8, the sensitivities for the four countries ranged from 61% to 88%; the specificities, from 43% to 85%; and the percentage of misclassified children, from 22% to 29%. These cutoff points favor specificity over sensitivity in Peru and Honduras, but the opposite was true in Ghana and Bangladesh. Using a dietary diversity index cutoff point of ≤ 3 would increase the sensitivity, but at the expense of a marked increase in the percentage of children misclassified and a large drop in specificity.

The sensitivity/specificity curves (Figures 13-16) for the FGI-8 confirm these findings, although the cutoff point of ≤ 1 may seem more appropriate for Bangladesh for maximizing both sensitivity and specificity. As indicated in Box 2, the final decision on the best cutoff point should be driven by the objective of using the indicator and the desirability of maximizing sensitivity, specificity, and positive predictive value for different purposes.

Box 2. Sensitivity/Specificity Analysis and Considerations in Selecting Best Indicators and Cutoff Points

The diagram below shows how the sensitivity (Se), specificity (Spe) and positive predictive value (V+) of indicators are calculated. Se is the percentage of all children who are truly at risk of nutrient inadequacy (in this case low nutrient density of complementary foods) who are correctly identified as being at risk by the dietary diversity (DD) indicator (low DD). Spe is the percentage of all children who are above the cut-off for nutrient inadequacy and who are correctly identified as such by the diversity indicator (high DD). V+ is the percentage of all children who are identified as being at risk by the diversity indicator (low DD) who truly are at risk of nutrient inadequacy (low nutrient density). Finally, false positives are children who are identified as being at risk by the diversity indicator but who are not below the cutoff for nutrient inadequacy, and false negatives are those who are identified by the diversity indicator as being not at risk but who in fact are (i.e., they have low nutrient density diets).

The selection of best cutoff points for indicators should be guided by the purpose for which they are to be used. Indicators of dietary diversity may be used for *assessment* (i.e., to assess prevalence of children at risk of nutrient inadequacy); for *screening* and to target interventions to children who are truly at risk of poor diet quality; or for *monitoring and evaluating* changes over time or program impact. For assessment, the optimal sensitivity/specificity combination will improve the precision of the estimates. For screening for interventions, one approach may be to maximize Se (and minimize the number of false negatives) so that as many of the children at risk are correctly identified, and are provided the intervention. This is a valid approach, especially because nutrition interventions to improve diet quality (such as food supplementation or nutrition education) do not present any risk for those who do not need it (i.e., false positives). When resources are scarce, however, indicators with high Spe and V+ should be prioritized because they help reduce the leakage resulting from treating those who are not truly at risk, thereby increasing the cost-effectiveness of interventions.

Dietary Diversity Index	**Gold Standard (MNDA)** **Low MNDA** (High risk of inadequate nutrient density)	 **High MNDA** (Low risk of inadequate nutrient density)	
Low DD	a True positive	b False positive	*Positive Predictive Value: a/a+b*
High DD	c False negative	d True negative	
	Sensitivity: *a/a+c*	*Specificity*: *d/b+d*	

Table 22. Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%)[a] using selected cutoff points of dietary diversity (FGI-8: 1-gram minimum)

Country	Age in months	Cutoff	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru								
	6-11.9	≤ 1	0.35	0.96	0.79	0.03	0.18	0.20
		≤ 2	0.62	0.85	0.61	0.11	0.10	0.22
		≤ 3	0.84	0.58	0.43	0.31	0.05	0.35
Honduras								
	6-8.9	≤ 1	0.33	0.95	0.62	0.04	0.12	0.16
		≤ 2	0.61	0.76	0.36	0.20	0.07	0.27
		≤ 3	0.75	0.49	0.25	0.42	0.05	0.47
Ghana								
	6-11.9	≤ 1	0.19	0.99	0.93	0.01	0.30	0.31
		≤ 2	0.78	0.77	0.67	0.14	0.08	0.23
		≤ 3	0.88	0.42	0.48	0.36	0.05	0.41
Bangladesh								
	6-11.9	≤ 1	0.63	0.93	0.94	0.03	0.23	0.26
		≤ 2	0.88	0.43	0.72	0.22	0.08	0.29
		≤ 3	0.99	0.16	0.66	0.32	0.01	0.33

[a] The MNDA averages the percent desired nutrient density, capped at 100%, for nine problem nutrients.

Table 23. Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%)[a] using selected cutoff points of dietary diversity (<u>FGI-8R:</u> 10-gram minimum)

Country	Age in months	Cutoff	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru								
	6-11.9	0	0.09	0.98	0.58	0.02	0.25	0.27
		≤ 1	0.63	0.80	0.54	0.14	0.10	0.25
		≤ 2	0.89	0.52	0.41	0.35	0.03	0.38
Honduras								
	6-8.9	0	0.12	0.97	0.46	0.03	0.16	0.19
		≤ 1	0.59	0.80	0.40	0.16	0.08	0.24
		≤ 2	0.84	0.50	0.28	0.41	0.03	0.43
Ghana								
	6-11.9	0	0.01	1.00	1.00	0.00	0.37	0.37
		≤ 1	0.39	0.90	0.71	0.07	0.23	0.29
		≤ 2	0.85	0.52	0.52	0.30	0.06	0.35
Bangladesh								
	6-11.9	0	0.18	0.98	0.93	0.01	0.51	0.52
		≤ 1	0.76	0.77	0.85	0.09	0.15	0.23
		≤ 2	0.99	0.30	0.70	0.27	0.01	0.28

[a] The MNDA averages the percent desired nutrient density, capped at 100%, for nine problem nutrients.

Figure 13. Peru: Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50) using selected cutoff points of dietary diversity (FGI-8)

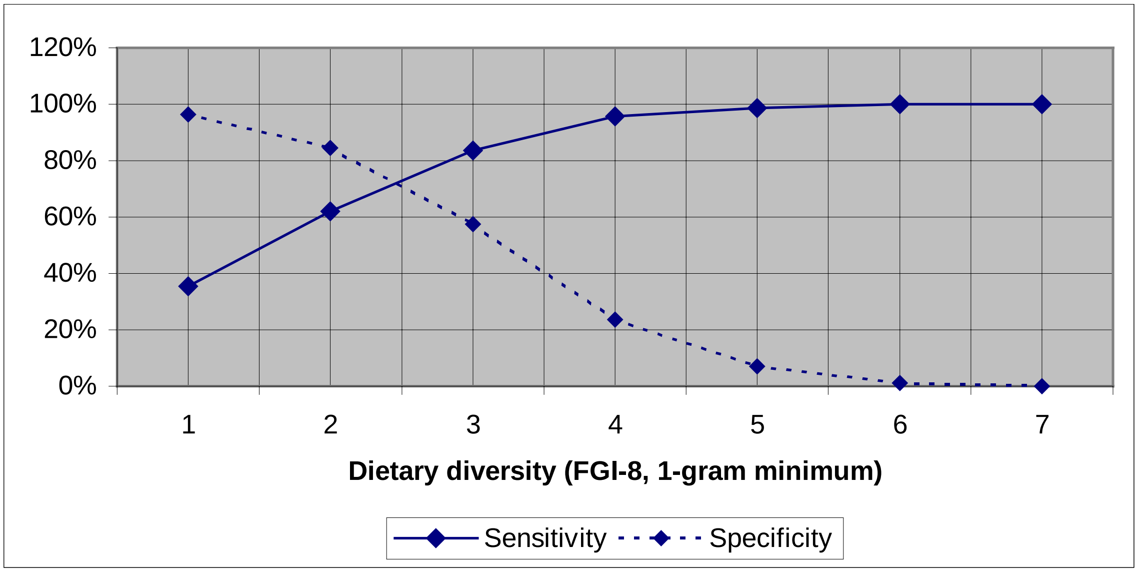


Figure 14. Honduras: Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%) using selected cutoff points of dietary diversity (FGI-8)

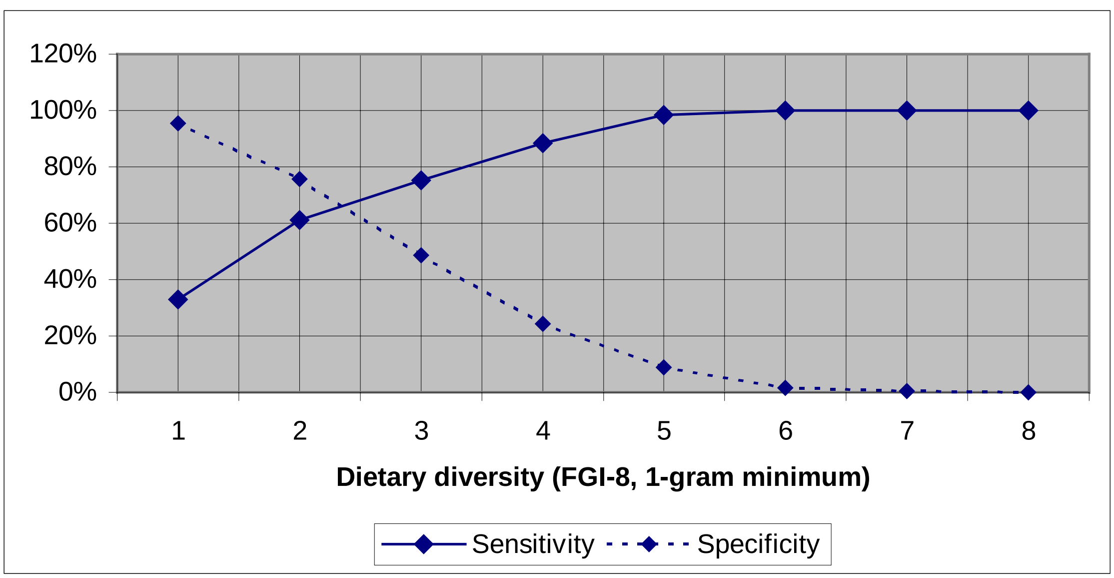


Figure 15. <u>Ghana</u>: Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%) using selected cutoff points of dietary diversity (<u>FGI-8</u>)

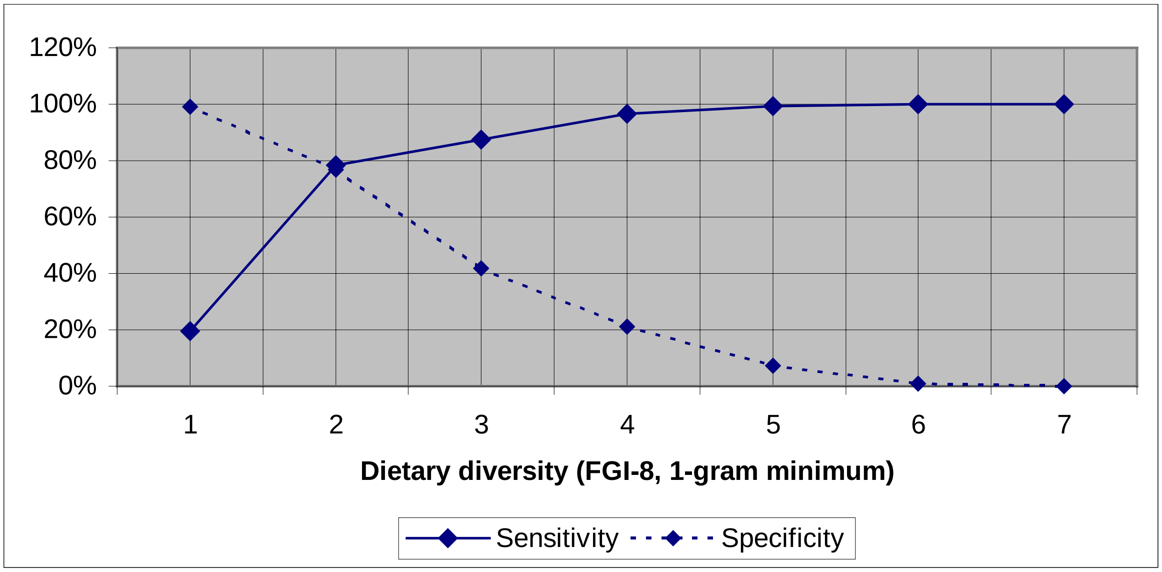
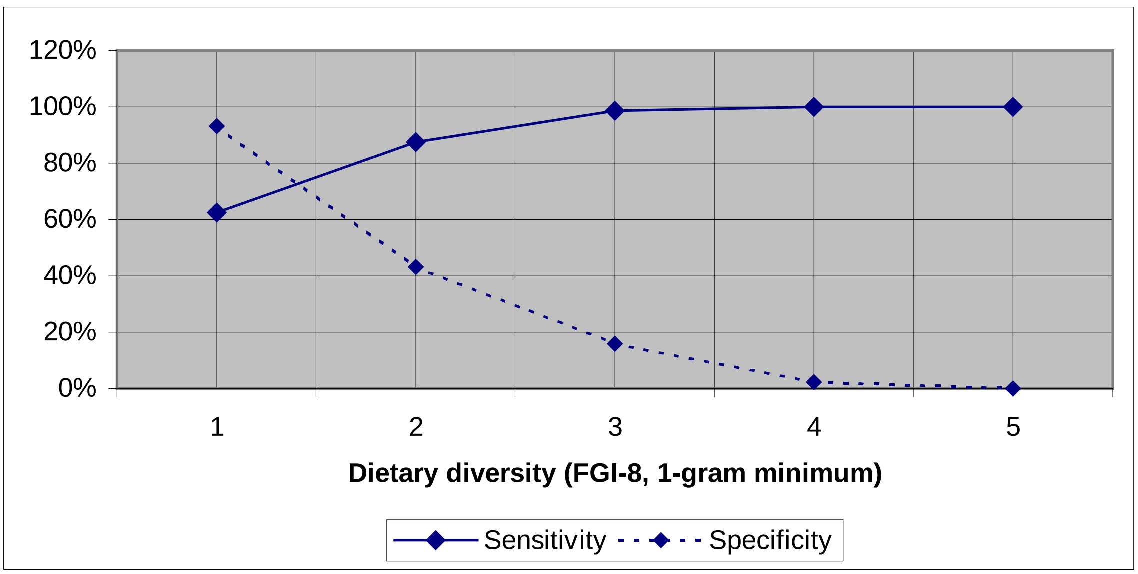


Figure 16. <u>Bangladesh</u>: Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%) using selected cutoff points of dietary diversity (<u>FGI-8</u>)



Tables 24 and 25 (below) show that for the ≥ 75% MNDA cutoff, the best combinations of sensitivity/specificity were generally achieved at a cutoff point of ≥ 4 for the FGI-8 index (except in Bangladesh) and at a cutoff point of ≥ 3 for the FGI-8R. The index that included a 10-gram minimum restriction (FGI-8R) generally did not perform better than the simpler FGI-8 (except possibly in Honduras).

Using ≥ 4 for the FGI-8, the sensitivities for the four countries ranged from 50% to 81%; the specificities, from 61% to 96%; and the percentage of misclassified children, from 7% to 36%. This cutoff point favors sensitivity over specificity in Peru and Ghana, but the opposite was true in Bangladesh. Using a dietary diversity index cutoff point of ≥ 3 would increase the sensitivity, but at the expense of a marked increase in the percentage of children misclassified and unacceptably low specificity (except in Bangladesh).

3.5 "Sentinel food groups" as predictors of individual nutrient density adequacies (NDA) and mean nutrient density adequacy (MNDA)

Sensitivity and specificity analyses were also conducted for each data set to identify which food groups were most predictive of whether each of the nine individual nutrient density adequacy scores fell above or below 60% of desired nutrient density (except for iron, for which a cutoff of < 10% of desired was used).[14] Table 26 shows the food groups that were predictive of NDAs above the cutoff for each nutrient in each country (with all age groups combined). These are the food groups identified without imposing the 10-gram minimum quantity criterion, as doing so did not generally change or improve the results. To select results that reflect a reasonable balance of Se and Spe, only food groups for which the sum of Se and Spe was greater than 1.25 are included.[15]

Consumption of vitamin A-rich fruits and vegetables was predictive of vitamin A NDA in Peru, Ghana and Bangladesh.[16] In addition, vitamin A NDA was predicted by dairy product consumption in Peru, Honduras and Ghana, egg consumption in Honduras, fats/oils in Ghana, and consumption of other fruits and vegetables in Ghana and Bangladesh.

Thiamin NDA was not predicted by any single food group except for legumes/nuts in Ghana. Riboflavin NDA was predicted by consumption of dairy products in Peru, Ghana, and Bangladesh, as well as by consumption of flesh foods in Peru and of eggs in Honduras. Vitamin B6 NDA was predicted by consumption of other fruits and vegetables in Peru, Honduras, and Bangladesh, and by flesh foods and eggs in Peru and Ghana. Folate NDA was predicted by consumption of other fruits and vegetables in three countries (all but Ghana), legumes/nuts in Ghana and Bangladesh, and vitamin A-rich fruits and vegetables in Peru. Vitamin C NDA was

[14] As noted, cutoffs of 60% (and 10% for iron) were chosen based on the distribution of densities, and the need to have sufficient numbers of child-days above the cutoff to conduct the analysis.

[15] This criterion (Se + Spe > 1.25) is arbitrary, but allows us to narrow our presentation to those results that provide some balance (i.e. neither Se nor Spe nears 0). As discussed in Box 2, depending on the application, either Se, or Spe, or a balance of the two might be more desirable."

[16] For simplicity, in the next several paragraphs we refer to consumption of a particular food group as "predictive of NDA," rather than repeating "predictive of nutrient density above a cutoff of 60% (or 10%)."

predicted by consumption of other fruits and vegetables in all four sites, vitamin A-rich fruits and vegetables in Peru and Bangladesh, dairy products in Honduras, and oils and fats in Ghana.

Table 24. Sensitivity and specificity analysis of dietary diversity (FGI-8: 1-gram minimum) to predict better mean nutrient density adequacy (MNDA ≥ 75%)[a]

Country	Age in months	Cutoff	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru								
	6-11.9	≥ 5	0.29	0.85	0.57	0.11	0.15	0.26
		≥ 4	0.71	0.61	0.40	0.29	0.06	0.35
		≥ 3	0.91	0.34	0.30	0.50	0.02	0.52
Honduras								
	6-8.9	≥ 5	0.34	0.82	0.53	0.13	0.15	0.28
		≥ 4	0.62	0.62	0.44	0.27	0.09	0.36
		≥ 3	0.90	0.38	0.34	0.46	0.02	0.48
Ghana								
	6-11.9	≥ 5	0.38	0.89	0.51	0.09	0.07	0.16
		≥ 4	0.81	0.76	0.36	0.20	0.02	0.23
		≥ 3	0.96	0.50	0.22	0.44	0.01	0.44
Bangladesh[b]								
	6-11.9	≥ 4	0.50	0.96	0.50	0.04	0.03	0.07
		≥ 3	0.83	0.79	0.21	0.20	0.01	0.21
		≥ 2	1.00	0.44	0.09	0.53	0.00	0.53

[a] The MNDA averages the percent desired nutrient density, capped at 100%, for nine problem nutrients.
[b] Note that the trade-off between sensitivity and specificity occurs at lower cutoff values in Bangladesh than in the other countries.

Table 25. Sensitivity and specificity analysis of dietary diversity (<u>FGI-8R:</u> 10-gram minimum) to predict better mean nutrient density adequacy (MNDA ≥ 75%)[a]

Country	Age in months	Cutoff	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru								
	6-11.9	≥ 4	0.36	0.87	0.44	0.10	0.14	0.25
		≥ 3	0.63	0.65	0.35	0.27	0.08	0.35
		≥ 2	0.80	0.35	0.26	0.50	0.05	0.55
Honduras								
	6-8.9	≥ 4	0.33	0.88	0.46	0.09	0.17	0.26
		≥ 3	0.69	0.64	0.39	0.27	0.08	0.34
		≥ 2	0.92	0.33	0.31	0.50	0.02	0.52
Ghana								
	6-11.9	≥ 4	0.53	0.89	0.40	0.10	0.06	0.16
		≥ 3	0.85	0.68	0.27	0.28	0.02	0.30
		≥ 2	1.00	0.24	0.16	0.67	0.00	0.67
Bangladesh								
	6-11.9	≥ 4	0.33	0.99	0.67	0.01	0.03	0.04
		≥ 3	0.67	0.91	0.29	0.09	0.02	0.10
		≥ 2	0.67	0.57	0.08	0.41	0.02	0.42

[a] The MNDA averages the percent desired nutrient density, capped at 100%, for nine problem nutrients.

Table 26. Food groups predictive[a] of nutrient density adequacy[b], by country

	Country			
Nutrients	**Peru**	**Honduras**	**Ghana**	**Bangladesh**
Vitamin A	► Dairy products ► Vitamin A-rich fruits and vegetables	► Eggs ► Dairy products	► Dairy products ► Other fruits and vegetables ► Vitamin A-rich fruits and vegetables ► Fats/oils	► Other fruits and vegetables ► Vitamin A-rich fruits and vegetables
Thiamin			► Legumes/nuts	
Riboflavin	► Dairy products ► Flesh foods	► Eggs	► Dairy products	► Dairy products
Vitamin B6	► Flesh foods ► Eggs ► Other fruits and vegetables	► Other fruits and vegetables	► Flesh foods ► Eggs	► Other fruits and vegetables
Folate	► Other fruits and vegetables ► Vitamin A-rich fruits and vegetables	► Other fruits and vegetables	► Legumes/nuts	► Other fruits and vegetables ► Legumes/nuts
Vitamin C	► Other fruits and vegetables ► Vitamin A-rich fruits and vegetables	► Dairy products ► Other fruits and vegetables	► Oils/fats ► Other fruits and vegetables	► Other fruits and vegetables ► Vitamin A-rich fruits and vegetables
Calcium	► Dairy products	► Dairy products	► Flesh foods[c]	► Dairy products
Iron	► Flesh foods	► Eggs	► Flesh foods	► Legumes/nuts
Zinc	► Flesh foods	► Flesh foods	► Flesh foods	► Eggs ► Legumes/nuts ► Other fruits and vegetables

[a] Sensitivity plus specificity > 1.25.

[b] Cutoff for low nutrient density was < 60% of desired, except for iron for which the cutoff was < 10% of desired.

[c] Fish powder, including the bones, was an ingredient in the improved complementary foods provided to infants in two of the three intervention groups in Ghana.

Calcium NDA was predicted by consumption of dairy products in Peru, Honduras, and Bangladesh, as well as by consumption of flesh foods in Ghana. The relationship with flesh foods was due to the consumption of fish powder (including the bones), which was an ingredient in the improved complementary foods provided to infants in two of the three intervention groups in Ghana. Iron NDA was predicted by consumption of flesh foods in Peru and Ghana, eggs in Honduras, and legumes/nuts in Bangladesh. Lastly, zinc NDA was predicted by consumption of flesh foods in Peru, Honduras and Ghana, and by consumption of eggs, legumes/nuts and other fruits and vegetables in Bangladesh.

Sensitivity and specificity analyses were also conducted to identify whether any of the individual food groups were predictive of mean nutrient density adequacy (MNDA). Tables 27-28 show results for the < 50% cutoff point of MNDA; the results using the 1-gram minimum criterion for food group consumption are shown in Table 27, and those with the 10-gram minimum criterion for each food group are shown in Table 28. Comparable results using the ≥ 75% cutoff point of MNDA are presented in Tables 29-30. Only food groups for which the sum of Se and Spe was greater than 1.25 are included. In addition to the eight food groups used in previous analyses, a new group was created for animal source foods (ASF, which included dairy products, flesh foods, or eggs).

Using the 50% MNDA cutoff and the 1-gram minimum, non-consumption of the ASF and other fruits and vegetables food groups was predictive of low MNDA in all four countries. Non-consumption of dairy products was predictive of low MNDA in three of the four countries, but specificity was quite low. In general, the results were not improved by using the 10-gram minimum.

When compared with the results for dietary diversity (using a cutoff of ≤ 2 food groups for FGI-8) and the 50% MNDA cutoff (Table 22), non-consumption of the ASF food group yielded similar or better results in three of the four sites (the exception being Peru). In Honduras, sensitivity was better with dietary diversity, but specificity and the percentage misclassified were better with ASF. In Ghana, the results were very similar whether dietary diversity or ASF was used. In Bangladesh, ASF clearly outperformed dietary diversity, but in Peru the dietary diversity indicator gave somewhat better results than ASF.

Using the ≥ 75% MNDA cutoff (with either 1-gram or 10-gram minimum), consumption of the ASF food group was predictive of higher MNDA in three of the four countries. The percentage misclassified was somewhat better when using the 10 gram minimum. When compared with the results for dietary diversity (using a cutoff of ≥ 4 food groups for FGI-8) and the ≥ 75% MNDA cutoff (Table 24), the ASF food group yielded similar results in Peru and Bangladesh, but the dietary diversity indicator performed better in Honduras and Ghana. When dietary diversity was defined using a cutoff of ≥ 3 food groups for FGI-8R and the ≥ 75% MNDA cutoff (Table 25), it outperformed the ASF food group in Peru, Honduras, and Bangladesh, but not in Ghana.

Table 27. Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%)[a], using individual food groups (1-gram minimum)

Country (Age range)	Food group (Y/N)	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru	Flesh foods	0.87	0.40	0.36	0.43	0.04	0.47
(6-11.9 months)	Dairy products	0.78	0.51	0.38	0.35	0.06	0.41
	Vitamin A-rich fruits and vegetables	0.70	0.75	0.52	0.18	0.08	0.26
	Other fruits and vegetables	0.63	0.66	0.41	0.25	0.10	0.35
	Animal source foods	0.60	0.81	0.54	0.14	0.11	0.26
Honduras	Dairy products	0.72	0.59	0.28	0.34	0.05	0.39
(6-8.9 months)	Eggs	0.88	0.48	0.28	0.42	0.02	0.44
	Other fruits and vegetables	0.59	0.75	0.35	0.20	0.08	0.28
	Animal source foods	0.49	0.87	0.45	0.11	0.09	0.20
Ghana	Flesh foods	0.79	0.68	0.60	0.20	0.08	0.28
(6-11.9 months)	Other fruits and vegetables	0.89	0.41	0.48	0.37	0.04	0.41
	Animal source foods	0.76	0.79	0.69	0.13	0.09	0.22
Bangladesh	Dairy products	0.97	0.39	0.72	0.23	0.02	0.25
(6-11.9 months)	Other fruits and vegetables	0.89	0.59	0.78	0.16	0.07	0.22
	Animal source foods	0.93	0.50	0.75	0.19	0.04	0.23

[a]The MNDA averages the percent desired nutrient density, capped at 100, for nine problem nutrients.

Table 28. Sensitivity/specificity analysis to predict low mean nutrient density adequacy (MNDA < 50%)[a], using individual food groups (10-gram minimum)

Country (Age range)	Food groups (Y/N)	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru	Dairy products	0.80	0.45	0.36	0.40	0.05	0.45
(6-11.9 months)	Vitamin A-rich fruits and vegetables	0.97	0.40	0.38	0.44	0.01	0.44
	Other fruits and vegetables	0.89	0.38	0.35	0.45	0.03	0.48
	Animal source foods	0.74	0.62	0.42	0.28	0.07	0.35
Honduras	Eggs	0.97	0.36	0.25	0.52	0.01	0.53
(6-8.9 months)	Other fruits and vegetables	0.69	0.66	0.31	0.28	0.06	0.34
	Animal source foods	0.73	0.67	0.33	0.27	0.05	0.32
Ghana (6-11.9 months)	Animal source foods	0.96	0.45	0.51	0.34	0.02	0.36
Bangladesh	Dairy products	0.97	0.36	0.71	0.24	0.02	0.26
(6-11.9 months)	Other fruits and vegetables	0.97	0.50	0.76	0.19	0.02	0.21
	Animal source foods	0.97	0.41	0.73	0.22	0.02	0.24

[a] The MNDA averages the percent desired nutrient density, capped at 100, for nine problem nutrients.

Table 29. Sensitivity/specificity analysis of individual food groups (1-gram minimum) to predict better mean nutrient density adequacy (MNDA ≥ 75%)[a]

Country (Age range)	Food groups (Y/N)	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru	Flesh foods	0.54	0.73	0.37	0.43	0.04	0.31
(6-11.9 months)	Vitamin A-rich fruits and vegetables	0.85	0.44	0.30	0.44	0.03	0.47
	Animal source foods	0.88	0.36	0.29	0.49	0.03	0.34
Honduras (6-8.9 months)	Eggs	0.65	0.66	0.39	0.26	0.09	0.34
Ghana	Flesh foods	0.77	0.54	0.19	0.40	0.03	0.43
(6-11.9 months)	Fats/oils	0.49	0.78	0.24	0.19	0.06	0.25
	Animal source foods	0.89	0.46	0.19	0.47	0.01	0.49
	Other fruits & vegetables	0.72	0.76	0.30	0.21	0.03	0.24
Bangladesh	Eggs	0.33	0.99	0.67	0.01	0.03	0.04
(6-11.9 months)	Legumes/nuts	0.50	0.76	0.10	0.22	0.03	0.25
	Other fruits and vegetables	0.67	0.73	0.12	0.26	0.02	0.28
	Vitamin A-rich fruits and vegetables	0.50	0.94	0.30	0.06	0.03	0.09
	Animal source foods	0.67	0.94	0.15	0.20	0.02	0.22

[a] The MNDA averages the percent desired nutrient density, capped at 100, for nine problem nutrients.

Table 30. Sensitivity/specificity analysis of individual food groups (10-gram minimum) to predict better mean nutrient density adequacy (MNDA $\geq$ 75%)[a]

Country (Age range)	Food groups (Y/N)	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru (6-11.9 months)	Vitamin A-rich fruits and vegetables	0.57	0.78	0.43	0.17	0.10	0.27
Honduras (6-8.9 months)	Eggs	0.54	0.78	0.44	0.17	0.11	0.28
	Animal source foods	0.84	0.48	0.35	0.39	0.04	0.43
Ghana (6-11.9 months)	Fats/oils	0.49	0.78	0.24	0.19	0.06	0.25
	Other fruits and vegetables	0.62	0.86	0.39	0.12	0.05	0.17
	Animal source foods	0.60	0.75	0.25	0.22	0.05	0.27
Bangladesh (6-11.9 months)	Eggs	0.33	0.99	0.67	0.01	0.03	0.04
	Other fruits and vegetables	0.67	0.82	0.17	0.17	0.02	0.19
	Vitamin A-rich fruits and vegetables	0.33	0.96	0.29	0.04	0.03	0.08
	Animal source foods	0.50	0.85	0.15	0.15	0.03	0.17

[a] The MNDA averages the percent desired nutrient density, capped at 100, for nine problem nutrients

3.6 Association between dietary diversity and energy intake

Examining associations between dietary diversity indicators and energy intake was not a main objective of our analysis. However, because such associations had been previously reported (Hatloy, Torheim, and Oshaug 2002; Ogle Hung, and Tuyet 2001; Onyango, Koski, and Tucker 1998; Brown et al. 2002), we took the opportunity to assess this relationship using our data sets.

We found that dietary diversity (using FGI-8) was significantly associated with energy intake from complementary foods in all four data sets (with correlation coefficients ranging from 0.15 to 0.38), but the association with total energy intake (breast milk plus complementary foods) was significant in only one of the two countries with these data (see Annex 11 for more information).

3.7 Association between frequency of feeding and energy intake

The second main objective of our analysis was to assess which cutoff points for frequency of feeding of complementary foods (meals + snacks or meals only) could best differentiate between children with low energy intake and those with adequate energy intake. For Honduras, we could only assess this in relation to energy intake from complementary foods, because energy intake from breast milk was not measured. For Peru and Bangladesh, data are available on energy intake from breast milk, although subsample sizes within frequency of feeding groups are very small for Bangladesh (e.g., the number of infants in either age group fed any given number of times ranges from 1 to 16). For these two sites, we assess frequency of feeding both in relation to energy intake from complementary food, and also in relation to total energy intake.[17]

Recently issued guidelines for frequency of feeding for breastfed children were described in Section 3.3.1, and Table 8 described the frequency of feeding in the sample data sets. The guidelines were based on theoretical estimates of the number of feedings required to meet energy needs. Figures 17-19 illustrate the actual relationship between feeding frequency and energy intake (kcal) in two of the data sets (Honduras and Peru). For Honduras (Figure 17), results are shown for complementary food energy by number of meals and by number of feeding episodes (meals plus snacks). In Peru, meals and snacks were not distinguished, but data are available for two age groups; Figure 18 shows the relationship between the number of feeding episodes and complementary food energy, while Figure 19 shows the relationship between the number of feeding episodes and total energy intake.

[17] As noted earlier, there are no frequency of feeding data for Ghana.

Figure 17. Honduras: Mean complementary food energy intake, by number of meals and number of feeding episodes

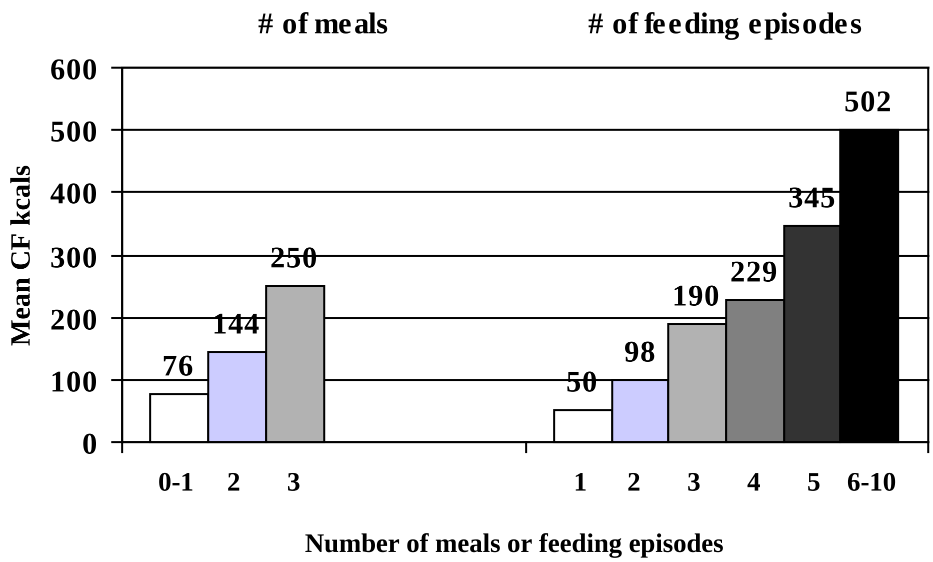


Figure 18. Peru: Mean complementary food energy intake, by number of feeding episodes

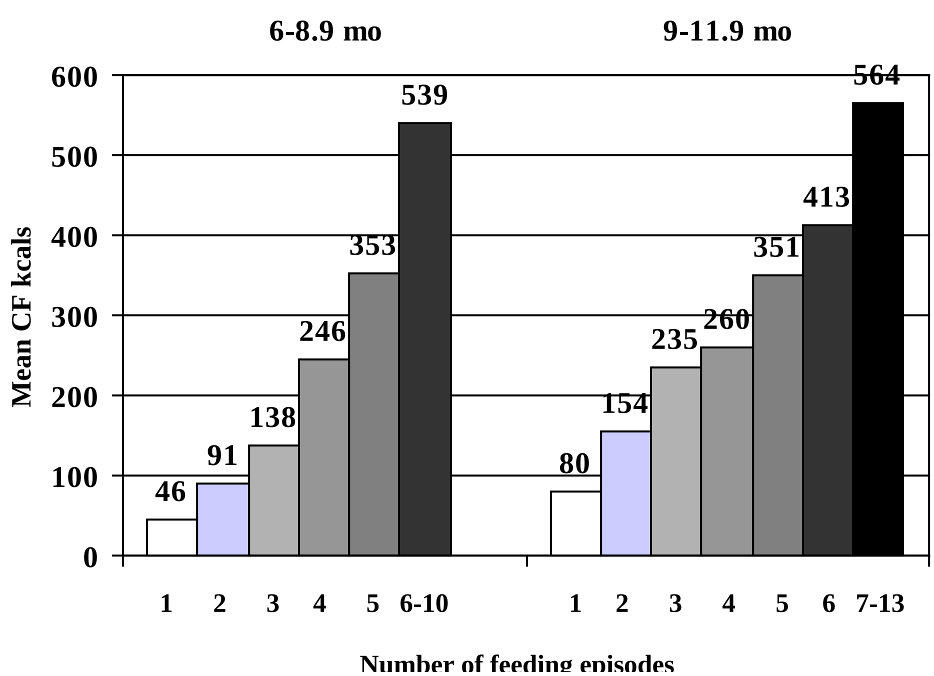
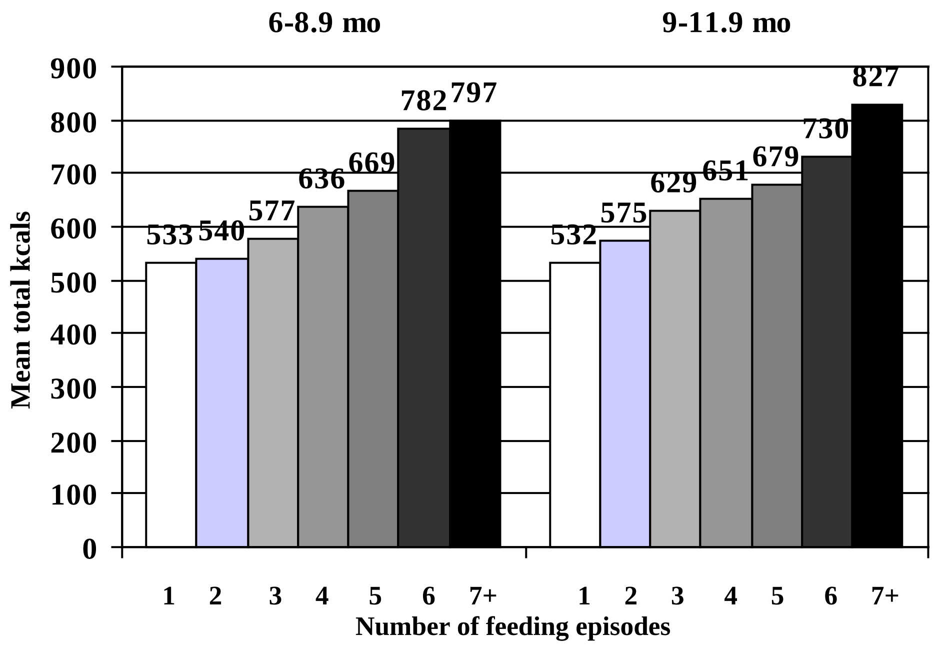


Figure 19. Peru: Total energy intake, by number of feeding episodes



Note that the overall energy requirements for these age groups are 615 kcal per day for infants 6-8.9 months, and 686 kcal for infants 9-11.9 months. With average breast milk intake, the younger infants need 202 kcal from complementary foods, and the older infants need 307 kcal. "Low energy intake" is defined for the purposes of these analyses as intakes lower than these cutoffs.

Figure 17 illustrates that the infants in Honduras, on average, reached the expected energy intake from complementary foods (202 kcal) when they had approximately three meals or feeding episodes. In Peru (Figure 18), the younger infants reached the expected energy intake from complementary foods when they had approximately four feeding episodes, and the older infants reached the expected energy intake from complementary foods (307 kcal) when they had approximately five feeding episodes. When considering total energy intake, the younger infants again met energy needs (615 kcal) at four feeding episodes, while the older infants nearly met needs at five feeding episodes (having, on average, 679 kcals as opposed to the requirement of 686 kcals).

Table 31 shows correlations between frequency of feeding and energy (kcal), and also indicates whether or not relationships are linear.

With the exception of snacks in Bangladesh, feeding frequency was strongly and significantly correlated with energy intake from complementary foods, and in most cases the relationship was linear; for the youngest infants in Peru, Figure 18 illustrates the nonlinear relationship. The correlations of feeding frequency with total energy intake were weaker but still significant, except for the younger infants in Bangladesh.

Table 31. Relationships between energy intake and feeding frequency, by country and by age group

	Correlations with energy intake from complementary foods			Correlation with total energy intake	
Country and age group	Number of meals	Number of snacks	Number of feeding episodes	Number of feeding episodes[a]	Test for linear trend[b]
Peru					
6-8.9 months			0.78	0.51	CF not linear
9-11.9 months	n/a[c]	n/a	0.66	0.44	Linear
Honduras					
6-8.9 months	0.37	0.44	0.54	n/a	All linear[d]
Bangladesh					
6-8.9 months	0.62	-0.21	0.48	0.02	All linear
9-11.9 months	0.64	-0.13	0.57	0.35	All linear

[a] With the exception of Bangladeshi infants aged 6-8.9 mo, all other correlations were significant ($p<0.05$).

[b] Tests for linearity were performed using SAS PROC REG by adding a quadratic term to the equation; a significant quadratic term was taken to indicate a non-linear relationship.

[c] n/a = data not available.

[d] For meals, relationship was linear when 3 outliers with high milk intake were excluded.

To assess the performance of feeding frequency in predicting energy adequacy, we examined sensitivity, specificity, positive predictive value, and the proportion of infants misclassified when various cutoffs of feeding frequency (either meals or feeding episodes) were used. This was done first when considering frequency of feeding as a proxy indicator of complementary food energy, and second when considering frequency of feeding as a proxy indicator of total energy intake (for the two sites for which this information was available).

Figures 20-24, reflecting energy intake from complementary foods, illustrate trade-offs between sensitivity and specificity, depending on the selected cutoff for feeding frequency. Table 32 follows, and summarizes a number of characteristics of indicator cutoffs (sensitivity, specificity, positive predictive value, the proportion of false positives and false negatives, and the total proportion of child-days misclassified) across the different countries and age groups.

When considering complementary food energy (Table 32), a cutoff of "≤ 3" minimizes the proportion of child-days misclassified for infants 6-8.9 months in all three sites. This is also the cutoff that maximizes sensitivity without major sacrifices in specificity. For infants 9-11.9 months, cutoffs of ≤ 4 or 5 minimize the proportion of child-days misclassified; however, in Peru, there is a sacrifice in specificity at the cutoff of ≤ 5.

While criteria for selecting a cutoff will depend on the objectives, note that in these data sets, cutoffs of "≤ 2" at 6-8.9 months or "≤ 3" at 9-11.9 months (corresponding to the lower end of the recommended range for frequency of feeding) have quite low sensitivity. That is, these cutoffs yield a high proportion of "false negatives," or child-days with low energy intakes that are not identified by the indicator using this cutoff.

Figure 20: Peru: Sensitivity and specificity of different cutoff points of number of feeding episodes for predicting low energy intake from complementary foods (infants 6-8.9 months)

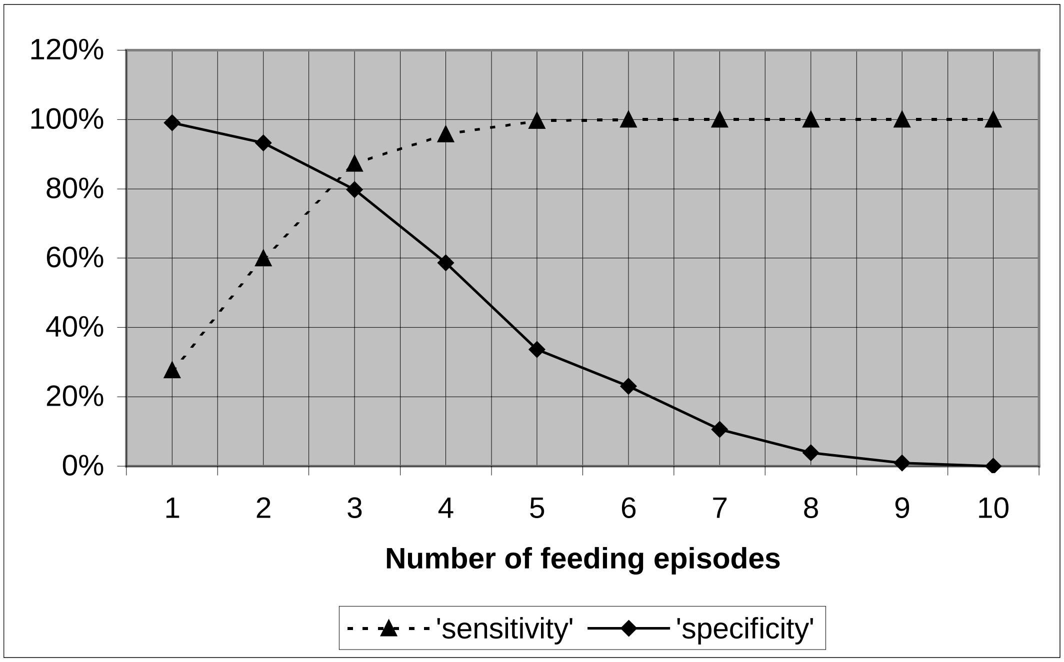


Figure 21: Peru: Sensitivity and specificity of different cutoff points of number of feeding episodes for predicting low energy intake from complementary foods (infants 9-11.9 months)

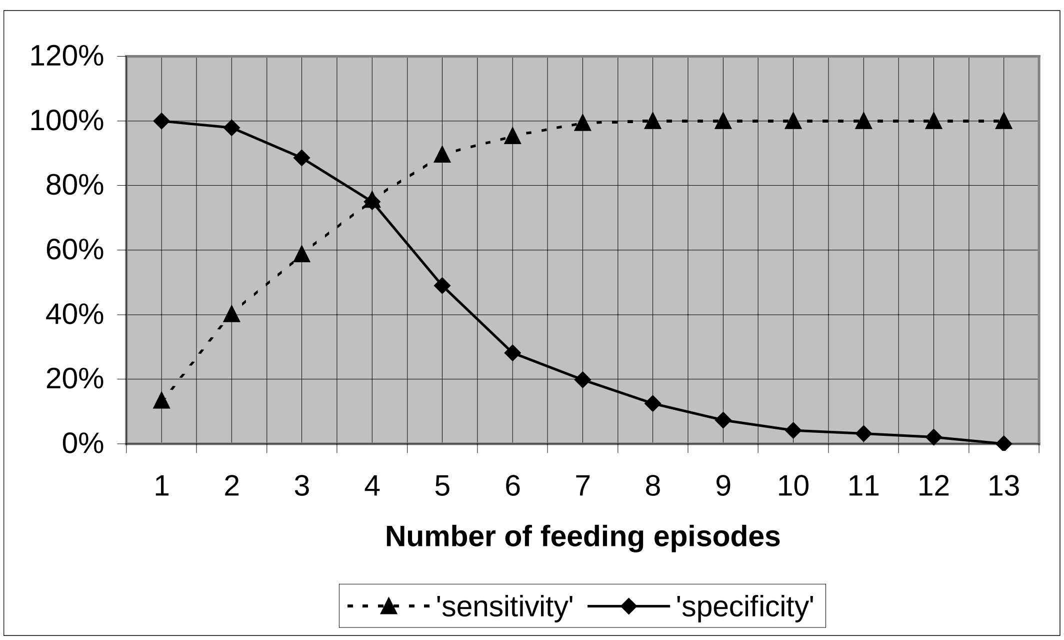


Figure 22: <u>Honduras:</u> Sensitivity and specificity of different cutoff points of number of feeding episodes for predicting low energy intake from complementary foods (<u>infants 6-8.9 months</u>)

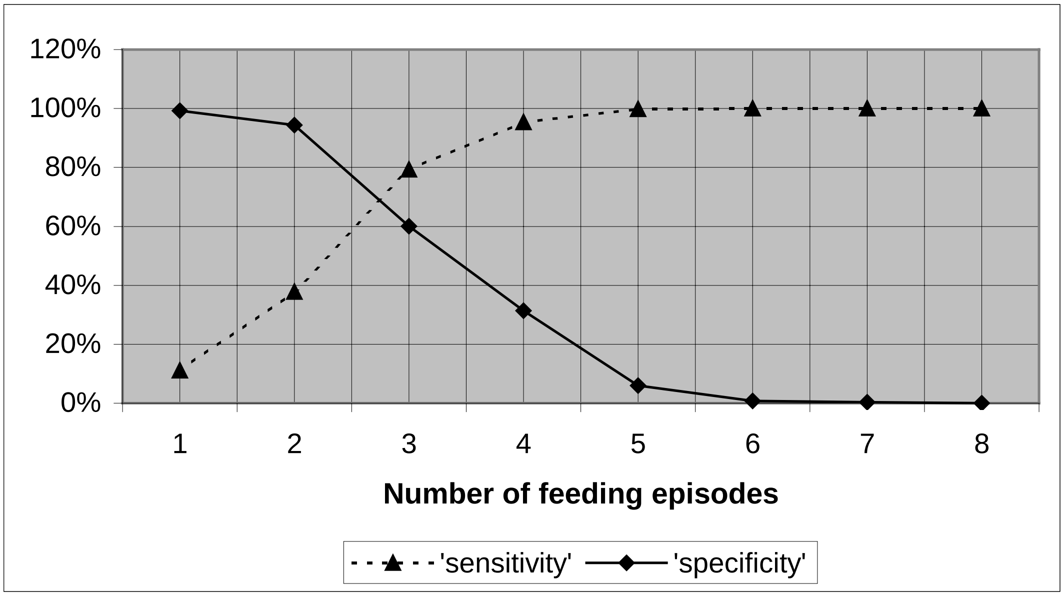


Figure 23: <u>Bangladesh</u>: Sensitivity and specificity of different cutoff points of number of meals (> 10 g of food) for predicting low energy intake from complementary foods (<u>infants 6-8.9 months</u>)

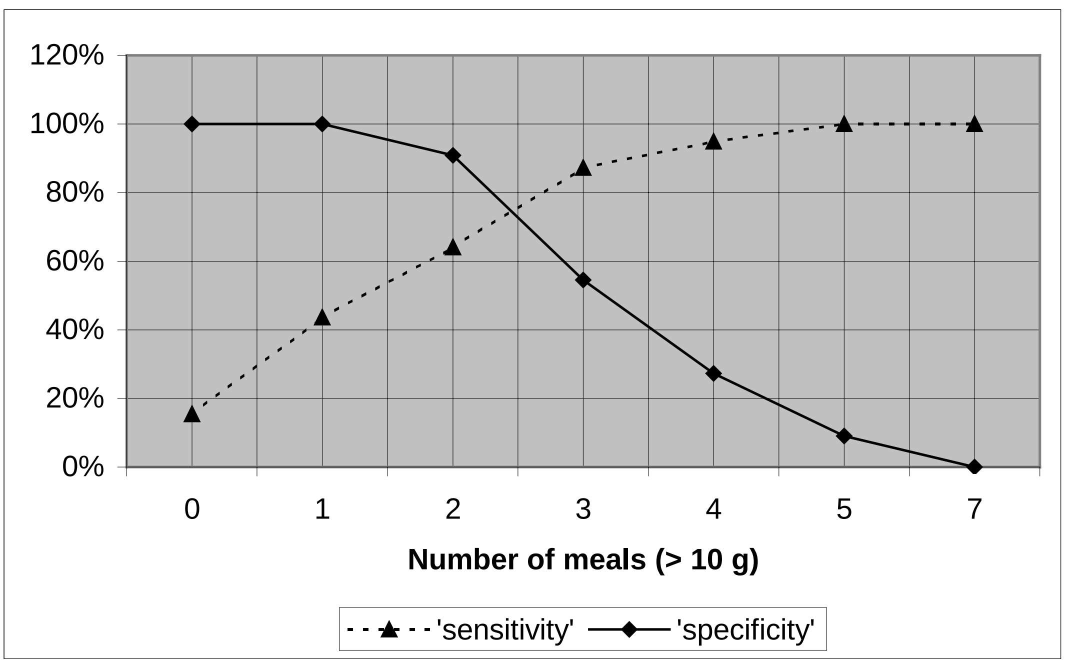
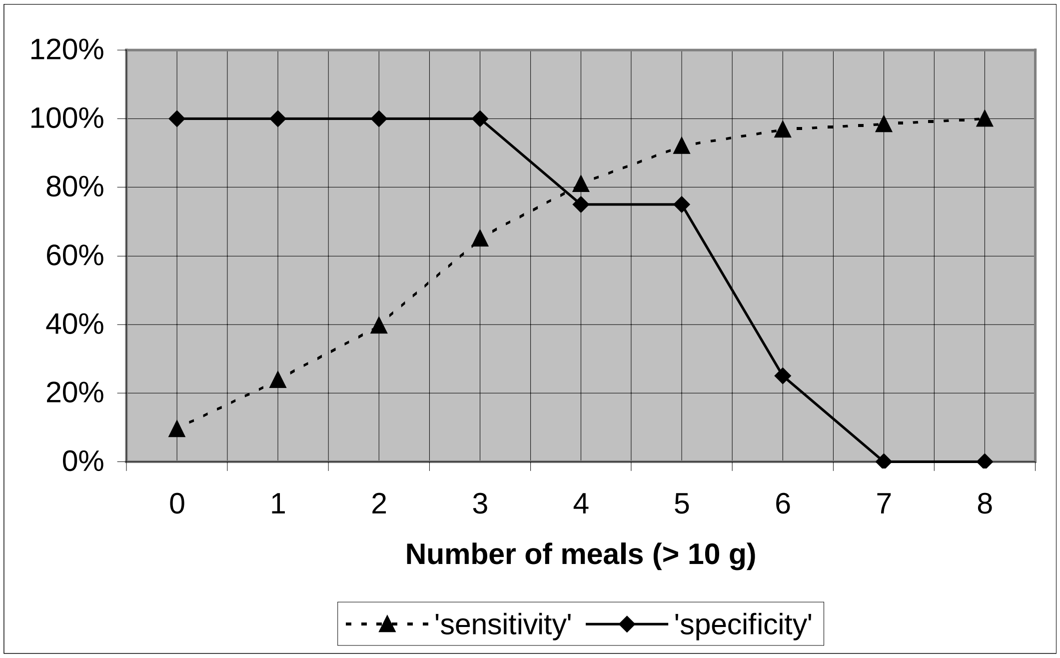


Figure 24: <u>Bangladesh</u>: Sensitivity and specificity of different cutoff points of number of meals (> 10 g of food) for predicting low energy intake from complementary foods (<u>infants 9-11.9 months</u>)



Figures 25-28 and Table 33 illustrate the findings when considering total energy intake in Peru and Bangladesh. The cutoffs that yield the lowest proportion misclassified are the same as those identified when energy intake from complementary foods was the outcome ("≤ 3" at 6-8.9 and ≤ 4 or 5 at 9-11.9 months). However, at these cutoffs, specificity is lower and the proportion misclassified is higher in both sites and in both age groups when total energy intake is the outcome than when energy intake from complementary foods is the outcome. As mentioned above, cutoffs of "≤ 2" at 6-8.9 months or "≤ 3" at 9-11.9 months have quite low sensitivity.

Table 32. Sensitivity/specificity analysis of frequency of feeding[a] to predict low energy intake from complementary foods[b]

Country	Age in months	Cut off	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru	**6-8.9**	≤ 1	0.28	0.99	0.98	0.50	0	0.50
		≤ 2	0.60	0.93	0.95	0.28	0.02	0.30
		≤ 3	0.87	0.80	0.91	0.09	0.06	0.15
		≤ 4	0.96	0.59	0.84	0.03	0.20	0.16
		≤ 5	1.00	0.34	0.77	0	0.24	0.21
	9-11.9	≤ 1	0.13	1.00	1.00	0.56	0	0.56
		≤ 2	0.40	0.98	0.97	0.38	0.01	0.39
		≤ 3	0.59	0.89	0.90	0.27	0.04	0.31
		≤ 4	0.76	0.75	0.84	0.16	0.09	0.25
		≤ 5	0.90	0.49	0.76	0.07	0.18	0.25
Honduras	**6-8.9**	≤ 1	0.11	0.99	0.96	0.55	0	0.55
		≤ 2	0.38	0.94	0.92	0.39	0.02	0.41
		≤ 3	0.79	0.60	0.76	0.13	0.15	0.28
		≤ 4	0.95	0.31	0.69	0.03	0.26	0.29
		≤ 5	1.00	0.06	0.63	0	0.36	0.36
Bangladesh	**6-8.9**	≤ 1	0.44	1.00	1.00	0.44	0	0.44
		≤ 2	0.64	0.91	0.96	0.28	0.02	0.30
		≤ 3	0.87	0.55	0.87	0.10	0.10	0.20
		≤ 4	0.95	0.27	0.82	0.04	0.16	0.20
		≤ 5	1.00	0.09	0.80	0.16	0.04	0.20
	9-11.9	≤ 1	0.24	1.00	1.00	0.72	0	0.72
		≤ 2	0.40	1.00	1.00	0.57	0	0.57
		≤ 3	0.65	1.00	1.00	0.33	0	0.33
		≤ 4	0.81	0.75	0.98	0.18	0.01	0.19
		≤ 5	0.92	0.75	0.98	0.08	0.01	0.09

[a] In Peru, "frequency" reflects the number of feeding episodes, as observed by enumerators; in Honduras, frequency represents the number of feeding episodes as self-reported by mothers (meals and snacks); in Bangladesh, frequency refers to any feeding episode where the child ate > 10 grams of food; this was defined as a meal.

[b] Low energy intake is defined here as less than 202 kcal from complementary foods for infants 6-8.9 months, and less than 307 kcal for infants 9-11.9 months.

Figure 25: <u>Peru</u>: Sensitivity and specificity of number of feeding episodes for predicting low total energy intake (infants <u>6-8.9 months</u>)

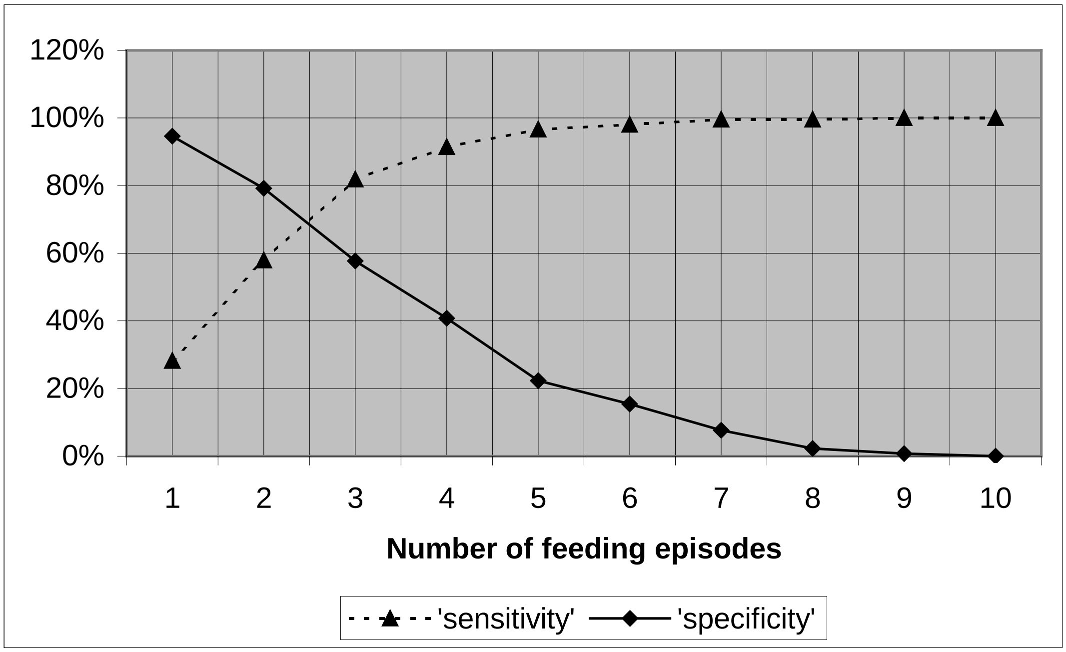


Figure 26: <u>Peru</u>: Sensitivity and specificity of number of feeding episodes for predicting low total energy intake (infants <u>9-11.9 months</u>)

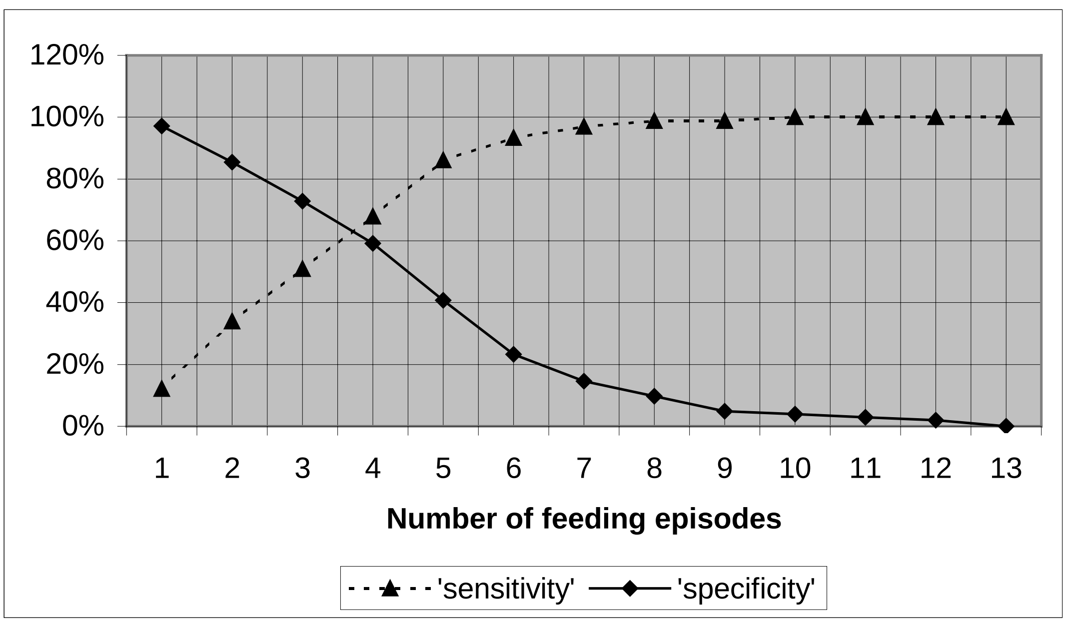


Figure 27: Bangladesh: Sensitivity and specificity of number of meals (> 10 g food) when predicting low total energy intake (infants 6-8.9 months)

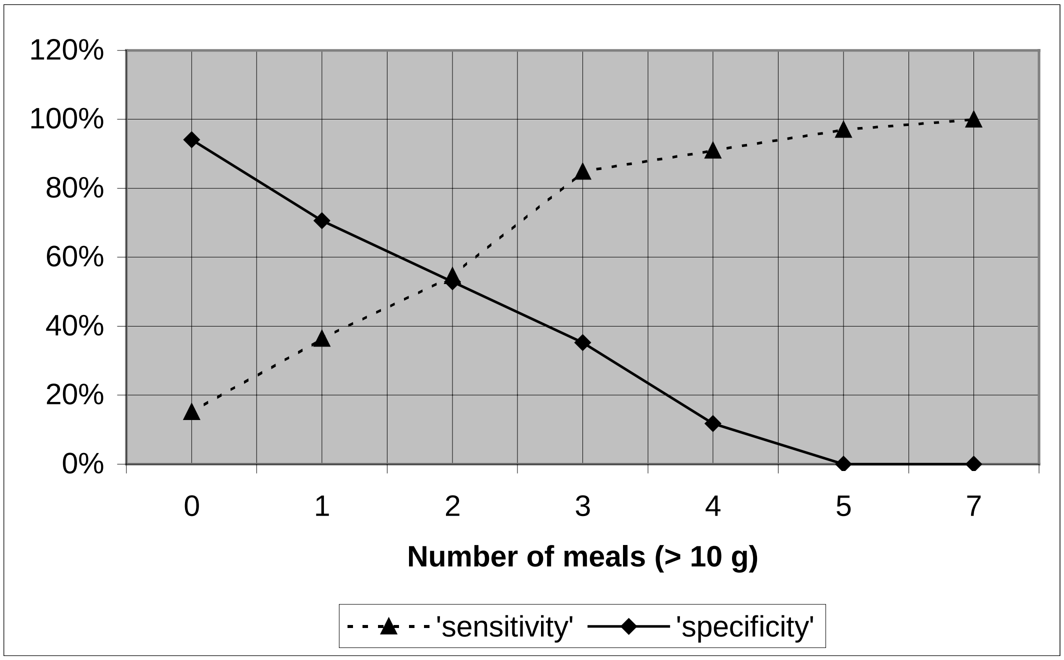


Figure 28: Bangladesh: Sensitivity and specificity of number of meals (> 10 g food) for predicting low total energy intake (infants 9-11.9 months)

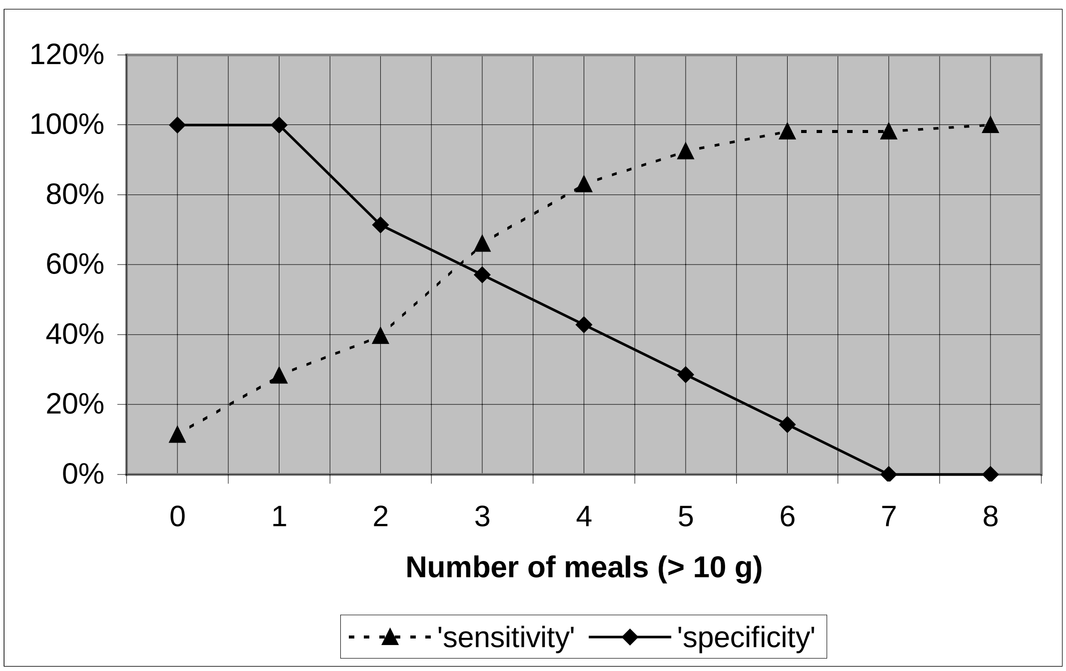


Table 33. Sensitivity/specificity analysis of feeding frequency[a] to predict with low total energy intake[b]

Country	Age in months	Cutoff	Sensitivity	Specificity	Positive predictive value	Proportion of false positives	Proportion of false negatives	Total proportion misclassified
Peru	**6-8.9**	≤ 1	0.28	0.95	0.89	0.02	0.44	0.46
		≤ 2	0.58	0.79	0.82	0.08	0.26	0.34
		≤ 3	0.82	0.58	0.76	0.16	0.11	0.27
		≤ 4	0.91	0.41	0.71	0.23	0.05	0.28
		≤ 5	0.97	0.22	0.67	0.30	0.02	0.32
	9-11.9	≤ 1	0.12	0.97	0.87	0.01	0.54	0.55
		≤ 2	0.34	0.85	0.79	0.05	0.41	0.46
		≤ 3	0.51	0.73	0.75	0.11	0.30	0.41
		≤ 4	0.68	0.59	0.73	0.15	0.20	0.35
		≤ 5	0.86	0.41	0.70	0.23	0.08	0.31
Bangladesh	**6-8.9**	≤ 1	0.36	0.71	0.71	0.10	0.42	0.52
		≤ 2	0.55	0.53	0.69	0.16	0.30	0.46
		≤ 3	0.85	0.35	0.72	0.22	0.10	0.32
		≤ 4	0.91	0.12	0.67	0.30	0.06	0.36
		≤ 5	0.97	0.00	0.65	0.34	0.02	0.36
	9-11.9	≤ 1	0.28	1.00	1.00	0	0.57	0.57
		≤ 2	0.40	0.71	0.84	0.06	0.48	0.54
		≤ 3	0.66	0.57	0.85	0.09	0.27	0.36
		≤ 4	0.83	0.43	0.85	0.12	0.13	0.25
		≤ 5	0.93	0.29	0.83	0.15	0.06	0.21

[a] In Peru, "frequency" reflects the number of feeding episodes, as observed by enumerators; in Bangladesh, frequency refers to any feeding episode where the child ate.

[b] Low total energy intake is defined here as less than 615 kcal for infants 6-8.9 months, and less than 686 kcal for infants 9-11.9 months.

4. DISCUSSION

4.1 Dietary patterns in the sample populations

The diets of infants in the four studies (Peru, Honduras, Ghana, and Bangladesh) reflect a wide range of food intake patterns. The sample population is not necessarily representative of the general population in each country, particularly in Ghana, where the infants received improved complementary foods as part of the intervention study. Nonetheless, the range in dietary patterns is valuable for our purposes, as it allows for exploration of site differences when evaluating potential indicators of dietary adequacy.

Breast milk intake was measured in Peru and Bangladesh, but not in Honduras or Ghana. In Peru, mean breast milk intake was slightly lower than the global average, whereas in Bangladesh, it was higher, particularly at 9-11.9 months. It is important to take these differences into account when evaluating the adequacy of energy intake from complementary foods.

Frequency of feeding complementary foods was recorded in three of the countries (Peru, Honduras, and Bangladesh). However, meals and snacks were recorded separately in only two sites (Honduras and Bangladesh), and the definition of a "meal" differed between those two sites. Therefore, the discussion will focus on feeding frequency rather than meal frequency. Mean feeding frequency was 3.0-3.6 per day at 6-8.9 months, with 7-24% receiving fewer than the minimum of two feedings per day stipulated for this age range in the Guiding Principles recommendations (PAHO/WHO 2003). At 9-11.9 months, mean feeding frequency was 3.9-4.8 per day, with 18-27% receiving fewer than the minimum of three feedings per day recommended for this age range. Feeding frequency was lower in Bangladesh than in Honduras and Peru for both age groups. Overall, the large majority of the infants in our three samples met the minimum feeding frequency guidelines.

The most commonly consumed foods were those categorized into the "grain products, roots and tubers" group, with at least one of these foods being recorded on 92-100% of child-days and consumption of at least 10 g from this food group on 78-99% of child-days. There was great variability across sites in the consumption of the other food groups. Legumes and nuts were consumed commonly in Ghana (67-70%), occasionally in Bangladesh (18-30%), and rarely in Peru (4-5%) and Honduras (14%). By contrast, dairy products were infrequently consumed in Ghana (12-18%) and Bangladesh (10-21%), but commonly consumed in Peru (40-48%) and Honduras (53%). Flesh foods were consumed on 28-58% of child-days in Peru, Honduras, and Ghana, though these percentages dropped to 12-24% when imposing the 10-gram minimum. In Bangladesh, flesh foods were rarely consumed, and none of the infants consumed ≥ 10 g on a given day. Eggs were consumed on 42% of child-days in Honduras, but much less frequently in Peru (11-16%), Ghana (1-3%), and Bangladesh (1-4%). Vitamin A-rich fruits and vegetables were commonly consumed in Peru (60-66%), but infrequently consumed in Honduras (16%), Ghana (5-13%), and Bangladesh (4-12%). Other fruits and vegetables were consumed on half or more of child-days in Peru (49-69%) and Honduras (69%), but on less than half of child-days in Ghana (15-48%) and Bangladesh (27-31%). Fats and oils were consumed occasionally in Peru (13-30%), Honduras (19%) and Ghana (10-44%), but rarely in Bangladesh (4-6%).

Because of the wide range in dietary patterns, there was also variability across sites in terms of which food groups were the most important sources of energy and the nine key nutrients. Eggs, for example, were a key source of many nutrients in Honduras, whereas dairy products played a key role in Peru and legumes and nuts contributed a relatively large proportion of the intake of certain nutrients in Ghana and (to a lesser extent) Bangladesh. The dependence on a single food group (grain products, root and tubers) was highest in Bangladesh (76% of energy from complementary foods), followed by Ghana (56%), Peru (51%), and Honduras (33%).

Mean dietary diversity (measured using a food group index including eight food groups (FGI-8)) was higher in Peru (3.0-3.7) and Honduras (3.3) than in Ghana (2.6-3.4) and Bangladesh (1.7-2.1). When considering only food groups from which at least 10 g were consumed (using an eight-food group index with 10-gram minimum restriction for each food group except fats and oils (FGI-8R)), the mean diversity scores were lower: approximately 2-3 in Peru, Honduras, and Ghana and < 2 in Bangladesh. Thus, the diets of most of the children included foods from less than three of the eight food groups on any given day.

Nutrient density of the complementary food diet was generally inadequate during the first year of life. The median percentage of desired nutrient density was particularly low for absorbed iron: 5-9% in Bangladesh, 6-10% in Peru, 8% in Honduras, and 13-36% in Ghana. Of the other nutrients, the median percentage of desired nutrient density at 6-11.9 months was low (generally < 60%) in all sites for absorbed zinc and in several sites for absorbed calcium, vitamin A, riboflavin, vitamin B6, and vitamin C. Median nutrient density of folate and thiamin was generally > 60% of desired.

As a consequence of the generally low nutrient densities, the mean nutrient density adequacy (MNDA) of the complementary food diet (average of percent desired nutrient density, capped at 100% for the nine nutrients) was low in all four sites, ranging from 35-49% in Bangladesh to 56-63% in Peru. MNDA increased with age in the three sites that had more than one age group (i.e., 6-8.9 and 9-11.9 months).

4.2 The relationship between dietary diversity and mean nutrient density adequacy

Mean nutrient density adequacy (MNDA) was used in this study as our indicator of diet quality. Dietary diversity was positively associated with MNDA in all four countries, with MNDA generally 50-60% when only two food groups were consumed, increasing to ~60-70% when at least four food groups were consumed (regardless of the quantity consumed). If a 10-gram minimum quantity was imposed, MNDA generally rose to ~70-80% when at least four food groups were consumed. Thus, a larger number of food groups in the child's diet is associated with greater dietary quality.

The correlations between dietary diversity and MNDA were significant in all sites and age groups, ranging from ~0.4 to ~0.7. Imposing a 10-gram minimum in counting the number of foods groups did not generally improve the correlation.

Sensitivity/specificity analyses were performed in order to explore the ability of various levels of food group diversity to predict MNDA above and below selected cutoffs. The process of selecting cutoffs for an indicator, like selection of indicators more generally, depends on many factors, including the intended uses of the indicator.

Because the MNDA is not a widely used indicator with consensus around the meaning of any particular cutoff, we initially explored relationships using MNDA cutoffs of 50%, 60%, 75%, and 80%. In subsequent discussions with colleagues who convened to discuss our research protocol, there was general consensus that a cutoff of <50% MNDA could be used to characterize low or poor MNDA. There was less agreement on the issue of identifying a cutoff for adequate or good MNDA.[18] Even at an MNDA of 75% or 80%, a child could be consuming far too little of one or more nutrients.

Finally, selection of a cutoff for adequate or good MNDA may also be constrained, as in the case of these analyses, by the nature of available data. In several of the data sets, very few children had an MNDA over 80% (only 6% in Ghana and 3% in Bangladesh), which may cause poor performance of an indicator based on a relatively high cutoff (in terms of mis-classification). Taking all these issues into account, we chose to use a cutoff of ≥ 75% to indicate "better" MNDA, while recognizing the limitation of this approach and anticipating that further discussion of these issues will be necessary.

In general, imposing the 10-gram minimum when calculating dietary diversity did not result in less misclassification. Because a simple indicator is easier to implement in the field, it is preferable to choose one that does not require collecting information on quantities consumed, unless there is a clear advantage to doing so. Thus, we focus the discussion below on the results using the dietary diversity indicator with the 1-gram minimum amount.

Findings from our four data sets suggest that to identify children with *low* nutrient density diet (MNDA < 50%), a cutoff point of ≤ 2 food groups results in the lowest percentage of misclassified children and an acceptable balance of sensitivity and specificity in all four data sets. With this cutoff (using FGI-8), sensitivity was 61-88%, specificity was 43-85%, and the percentage misclassified was 22-29%, depending on the country. The most consistent cutoff point of dietary diversity to identify children with a *better* nutrient density diet (MNDA ≥ 75%) was ≥ 4 food groups. In this situation (again using FGI-8), sensitivity was 50-81%, specificity was 61-96%, and the percentage misclassified was 7-36%.

While the values for sensitivity and specificity are not as high as one might like in some of the countries, the results indicate that the dietary diversity indicator holds promise at least at the population level, if not at the individual level. Results from analyses using additional data sets from other countries are needed before making conclusive statements about the best indicators of dietary quality.

Dietary diversity may be related not only to nutrient density, but also to energy intake. With a diet of the same nutrient density, an individual consuming more energy is more likely to meet

[18] WHO (2005). Dietary Diversity and Dietary Quality Workshop Report Rome: 11-13 October, 2004. Unpublished report.

nutrient requirements than an individual consuming less energy. Thus, dietary diversity may be predictive of nutrient adequacy (i.e., meeting nutrient needs) for two reasons: (1) it is associated with the nutrient density of the diet, and (2) it is associated with energy intake. While these two relationships are both likely to be significant in non-breastfed children and adults (Hatloy, Torheim, and Oshaug 2002; Ogle, Hung, and Tuyet 2001; Ruel et al. 2004), it is unclear whether the latter relationship holds true for breastfed children who receive a significant amount of energy and nutrients from breast milk.

In these data sets, there were significant correlations between dietary diversity and energy intake from complementary foods in all four countries (r = 0.15-0.38). The correlations with total energy intake (breast milk + complementary foods; available for only two countries) were significant in Peru (r = 0.17-0.30) but not in Bangladesh. This is likely due to the trade-off between energy from complementary foods and energy from breast milk. Thus, depending on the population, the diversity of the complementary foods consumed may or may not be predictive of total energy intake. Diversity is less likely to be predictive of energy intake when breast milk intakes are high, as in Bangladesh.

4.3 "Sentinel" foods groups as predictors of individual nutrient density adequacy and mean nutrient density adequacy

To evaluate which of the food groups were most predictive of the nutrient density adequacy (NDA) of each of the key nutrients, the sensitivity/specificity analyses for this component were based on a cutoff of < 60% of desired nutrient density for all nutrients except iron. For iron, a lower cutoff (< 10% of desired nutrient density) had to be used because the absorbed iron content of the diet was so low.

These analyses revealed that certain food groups were consistently associated with certain nutrients, i.e., they were predictive (Se + Spe > 1.25; see footnote 15) of NDA in at least three of the four sites. Consumption of vitamin A-rich fruits and vegetables was predictive of vitamin A NDA in three sites. Consumption of other fruits and vegetables was predictive of vitamin B6 NDA and of folate NDA in three sites, and of vitamin C NDA in all four sites. Consumption of dairy products was predictive of calcium, riboflavin, and vitamin A NDA in three sites. Consumption of flesh foods was predictive of zinc NDA in three sites. Iron NDA was best predicted by consumption of flesh foods in Peru and Ghana, but by consumption of eggs in Honduras and by consumption of legumes/nuts in Bangladesh (where flesh food and egg consumption was extremely low).

These findings may be useful in circumstances in which an indicator for a particular nutrient is desired. If subsequent analyses confirm the above results, indicators that reflect nutrient density of the complementary food diet may be feasible for several key nutrients.

In the sensitivity/specificity analyses using individual food groups as predictors of MNDA < 50%, non-consumption of the combined food group for animal source foods and the group for other fruits and vegetables was predictive of low MNDA in all four countries. Non-consumption of dairy products was predictive of low MNDA in three of the four countries. When compared with the results for dietary diversity (using a cutoff of ≤ 2 food groups for FGI-8 and the < 50%

MNDA cutoff), the ASF food group yielded similar or better results in three of the four sites (the exception being Peru, in which the dietary diversity indicator gave slightly better results). Sensitivity was 49-93%, specificity was 50-87% and the percentage misclassified was 20-26%, depending on the country.

Consumption of the combined food group for animal source foods was predictive of MNDA ≥ 75% in three of the four countries. When compared with the results for dietary diversity (using a cutoff of ≥ 4 food groups for FGI-8 and the ≥ 75% MNDA cutoff), the ASF food group yielded similar results in Peru and Bangladesh, but the dietary diversity indicator performed better in Honduras and Ghana. The percentage misclassified using the animal source foods indicator was generally higher when predicting MNDA ≥ 75% than when predicting MNDA < 50%.

Further analyses with other data sets are needed to determine if consumption of animal source foods is as good or better than dietary diversity as an indicator of nutrient density in this age group. A recent validation study in school-age Kenyan children showed that ASF was not a good predictor of the mean probability of inadequate intake of 15 nutrients in a sample where only 14 percent of the children consumed ASF, and amounts consumed were very small (average 17 g) (Ruel et al. 2004). Thus, it will be important to continue to validate indicators of animal source food intake in different age groups and populations with varying consumption patterns.

4.4 The relationship between feeding frequency and energy intake

Feeding frequency was strongly correlated with energy intake from complementary foods, with correlation coefficients ranging from ~0.5 in Honduras and Bangladesh to 0.66-0.78 in Peru. In the two sites in which meal frequency was also recorded, the correlation with energy intake from complementary foods was higher for meal frequency than for feeding frequency in Bangladesh, but the opposite was true in Honduras. This suggests that there is no consistent advantage in distinguishing meals from snacks, in terms of predicting energy intake from complementary foods.

In the two sites in which total energy intake (including energy from breast milk) was measured (Peru and Bangladesh), the correlations with feeding frequency were lower for total energy intake than for energy intake from complementary foods. This is not surprising, given that there is usually a trade-off between energy intake from breast milk and energy intake from complementary foods. Thus, when evaluating indicators that are predictive of the adequacy of energy intake, it is preferable to use total energy intake as the yardstick, rather than energy intake from complementary foods. Otherwise, the risk of misclassification is high (e.g., concluding that a child with a low feeding frequency had low energy intake, when energy intake was actually adequate because of a relatively high breast milk intake). This is particularly true when the average breast milk intake in a given population deviates from the global average breast milk intake upon which the feeding frequency recommendations are based, which was certainly the case for Bangladesh. However, there may be circumstances when an indicator of energy intake from complementary foods may be of use.

The results section presented sensitivity/specificity analyses using both total energy intake and energy intake from complementary foods as the outcome. With the latter option, a cutoff of ≤ 3 feedings at 6-8.9 months yielded the best results when predicting low energy intake from complementary foods, with sensitivity of 79-87%, specificity of 55-80%, and 15-28% of cases misclassified. At 9-11.9 months, a cutoff of ≤ 4 feedings yielded the best results, with sensitivity of 75-81%, specificity of 75% and 18-25% misclassified. With the former option (total energy intake as outcome), the results were not as good (as expected, given the lower correlations between feeding frequency and total energy intake than between feeding frequency and energy intake from complementary foods). The cutoffs that yielded the lowest percentage misclassified were the same as those identified when energy intake from complementary foods was the outcome, and sensitivity was comparable, but specificity was lower (35-59%) and the percentage misclassified was higher (25-35%). In other words, when using total energy intake as the outcome, there was an excess of "false positives," or children identified by the indicator as having low energy intake who, in fact, had adequate energy intake. Whether this is acceptable depends on the purposes and uses of the indicators.

For either option (i.e., using total energy intake or complementary food energy intake), indicators using cutoffs based on the Guiding Principles (≤ 2 meals at 6-8.9 months and ≤ 3 meals at 9-11.9 months) had relatively low sensitivity. With total energy intake as the outcome, sensitivity for detecting low total energy intake (i.e., less than the mean energy requirement at that age) was 51-58% in Peru and 55-66% in Bangladesh, and the percentage of cases misclassified was relatively high (34-41% in Peru, 36-46% in Bangladesh). In other words, these cutoffs yielded a high proportion of "false negatives," or children with low energy intakes who were not identified by the indicator.

However, it should be noted that the Guiding Principles are based on *meal* frequency, and that they also allow for optional "additional nutritious snacks offered 1-2 times per day, as desired." Thus, the cutoffs for feeding frequency (meals plus snacks) that performed best in these analyses (≤ 3 at 6-8.9 months and ≤ 4 at 9-11.9 months) are not necessarily inconsistent with the Guiding Principles. The better results obtained using slightly higher cutoffs may also be related to the fact that children often do not eat to "gastric capacity" at each meal. The recommended meal frequencies in the Guiding Principles are based on eating to gastric capacity, with the caveat stated that "if energy density or amount of food per meal is low…, more frequent meals may be required."

Additional analyses of the relationship between feeding frequency and total energy intake, using other data sets, are necessary before drawing any conclusions about appropriate indicators. The mediocre sensitivity and specificity results (when total energy intake was the outcome) suggest that it may not be valid to attempt to predict adequacy of energy intake based on feeding frequency.

4.5 Strengths and limitations of these analyses

This is the first attempt to develop indicators of complementary feeding for breastfed children. Because the analyses are based on data from four different countries representing three major world regions, the results are more likely to be generalizable than if only one or two populations had been examined. The number of child-days of dietary data for children 6-12 months of age was relatively large in three of the four data sets, and two of the data sets included measurements of breast milk intake, which allowed for examination of total energy intake. In addition, the nutrient density calculations were based on complete food composition data (including phytate content) and took into account the estimated bioavailability of iron, zinc, and calcium from each dietary record.

Despite these strengths, several limitations of these findings should be kept in mind. First, these analyses were limited to children < 12 months of age. Additional analyses for the age range of 12-24 months are needed. The validation of indicators of nutrient adequacy and energy intake also needs to be done in non-breastfed children 6-24 months of age.

Second, there is still uncertainty about recommended nutrient intakes (RNIs) during infancy. The RNI values chosen for calculating the NDA and MNDA scores were based on the latest FAO/WHO or IOM (Dietary Reference Intakes) recommendations (Dewey and Brown 2003), whichever was lower for a given nutrient (for the 6-12 months age interval). The lower value was chosen because most of the RNI values are based on "Adequate Intake" estimates, which may overestimate actual nutrient needs. In the absence of a consistent, harmonized set of RNIs for this age group, this is a reasonable approach, but it should be noted that the results could be different if other RNI values had been used.

Third, although the analyses take the bioavailability of iron, zinc, and calcium into account, the calculations are based on the entire day's diet, not the bioavailability of each individual meal. This introduces some unavoidable random error into the results.

4.6 Conclusions

With regard to the two main objectives of these analyses, we conclude the following:

1) ***Dietary diversity as an indicator of diet quality:***

   a) Diet diversity was associated with diet quality – measured as mean nutrient density adequacy (MNDA) of complementary foods in this study - in all samples, for all age groups: mean MNDA increased with increasing dietary diversity, although the relationship was not always linear. All correlation coefficients between dietary diversity and MNDA were statistically significant, and they ranged from 0.37 to 0.74, depending on the age group and country.

   b) The dietary diversity indicator that included a 10-g minimum restriction did not result in lower percentages of misclassified children or higher sensitivities or specificities than the simpler indicator based on a 1-g limit (for practical purposes, equivalent to "any or none" for consumption), and therefore the simpler one is recommended.

   c) Best cutoff points varied depending on the diversity indicator and the cutoff point for MNDA used. Additional analyses in other age groups and contexts are required to confirm whether universal cutoff points can be recommended.

   d) An indicator based on consumption of animal source foods (yes/no) performed as well as or better than the dietary diversity indicator as a predictor of adequacy of nutrient density of complementary foods (when using the MNDA cutoff point of <50%). Again, further analyses are needed to determine if this holds true for other data sets.

2) ***Feeding frequency as an indicator of energy intake:***

a) Feeding frequency was associated with both total energy intake and energy from complementary foods.

b) All correlation coefficients between frequency of feeding and energy from complementary foods were statistically significant and ranged from 0.48 to 0.78, depending on the age group and country.

c) As expected, the association of feeding frequency with total energy intake (from breast milk and complementary foods combined) was weaker than the association with energy from complementary foods only. Statistically significant correlations ranged from 0.35 among older infants in Bangladesh to 0.51 among young infants in Peru. The association was not significant among younger infants in Bangladesh (correlation coefficient was 0.02).

Analyses with other data sets will allow further evaluation of the performance of feeding frequency indicators (and cutoff points) to predict total energy intake as well as energy intake from complementary foods. Depending on the results, the usefulness of feeding frequency for these purposes will be re-evaluated. Irrespective of the results, however, feeding frequency may still be a useful indicator of the adequacy of infant caregiving practices.

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ANNEX 1. PRELIMINARY ANALYSES WITH VARYING ASSUMPTIONS REGARDING BREAST MILK INTAKE

For many of the analyses in this report, assumptions had to be made regarding intake of energy and nutrients from breast milk. This was particularly important for estimating nutrient density adequacy, as the desired nutrient density within a given age interval will depend on the amount of breast milk consumed. Data on actual day-time (12-hour) and estimated 24-hour intake from breast milk were available for only two of the four countries (Peru and Bangladesh). Therefore, several types of preliminary analyses were conducted to explore options for estimating breast milk intake when such data are unavailable. We first explored the relationship between frequency of breastfeeding and breast milk intake in Peru and Bangladesh, and concluded that frequency of feeding could not be used to predict intake (see Table 7 in section 3.2).

Next, we completed a series of analyses in which we used complementary food intake to create a proxy for breast milk intake, with the idea being that the two are roughly inversely related, and that this inverse relationship could be sufficient for categorizing infants into two or three levels of breast milk intake. In an earlier draft of this report, we categorized infants as having "low" or "high" breast milk intake, using energy from complementary foods (kcal/d) as a "reverse proxy." In discussions of that draft, questions were raised as to whether the reverse proxy adequately categorized the level of breast milk intake.

To examine this question, we used the two countries for which data on breast milk intake were available to look at the relationship between actual intake category (low or high) and the category to which the child-day was assigned based on the "reverse proxy." The results for Peru were acceptable, but for Bangladesh, specificity was very low. Specificity was better when the reverse proxy was based on infant body weight (kcal/kg/d) instead of the absolute amount (kcal/d). This is understandable, given the small body weights of the infants in Bangladesh and thus their lower energy needs.

We then examined whether three categories of estimated breast milk intake (low, average and high) would result in less misclassification than putting all child-days in the "average" category. For these analyses, we based the reverse proxy on intake per kg body weight. As expected, using three categories resulted in less misclassification (Table A1.1), but it resulted in some misclassification to the extreme tertile (which is by definition zero when only one level is used).

Table A1.1. Percent of child-days where actual breast milk intake is misclassified

	Correct (%)	Misclassified by one category[a] (%)	Extreme misclassification (%)[b]
Bangladesh			
3-levels based on inverse of CF intake[c]	53	37	10
1 level (all categorized as "average")	32	68	0
Peru			
3-levels based on inverse of CF intake	55	29	16
1 level (all categorized as "average")	26	74	0

[a] For example, categorized as low when intake was average.

[b] Categorized as low when intake was high or categorized as high when intake was low.

[c] CF is complementary food.

The next question was whether nutrient density adequacy, and the relationship between dietary diversity and nutrient density adequacy, would differ depending on whether the dietary data (for all four countries) were categorized into three levels of breast milk intake (low, average, or high) or only one category (assuming average breast milk intake for all). We based the three-level categorization on expected total energy intake per kg body weight, using recent values for energy requirements (Dewey and Brown 2003). We first calculated the expected total energy intake for each child based on body weight and age. Then we subtracted the child's energy intake from complementary foods (per kg body weight) to obtain the child's estimated energy intake from breast milk. This estimate was used to assign a category for breast milk intake (low, medium or high), based on tertiles of the global estimates for breast milk energy intake at each age range (WHO 1998).

To derive the desired nutrient density values specific for age group and breast milk intake category, the 17th, 50th, and 83rd percentiles of breast milk intake were calculated from the breast milk intake values published by WHO (footnote to Table 23 in WHO 1998). These "low," "average," and "high" breast milk intake values were then used to calculate the amount required from complementary foods for each of nine "problem" nutrients identified in Dewey and Brown (2003): vitamins A, B6, and C, riboflavin, thiamin, folate, iron, zinc, and calcium, in each of the two age groups. The estimated amount of each of these nutrients contributed by breast milk (based on breast milk concentrations published in WHO 1998) was subtracted from the Recommended Nutrient Intake (RNI) for each nutrient.

As described in Section 2.4 of the current report, we used RNI values from FAO/WHO for all of the vitamins (Joint FAO/WHO Expert Consultation 2002). For the minerals, the recommended amount *absorbed* was the basis for the calculation (see Section 2.4 for details).

Once desired amounts were determined for each level of estimated breast milk intake, desired densities, NDAs for each nutrient, and the MNDA were calculated in the same way as described in this report.

For most of the nutrients examined, the median percentage of desired nutrient density was similar regardless of whether one or three categories of breast milk intake were used to calculate the amounts needed from complementary foods. However, for vitamin A and vitamin C the results differed substantially. When three categories are used, infants in the top tertile of breast milk intake at 6-8.9 mo of age do not require *any* vitamin A or vitamin C from complementary foods, and thus all such infants are assigned a value of "100%" for vitamin A and vitamin C adequacy. The same situation applies at 9-11.9 mo for vitamin C (though not for vitamin A). For this reason, in countries where vitamin A or vitamin C content of complementary foods is typically low, but a substantial number of infants are in the top tertile of breast milk intake (e.g., Ghana and Bangladesh), median percentage of desired nutrient density for these two nutrients will look better when three categories of breast milk intake are used than when only one category is used. With three categories (and age groups combined), median vitamin A density was 45% in Ghana and 4% in Bangladesh (compared to 1% and 0.2%, respectively, with one category), and median vitamin C density was 67% in Ghana and 100% in Bangladesh (compared to 12% and 11%, respectively, with one category).

For the sensitivity and specificity analyses, use of the more complicated approach (using CF intake to assign child-days to one of three breast milk intake categories) generally did not improve the ability of the dietary diversity indicators to predict MNDA. There was only one situation in which using three categories resulted in less misclassification, and that was with the ≥ 75% MNDA cutoff, using the 10 g minimum for the food groups in the dietary diversity indicator (FGI-8R). In this situation, using three categories caused less misclassification than using one category for Peru (21% vs. 25%) and Honduras (26% vs. 30%), though not for Ghana or Bangladesh. However, these differences (4%) were not large. For all other situations, using one category gave similar or better results than using three categories.

Because the simpler alternative (to assign all infants to the “average” breast milk category) is not dependent on any assumptions about the nature of the relationship between intake from breast milk and intake from complementary foods, and did not yield substantially different results than the more complex approach, we ultimately chose to present results only for the simpler, one-category approach.

ANNEX 2. PERU: SUMMARY OF FOOD GROUP INTAKE FOR ALL CHILD-DAYS AND FOR DAYS FOOD GROUP WAS CONSUMED (CHILDREN 6-11.9 MONTHS)

	All (n =573)					Among those who consume			
Food group	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)	Percent (n) consuming	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)
Grains, roots, tubers	79	95	58	70	95 (544)	83	101	60	75
Legumes and nuts	1	1	0	0	5 (26)	16	33	9	21
Dairy	59	72	0	0	43 (248)	136	165	95	100
Flesh foods	5	8	0	0	33 (188)	15	24	10	15
Eggs	2	3	0	0	13 (76)	14	26	9	14
Vitamin A-rich fruits and vegetables	12	5	3	1	63 (361)	19	8	9	3
Other fruits and vegetables	15	10	2	0	58 (332)	25	17	11	4
Fats and oil	0	3	0	0	20 (117)	2	16	1	9

ANNEX 3. HONDURAS: SUMMARY OF FOOD GROUP INTAKE FOR ALL CHILD-DAYS AND FOR DAYS FOOD GROUP CONSUMED ONLY (INFANTS 6-8.9 MONTHS)

	All (n = 658)					Among those who consume			
Food group	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)	Percent (n) consuming	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)
Grains, roots, tubers	32	58	24	40	95 (623)	34	61	25	43
Legumes and nuts	1	1	0	0	14 (92)	8	8	5	6
Dairy	28	24	2	4	53 (349)	52	46	10	21
Flesh foods	5	13	0	0	28 (186)	18	45	9	21
Eggs	10	18	0	0	42 (274)	23	44	17	32
Vitamin A-rich fruits and vegetables	3	2	0	0	16 (102)	20	10	4	2
Other fruits and vegetables	58	45	26	22	69 (453)	84	65	61	47
Fats and oil	1	6	0	1	19 (123)	3	25	2	19

ANNEX 4. GHANA: SUMMARY OF FOOD GROUP INTAKE FOR ALL CHILD-DAYS AND FOR DAYS FOOD GROUP WAS CONSUMED (INFANTS 6-11.9 MONTHS)

	All (n = 381)					Among those who consume			
Food group	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)	Percent (n) consuming	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)
Grains, roots, tubers	313	137	257	111	99 (378)	316	138	258	111
Legumes and nuts	39	30	22	20	69 (262)	57	43	49	34
Dairy	11	5	0	0	15 (58)	70	32	41	21
Flesh foods	4	16	0	3	50 (190)	9	32	8	28
Eggs	0	1	0	0	2 (8)	11	34	12	36
Vitamin A-rich fruits and vegetables	2	3	0	0	9 (33)	18	35	8	5
Other fruits and vegetables	7	3	0	0	30 (113)	24	10	16	5
Fats and oil	2	20	0	0	25 (95)	9	79	4	36

ANNEX 5. BANGLADESH: SUMMARY OF FOOD GROUP INTAKE FOR ALL CHILDREN[A] AND FOR CONSUMERS ONLY (CHILDREN 6-11.9 MONTHS)

	All (n = 116)					Among those who consume			
Food group	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)	Percent (n) consuming	Mean amount (g)	Mean energy (kcal)	Median amount (g)	Median energy (kcal)
Grains, roots, tubers	60	92	45	74	97 (113)	61	95	46	75
Legumes and nuts	4	4	0	0	25 (29)	14	16	13	16
Dairy	12	8	0	0	16 (19)	76	47	71	43
Flesh foods	0	0	0	0	6 (7)	3	2	2	2
Eggs	1	1	0	0	3 (3)	29	54	30	56
Vitamin A-rich fruits and vegetables	2	1	0	0	9 (10)	23	10	20	7
Other fruits and vegetables	8	7	0	0	29 (34)	27	22	22	16
Fats and oil	0	1	0	0	5 (6)	3	25	2	17

[a] In Bangladesh, there was only one day's data for each child, so number of children equals number of "child-days" of dietary data.

ANNEX 6. PERU: FOOD GROUP CONSUMPTION, BY FOOD GROUP DIVERSITY SCORE (FGI-8, 1-GRAM MINIMUM) (INFANTS 6-11.9 MONTHS)

	FGI-8 score (number of food groups)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Percent (number) of child-days at each diversity score	12% (71)	16% (91)	25% (146)	28% (160)	13% (74)	5% (26)	1% (5)	0% (0)
Food groups	**Percent of child-days on which each food group was consumed**							
Grains, roots, tubers	72	96	98	99	100	100	100	n/a[a]
Legumes and nuts	0	0	1	8	9	15	20	
Dairy	18	29	38	48	65	92	100	
Flesh foods	0	14	24	48	53	73	100	
Eggs	3	4	9	15	23	46	80	
Vitamin A-rich fruits and vegetables	3	36	71	77	96	92	100	
Other fruits & vegetables	4	20	51	83	97	100	100	
Fats and oil	0	1	8	23	57	81	100	

[a] There were no child-days with a food group diversity score of 8 in Peru.

ANNEX 7. HONDURAS: FOOD GROUP CONSUMPTION, BY FOOD GROUP DIVERSITY SCORE (FGI-8; 1-GRAM MINIMUM) (INFANTS 6-8.9 MONTHS)

	Diversity score (number of food groups)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Percent (number) of child-days at each diversity score	**10% (65)**	**21% (139)**	**25% (173)**	**22% (147)**	**14% (94)**	**6% (41)**	**1% (6)**	**0% (3)**
Food groups	**Percent of child-days on which each food group was consumed**							
Grains, roots, tubers	72	91	98	99	100	100	100	100
Legumes and nuts	0	2	5	18	34	41	50	100
Dairy	2	22	53	77	78	90	83	100
Flesh foods	0	12	21	35	52	61	100	100
Eggs	5	25	33	52	68	83	83	100
Vitamin A-rich fruits and vegetables	2	6	6	18	35	39	83	100
Other fruits and vegetables	20	39	79	84	89	100	100	100
Fats and oil	0	4	6	16	44	85	100	100

ANNEX 8: GHANA: FOOD GROUP CONSUMPTION, BY FOOD GROUP DIVERSITY SCORE (FGI-8; 1-GRAM MINIMUM) (INFANTS 6-11.9 MONTHS)

	Diversity score (number of food groups)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Percent (number) of child-days at each diversity score	**8% (30)**	**36% (138)**	**25% (96)**	**16% (62)**	**10% (37)**	**4% (16)**	**1% (2)**	**0% (0)**
Food groups	**Percent of child-days on which each food group was consumed**							
Grains, roots, tubers	93	99	100	100	100	100	100	n/a[a]
Legumes and nuts	0	64	80	74	92	94	100	
Dairy	7	4	27	26	11	19	50	
Flesh foods	0	31	60	66	81	100	100	
Eggs	0	0	1	2	8	13	50	
Vitamin A-rich fruits and vegetables	0	0	0	8	35	81	100	
Other fruits and vegetables	0	0	18	69	95	100	100	
Fats and oil	0	1	14	55	78	94	100	

[a] There were no child-days with a food group diversity score of 8 in Ghana.

ANNEX 9: BANGLADESH: FOOD GROUP CONSUMPTION, BY FOOD GROUP DIVERSITY SCORE (FGI-8, 1-GRAM MINIMUM) (INFANTS 6-11.9 MONTHS)

	Diversity score (number of food groups)							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Percent (number) of child-days at each diversity score	**41% (48)**	**34% (40)**	**17% (20)**	**6% (7)**	**1% (1)**	**0% (0)**	**0% (0)**	**0% (0)**
Food groups	**Percent of child-days on which each food group was consumed**							
Grains, roots, tubers	96	100	95	100	100	n/a[a]	n/a	n/a
Legumes and nuts	0	38	50	43	100			
Dairy	0	33	30	0	0			
Flesh foods	0	0	25	29	0			
Eggs	0	0	5	29	0			
Vitamin A-rich fruits and vegetables	0	0	20	71	100			
Other fruits and vegetables	4	28	65	100	100			
Fat and oil	0	3	10	29	100			

[a] There were no child-days with a food group diversity score higher than 5 in Bangladesh.

ANNEX 10: ENERGY AND NUTRIENT INTAKE BY COUNTRY AND BY AGE, COMPARED TO DESIRED AMOUNT FROM COMPLEMENTARY FOOD

	RNI[a]	Desired amount from CF[b]	Mean intake (SD) and percent desired amount												
			Peru			Honduras			Ghana			Bangladesh			
6-8.9 months			**Mean**	**SD**	**Percent**	**Mean**	**SD**	**Percent**	**Mean**	**SD**	**Percent**	**Mean**	**SD**	**Percent**
Energy (kcal)	615	202	194	200	96	192	166	95	185	114	92	118	97	58
Vitamin A (RE)	400	63	110	179	174	105	434	167	487	2358	773	14	45	22
Thiamin (mg)	0.3	0.16	0.06	0.05	40	0.14	0.12	87	0.12	0.09	72	0.05	0.06	34
Riboflavin (mg)	0.4	0.16	0.45	0.77	281	0.26	0.43	162	0.08	0.06	49	0.06	0.09	38
Vitamin B6 (mg)	0.3	0.24	0.13	0.13	55	0.19	0.25	79	0.14	0.10	59	0.07	0.14	31
Folate (µg)	80	23	23	28	100	27	48	119	14	11	61	15	22	65
Vitamin C (mg)	30	3	4.5	6.9	148	20.9	32.4	686	1.3	3.0	41	1.5	3.2	48
Absorbed calcium (mg)	81	24	47	89	194	29	50	117	43	56	177	8	17	34
Absorbed iron (mg)	0.93	0.89	0.07	0.11	8	0.08	0.09	9	0.29	0.33	32	0.03	0.04	4
Absorbed zinc (mg)	1	0.60	0.23	0.28	39	0.19	0.25	32	0.26	0.18	43	0.10	0.10	16
9-11.9 months														
Energy (kcal)	686	307	290	212	95				319	196	106	128	90	42
Vitamin A (RE)	400	92	128	226	140				1345	4115	74	12	29	13
Thiamin (mg)	0.3	0.17	0.11	0.08	64				0.19	0.15	112	0.07	0.06	40
Riboflavin (mg)	0.4	0.18	0.44	0.63	243				0.12	0.11	68	0.07	0.06	38
Vitamin B6 (mg)	0.3	0.24	0.21	0.20	89				0.26	0.26	108	0.07	0.09	29
Folate (µg)	80	28	32	37	117				29	31	104	19	21	68
Vitamin C (mg)	30	5	8.3	11.0	155				7.8	14.4	148	3.5	9.1	66
Absorbed calcium (mg)	81	29	46	73	157				67	79	159	10	12	35
Absorbed iron (mg)	0.93	0.89	0.10	0.10	12				0.46	0.48	38	0.04	0.03	4
Absorbed zinc (mg)	1	0.63	0.32	0.28	50				0.39	0.27	59	0.12	0.08	18

[a] Ref for RNIs.

[b] Explain this is "desired" with average breast milk intake; give ref for desired amounts.

ANNEX 11. ANALYSIS OF THE ASSOCIATION BETWEEN DIETARY DIVERSITY AND ENERGY INTAKE

Figures A1-A4 show the relationship between dietary diversity and energy intake from complementary food in our four data sets. Overall, there is a trend of increasing energy from complementary food as dietary diversity increases. The correlation coefficients between dietary diversity and energy from complementary foods (Table A11.1) are also statistically significant for all countries and all age groups. The correlation coefficients between dietary diversity and total energy intake (including energy from complementary foods + breast milk) are significant in Peru, but not in Bangladesh. Information on breast milk energy intake was not available for the other two countries, and thus the correlation between diversity and total energy intake could not be tested for these other countries.

Figure A1: Peru: Mean complementary food energy, by dietary diversity score (FGI-8)

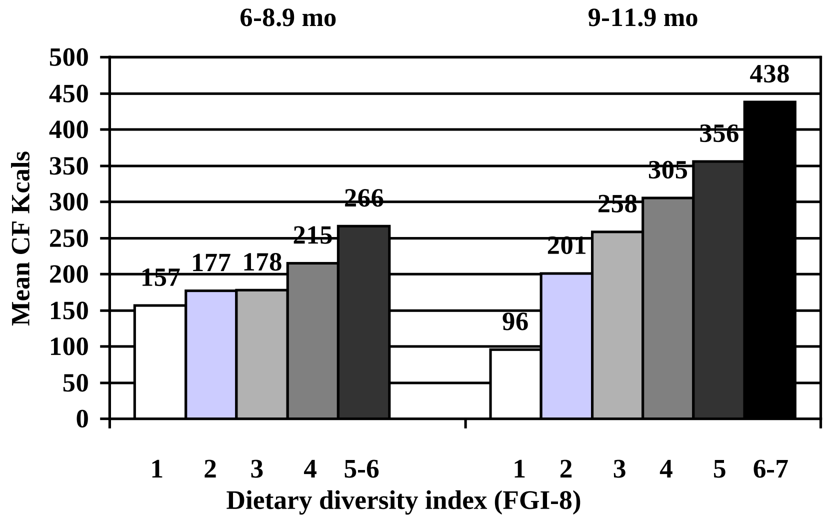


Figure A2: Honduras: Mean complementary food energy, by dietary diversity score (FGI-8)

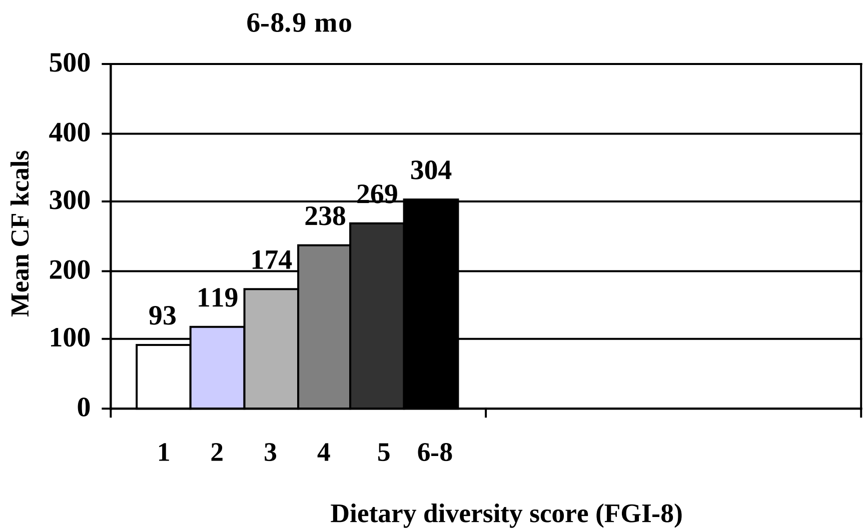


Figure A3: Ghana: Mean complementary food energy, by dietary diversity score (FGI-8)

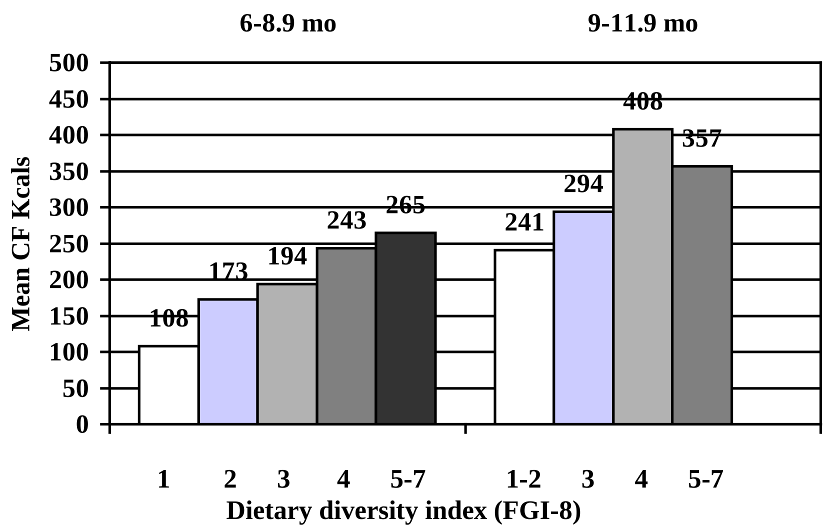
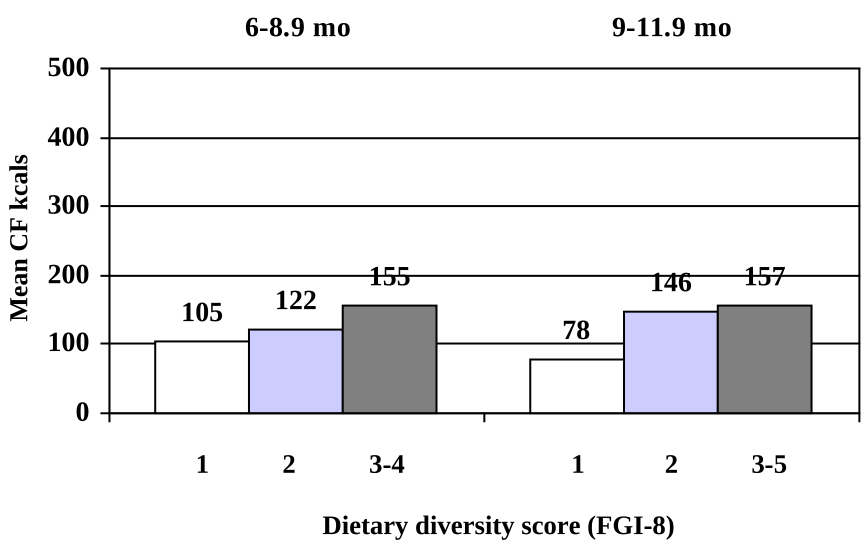


Figure A4: Bangladesh: Mean complementary food energy, by dietary diversity score (FGI-8)



Figures A1-A4 reflect the cross-country differences both in diversity and in overall energy intake from complementary foods. Though the relationship differs across countries and age groups, correlations between dietary diversity and energy from complementary food are significant in all groups (Table A11.1). Correlations between dietary diversity and total energy intake (including breast milk) are significant in Peru, but not in Bangladesh. This may reflect the overall low intake of complementary food in Bangladesh (Table A11.1).

Table A11.1: Relationship between dietary diversity and energy intake from complementary foods and total energy intake, by country and by age group

Country and age group	Correlations[a] between dietary diversity (FGI-8) and energy: From complementary foods (kcal)	Total energy intake (kcal)	Mean energy intake from complementary foods (kcal)	Test for linear trend[b]
Peru				
6-8.9 months	0.15	0.17	194	Both linear
9-11.9 months	0.38	0.30	290	Both linear
Honduras				
6-8.9 months	0.22	n/a[c]	192	Not linear
Ghana				
6-8.9 months	0.32	n/a	185	Linear
9-11.9 months	0.30		319	Linear
Bangladesh				
6-8.9 months	0.19	-0.10	118	Both NS[d]
9-11.9 months	0.32	0.03	128	CF linear/ Total kcal NS

[a] All correlations are significant ($p < 0.05$) with the exception of the correlations between dietary diversity and total energy intake (kcal) in Bangladesh.

[b] Tests for linearity were performed using SAS PROC REG by adding a quadratic term to the equation.

[c] n/a = data not available.

[d] NS = not significant.