Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries

Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities[1,2]

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ABSTRACT Dietary diversity (DD) is universally recognized as a key component of healthy diets. There is still, however, a lack of consensus on how to measure and operationalize DD. This article reviews published literature on DD, with a focus on the conceptual and operational issues related to its measurement in developing countries. Findings from studies of the association between DD and individual nutrient adequacy, child growth and/or household socioeconomic factors are summarized. DD is usually measured using a simple count of foods or food groups over a given reference period, but a number of different groupings, classification systems and reference periods have been used. This limits comparability and generalizability of findings. The few studies that have validated DD against nutrient adequacy in developing countries confirm the well-documented positive association observed in developed countries. A consistent positive association between dietary diversity and child growth is also found in a number of countries. Evidence from a multicountry analysis suggests that household-level DD diversity is strongly associated with household per capita income and energy availability, suggesting that DD could be a useful indicator of food security. The nutritional contribution of animal foods to nutrient adequacy is indisputable, but the independent role of animal foods relative to overall dietary quality for child growth and nutrition remains poorly understood. DD is clearly a promising measurement tool, but additional research is required to improve and harmonize measurement approaches and indicators. Validation studies are also needed to test the usefulness of DD indicators for various purposes and in different contexts. J. Nutr. 133: 3911S–3926S, 2003.

KEY WORDS: • *dietary diversity* • *dietary quality* • *developing countries* • *food security* • *indicators*

Dietary diversity (DD)[4] has long been recognized by nutritionists as a key element of high quality diets. Increasing the variety of foods across and within food groups is recommended in most dietary guidelines, in the U.S. (1) as well as internationally (2), because it is thought to ensure adequate intake of essential nutrients and to promote good health. Additionally, with the current recognition that dietary factors are associated with increased risks of chronic diseases, dietary recommendations promote increased dietary diversity along with reducing intake of selected nutrients such as fat, refined sugars and salt.

Lack of dietary diversity is a particularly severe problem among poor populations from the developing world because their diets are predominantly based on starchy staples and often include little or no animal products and few fresh fruits and vegetables. These plant-based diets tend to be low in a number of micronutrients, and the micronutrients they contain are often in a form that is not easily absorbed. Although other aspects of dietary quality such as high intakes of fat, salt and refined sugar have not typically been a concern for developing countries, recent shifts in global dietary and activity patterns resulting from increases in income and urbanization are making these problems increasingly relevant for countries in transition as well (2,3).

Despite the well-recognized importance of dietary diversity, there is still a lack of consensus about what dietary diversity represents. There is also a lack of uniformity in methods to measure dietary diversity and in approaches to develop and validate indicators. Experience from developed countries in measuring dietary diversity in the context of assessing overall dietary quality abounds, but measurement approaches, indicators and validation methods differ widely between

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[4] Abbreviations used: ASF, animal source food; DD, dietary diversity; DDS, dietary diversity score; DS, diversity score; DHS, Demographic and Health Survey; DQI, Dietary Quality Index; FVS, food variety score; HAZ, height-for-age Z-scores; HH, household; MAR, mean adequacy ratio; MDAT, Mozambique Diet Assessment Tool; MUAC, mid-upper arm circumference; NAR, nutrient adequacy ratio; NQS, nutritional quality score; RDA, recommended dietary allowance; TS, triceps skinfold; WAZ, weight-for-age Z-scores; WHZ, weight-for-height Z-scores.

studies. Experience from the developing world is scant, and again differences in methodological and analytical approaches affect the comparability and generalizability of findings.

This article focuses on the issue of dietary diversity in developing countries and addresses the following questions: *1*) How is dietary diversity usually conceptualized, operationalized and measured? *2*) What is the experience with the validation of dietary diversity against nutrient intake and adequacy? *3*) Is dietary diversity associated with child nutritional status and growth? *4*) Is there evidence of an association between dietary diversity and household socioeconomic factors and food security? *5*) What is the contribution of animal source foods (ASF) to dietary diversity and child nutritional status? *6*) What are key measurement issues that need to be addressed in the future to better operationalize and understand dietary diversity?

How is dietary diversity conceptualized, operationalized and measured?

Definitions. Before discussing operational and measurement issues related to dietary diversity and dietary quality, we provide definitions of the following terms: dietary diversity, dietary variety, dietary quality and nutrient adequacy.

Dietary Diversity is defined as the number of different foods or food groups consumed over a given reference period.

Dietary Variety, a term often used in the literature, is considered here to be synonymous with dietary diversity.

Dietary Quality: We found no official definition of dietary quality in the literature reviewed. Definitions vary widely, but historically, dietary quality has been used to refer to nutrient adequacy. Adequacy, in turn, refers to a diet that meets requirements for energy and all essential nutrients. The growing concern in developed countries as well as in countries in transition (or soon to be in transition) regarding overnutrition and excess intake of certain nutrients and foods has led to a global shift in the definition of dietary quality to include both concepts of nutrient deficiency and overnutrition (1,2,4). In the U.S., this has led to the incorporation of concepts of diversity, proportionality[5] and moderation[6] in the definition of dietary quality, following the principles underlying the current Food Guide Pyramid (5,6). These guidelines recommend that, in addition to including the recommended levels of energy and nutrients, a healthy, high quality diet should also contain a limited amount of fat, saturated fat, cholesterol, sodium and refined sugars, and many servings of fruits, vegetables and whole grain products.

Nutrient Adequacy: This term refers to the achievement of recommended intakes of energy and other essential nutrients. Note, however, that there is no standard list of nutrients for its assessment and researchers have used more or less exhaustive lists of nutrients when assessing nutrient adequacy. Measurement tools to assess nutrient adequacy are described in the following section.

Measuring dietary diversity. Dietary diversity is usually measured by summing the number of foods or food groups consumed over a reference period (7,8). The reference period usually ranges from 1 to 3 d, but 7 d is also often used and periods of up to 15 d have been reported (9).

[5] Proportionality refers to recommendations regarding the appropriate balance of certain key nutrients such as the proportion of energy from fat or carbohydrate, and the need to consume different numbers of servings of different food groups to ensure this balance.

[6] Moderation refers to the principle of limiting selected nutrients that are thought to be associated with excess risk of chronic diseases such as fat, sodium and refined sugars.

Although most dietary diversity measures consist of a simple count of foods or food groups, some scales developed in developed countries take into consideration the number of servings of different food groups in conformity with dietary guidelines. Examples of this latter approach include the "dietary score" developed by Guthrie and Scheer (10), which allocates equal weights to each of 4 food groups consumed in the previous 24 h: milk products and meat/meat alternatives receive 2 points for each of 2 recommended servings, and fruits/vegetables and bread/cereals receive 1 point for each of 4 recommended servings (total = 16 points). A modification of this approach developed by Kant (11,12) evaluates the presence of a desired number of servings from 5 food groups (2 servings each from the dairy, meat, fruit and vegetables groups and 4 servings from the grain group) over a period of 24 h. This score, called the "Serving Score," allocates a maximum of 4 points to each food group, for a total score of 20.

Finally, Krebs-Smith and colleagues used and compared three different types of dietary diversity measures (which they refer to as dietary variety) (7): *1*) an overall variety score (simple count of food items), *2*) a variety score among major food groups (6 food groups), *3a*) a variety score within major food groups, counting separate foods and *3b*) a variety score within major food groups, counting minor food groups. All dietary measures are based on a 3-d recall period.

In developing countries, single food or food group counts have been the most popular measurement approaches for dietary diversity, probably because of their simplicity. The number of servings based on dietary guidelines was not considered in any of the developing country studies reviewed. In China (13), Ethiopia (14) and Niger (15), researchers used food group counts, whereas in Kenya (16), Ghana and Malawi (17) they used the number of individual foods consumed. Studies in Mali (18) and Vietnam (19) used both single food counts [called food variety score (FVS)] and a food group count [called dietary diversity score (DDS)].

This brief overview highlights the fact that researchers have used a variety of dietary diversity measures based on different food and food group classification systems, different numbers of foods and food groups and varying reference period lengths. This has made comparisons between studies difficult to interpret. Specific measurement issues related to the development of dietary diversity tools are further discussed in the penultimate section of this review.

What is the experience with the validation of dietary diversity indicators against nutrient intake and adequacy in developing countries?

Validation studies of dietary diversity and dietary quality indicators abound in developed countries and research carried out up to 1996 has been summarized (20). This work is not reviewed here. Rather, this review focuses on studies that have validated dietary diversity against nutrient adequacy or intake in developing countries. **Table 1** presents a summary of the studies reviewed.

A study in Mali specifically validated dietary diversity against nutrient adequacy (18). The study used two types of diversity scores: one based on a simple count of number of foods (food variety score) and one based on 8 food groups (dietary diversity score). Both measures were computed from a quantitative dietary assessment using direct weighing for 2–3 d. Nutrient adequacy was measured using the nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR) method. The approach, first developed by Madden and Yoder (21), has since then been widely applied. The NAR is defined as the ratio of intake of a particular nutrient to its recommended dietary allowance (RDA). The MAR is the average of the NAR, computed by summing the NAR and dividing by the number of nutrients. NAR are usually truncated at 100% of the RDA to avoid high consumption levels of some nutrients compensating for low levels of others in the resulting MAR.[7]

The Mali study documents a significant association between nutrient adequacy (MAR) and both measures of dietary diversity: the correlation coefficients between nutrient adequacy and FVS and DDS were 0.33 and 0.39, respectively. Both indicators were also associated with a greater percentage of energy from fat and a higher density of vitamin C and vitamin A in the diet (expressed in terms of percentage of energy).

A useful contribution of this study is the comparison of the two diversity measures in a regression analysis, which shows that DDS (based on food groups) is a stronger determinant of nutrient adequacy than FVS (based on individual foods). Thus in this context, increasing the number of food groups has a greater impact on dietary quality than increasing the number of individual foods in the diet. This has important implications for future work in developing countries because the food group method has the advantage of being simpler and easier to use in survey field conditions.

An additional methodological contribution of the study is the sensitivity-specificity analysis carried out to identify best cutoff points for predicting nutrient adequacy for both diversity indicators. In this sample, the cutoff points of 6 for food group diversity and 23 for food variety provided the best sensitivity and specificity combinations to predict nutrient adequacy. Although these findings are highly context specific, they provide useful methodological guidance for similar studies to be conducted in other populations.

The study in Vietnam, which included adult women, used a similar methodology to validate the same diversity measures (FVS and DDS) against nutrient intake and nutrient density (19). FVS and DDS were derived from a 7-d food frequency questionnaire and included more than 120 foods and 12 food groups, respectively. The findings confirm a positive association between the two measures of diversity and intake of energy and a variety of nutrients. Women in the highest tertile of FVS—those who had consumed 21 or more different foods in 7 d—had a significantly higher intake of most nutrients studied compared to those from the lowest tertile—who had consumed 15 or less foods. Similarly, women with a food group diversity ≥8 (out of a maximum of 12 groups) had significantly higher nutrient adequacy ratios for energy, protein, niacin, vitamin C and zinc than women with lower food group diversity.[8] In both regions studied, the percentage of energy from fat and protein was greater among the higher diversity group, whereas the percentage of energy from carbohydrates was lower. The micronutrient density of the diet among the higher diversity group was greater, especially for vitamin C and A, and for riboflavin, but only in one of the two regions studied.

A recent publication looking at the adequacy of complementary foods among infants presents an interesting analysis of dietary diversity, using a sample of 9- to 11-mo-old Guatemalan children (22). Using the number of foods consumed (from direct weighing) in addition to breast milk over a 12-h period, the authors created dietary diversity tertiles. Their bivariate analyses show that children in the upper tertile of dietary diversity consumed higher amounts of energy, protein, fat and all the vitamins and minerals examined. There was, however, no difference in nutrient density (as percentage of energy) between diversity tertile groups for any of the nutrients studied, including both macro- and micronutrients. Thus, in this population, increased dietary diversity was associated with greater intake of energy and nutrients, but did not enhance the nutritional quality of the diet.

Two other studies that have looked at the association between diversity measures and nutrient intakes in Nigeria and Kenya, respectively, confirm the positive association between dietary diversity and intake of a variety of nutrients (15,16). Only one study, conducted in Ghana and Malawi, documents weak and even in some cases negative associations between diversity and certain nutrients (17). In this study, analysis of the association between diversity and nutrient intakes was not a primary objective and the findings are reported only briefly.

Finally, a rapid assessment tool developed in Mozambique and named the Mozambique Diet Assessment Tool (MDAT) was evaluated to determine whether it could accurately classify households into three categories of dietary quality (defined in this article as synonymous to dietary diversity) (23). The tool was applied at the household level and gathered information on all foods consumed by all household members in 1 d. Each food received a score of 1–4, based on its nutrient density, the bioavailability of the nutrients it contains and typical portion sizes (foods received a lower score if consumed in small amounts compared to foods of similar nutrient value consumed in larger amounts).[9] Total scores below 12 points were considered very low dietary "quality" (term used by authors), 12–19, average and 20 or higher, adequate. The association between this rapid assessment tool and a Dietary Quality Index (DQI) score[10] computed from data from a quantitative household-level 24-h recall was tested. Findings show that households classified by the rapid assessment tool as having acceptable diets had higher mean intakes of energy, protein and iron than those qualified as having poor or very poor diets. Findings for vitamin A intakes, however, were in the opposite direction.

This review of developing country research confirms the consistent pattern of a positive association between diversity measures and nutrient adequacy previously documented in developed countries (20). In most studies, greater dietary diversity was associated with an increase in energy, fat, protein, carbohydrates and a number of vitamins and minerals. The studies that have looked at the nutrient density of the diet, however, show inconsistent results: some find no increase in nutrient density with higher dietary diversity, whereas others find increased density, at least for some nutrients. Thus it appears that the specific nature of the association between dietary diversity and nutrient density varies between contexts and possibly between age groups. Because dietary diversity is usually associated with greater food intake and at least no reduction in nutrient density, greater diversity usually results in diets of higher absolute levels of energy and nutrients.

Future research should specifically test whether increased diversity is associated with both higher dietary quantity (energy) and quality (essential nutrients) in different contexts

[7] Note, however, that truncating the NAR at 100% does not completely eliminate the interpretation problems that may arise from situations where very low intake of some nutrients exists in combination with high (albeit lower than 100%) levels of intake of others.

[8] The authors also measured a variety of nutritional status indicators (anthropometry, hemoglobin, serum ferritin, retinol, retinol binding protein and C-reactive proteins) and report only weak associations between women's nutritional status and the dietary diversity measures.

[9] Examples of foods receiving different scores are: 1: vegetables, fruits, oils, sugars, some popular condiments; 2: cereals, tubers, bread, spaghetti, cookies, cakes; 3: beans, nuts, coconut; 4: meat, fish, shellfish, eggs, milk products.

[10] A composite measured was created based on household nutrient intakes of energy, protein, vitamin A, iron and seven other nutrients. Each of these five components received 2 points, for a maximum score of 10 points.

TABLE 1

Characteristics of the studies that looked at the association between dietary diversity and nutrient intake or adequacy in developing countries

Author	Country	Age group	DD approach (indicator)	Method and reference period	Descriptive DD findings	Type of validation/ association	Against which outcome?	Main findings
Hatløy (1998) (18)	Mali	<60 mo	*1*) FVS: single foods (*n* = 75) *2*) DDS: 8 food groups: staples, vegetables, fruits, meat, milk, fish, egg, green leaves	Direct weighing for 23 d; total consumed over 23 d	Mean FVS: 20.5 DDS: 5.8	Validation against NAR and MAR Calculated sensitivity and specificity of different cutoff points for FVS and DDS	NAR for energy, fat, protein, iron, vitamin A, thiamin; riboflavin, niacin, calcium folic acid. MAR (using 75% RDA)	*1*) Correlation FVS and DDS with NAR: significant for fat, vitamin C and vitamin A *2*) Correlation MAR with FVS = 0.33; with DDS = 0.39 *3*) DDS = stronger determinant of MAR than FVS (regression) *4*) Cutoff points: DDS = 6: Se 77%, Spe = 33% FVS=23: Se: 87%, Spe: 29%
Ogle et al. (2001) (19)	Vietnam	Adult women	1) FVS: all foods in 7 d (*n* > 120) 2) DDS: 12 food groups: cereals, starch, green leafy vegetables, other vegetables, fish/seafood, meat, eggs, nuts/ legumes, fruits/ juice, oil/fats, sauces, beverages/ biscuits/sweets	7-d food frequency	FVS: range: 6–39; mean = 18 and 20 (two regions); DDS: mean = 8 and 9 (range 5–11)	Validation against: *1*) intake of 13 nutrients; *2*) nutrient density; Created tertiles of FVS: low ≤15; high: ≥21	Measured: *1*) nutrient intake; *2*) nutrient intake (as percentage of energy)	*1*) FVS >21: significantly greater intake of most nutrients than FVS ≤15 *2*) FVS ≥21 also consumed higher variety of foods from most food groups *3*) DDS ≥8: significantly higher NAR of energy, protein, niacin, vitamin C, zinc *4*) High FVS group had higher micronutrient density, especially for vitamin A, C, riboflavin and calcium, but only in one of two regions studied

Brown et al. (2002) (22)	Guatemala	9–11 mo	Number of single foods	12-h weighed intake + 12-h recall	Mean number of foods = 10	Bivariate association between diversity tertiles and energy and nutrient intake and nutrient density (percentage of energy)	Energy, fat, protein, vitamin A, niacin, riboflavin, calcium, iron, zinc; percentage of energy from these nutrients and from animal source foods	*1*) Dietary diversity tertiles associated with: energy density, nonbreast milk energy, total energy, protein, fat, vitamin A, niacin, riboflavin, calcium, iron, zinc *2*) Dietary diversity NOT associated with higher density of any of these nutrients
Onyango et al. (1998) (16)	Kenya	12–36 mo	Number of single foods	Average daily intake from 3, 24-h recalls	Mean number of foods: 5 for BF children; 6 for non-BF children	Association between low ≤5 and high >5 diversity and percentage of RDA	RDA for energy, protein, vitamin A, C, thiamin, riboflavin, niacin, iron, calcium	Diversity >5 associated with greater intake of all nutrients
Tarini et al. (1999) (15)	Niger	24–48 mo	DS: 11 food groups over 3 d: cereals, green leafy vegetables, other vegetables, pulses/nuts, roots/tubers, fat, fruits, legumes, milk/eggs, meat, sugar	3-d modified weighed intake	DS: mean = 4.8, 5.3, 5.3 (three seasons)	Association between DS and NQS	NQS: energy, protein, vitamin A and zinc	Diversity ≤5 significantly lower NQS in all three seasons compared to DS ≥6
Ferguson et al. (1993) (17)	Ghana and Malawi	36–72 mo	*1*) Number of single foods (DD) *2*) 13 food groups: citrus, noncitrus fruits, kenkey, bread, banku (corn or cassava), fufu (cassava or plantain), fish, meat, bush meat, cassava, sweet potatoes, corn, groundnuts	Average over 3-d from direct weighing	Mean daily intake ranged from 6.4 to 7.1 in Malawi; from 7.1 to 8 in Ghana. Seasonal variations found	Correlation between DD and nutrient densities (results only briefly reported)	Nutrient densities (percentage of energy) for protein, fat, calcium, zinc, iron	*1*) No correlation with protein, fat, calcium density in either country *2*) Ghana: no correlation with zinc or iron density *3*) Malawi: negative correlation with iron and zinc density during food shortage season *4*) Malawi: correlation with energy intakes

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TABLE 1

Continued

Author	Country	Age group	DD approach (indicator)	Method and reference period	Descriptive DD findings	Type of validation/ association	Against which outcome?	Main findings
Rose et al. (2002) (23)	Mozambique	Adults	Mozambique Diet Assessment Tool Household level: Each food scored 1–4 based on nutrient density, availability, size of portion. E.g., vegetables, fruits, oils, sugars = 1; Cereals, bread, tubers = 2 Beans, nuts = 3 Meat, fish, milk, egg = 4	Qualitative recall of all foods consumed by all individuals at all meals in 1 d	Very low scores: (0–12: 11% of sample); average (12–19: 35%); adequate (≥ 20: 54%)	Association with DQI based on quantitative dietary assessment (24-h recall at HH level)	DQI: 10 points, based on nutrient adequacy for: energy (2 points), vitamin A (2 points), iron (2 points), protein (2 points), 7 other nutrients (2 points total)	1) MDAT associated with DQI for all nutrients except vitamin A 2) Changing cutoff points that define low, average and adequate scores improved performance of MDAT

DD, dietary diversity; DDS, dietary diversity score; DQI, Dietary Quality Index; DS, diversity score; FVS, food variety score; HH, household; MAR, mean adequacy ratio; MDAT, Mozambique Diet Assessment Tool; NAR, nutrient adequacy ratio; NQS, nutritional quality score; RDA, recommended dietary allowance.

and among different population groups. It is important for programmatic purposes to disentangling these mechanisms; programs need to know whether improved dietary quality (or nutrient adequacy) can be achieved with interventions that focus primarily on increasing food intake, or whether specific dietary diversification interventions are required to increase the likelihood that individuals and households meet their daily nutrient requirements. An additional question that needs to be addressed in future research is whether increased dietary diversity is associated with greater bioavailability of key micronutrients such as vitamin A, iron or zinc. This aspect was not examined in any of the studies reviewed and also has important programmatic implications.

Is dietary diversity associated with child nutritional status and growth?

A number of studies have looked at the association between some measure of dietary diversity and child nutrition outcomes, as seen in **Table 2**. Our recent analysis of data from the Ethiopia 2000 Demographic and Health Survey (DHS) (14,24) showed a strong and statistically significant association between food-group diversity measures based either on a 24-h or a 7-d recall and children's height-for-age Z-scores (HAZ) (14). **Figure 1** shows the adjusted mean HAZ of 12- to 36-mo-old children by the 7-d food group dietary diversity score. A positive, and generally linear, trend in mean HAZ is observed as food group diversity in the previous 7-d increases. A difference as large as 1.6 Z-scores is observed between children who consumed 1 food group in the previous 7 d compared to those who consumed 8 food groups. Note that the mean HAZ values presented here are adjusted by multivariate analysis for a variety of child, maternal and household socioeconomic factors, thereby reducing the possibility that this association is due to other potentially confounding influences.[11] When tertiles of dietary diversity are used, the difference in adjusted mean HAZ between children from the lowest diversity tertile compared to the highest tertile is 0.65 Z-scores. Similar findings are obtained when food group diversity in the previous 24 h is used.

Brown and collaborators, in their bivariate analyses, using a sample of 9- to 11-mo-old Guatemala infants, show no evidence of an association between dietary diversity and nutritional status (height-for-age and weight-for-height) (22).

By contrast, studies in Mali and Kenya document strong associations between dietary diversity and children's nutritional status (25,16). In urban areas of Mali, lower food variety or dietary diversity scores were associated with twice the risk of being stunted or underweight, controlling for socioeconomic factors.[12] No association between diversity and growth was found in rural areas, however. In Kenya, diversity measured by the number of individual foods consumed in 24 h (average of 3, 24-h recalls) was significantly associated with five nutritional status indicators [HAZ, weight-for-age Z-scores (WAZ), weight-for-height Z-scores (WHZ), triceps skinfold and mid-upper arm circumference] among 12- to 36-mo-old children (16).

An interesting finding of this study is that diversity >5 was more important for growth among children who were no longer

[11] The multivariate models controlled for: child age and gender, maternal age, height, body mass index, education, parity, attendance at prenatal visits, partner's education, household socioeconomic factors (assets, quality of housing, availability of services), number of preschool children and area of residence.

[12] The socioeconomic indicator in this study was based on a series of household assets. Many of the assets, however, were agricultural tools and were not relevant for urban areas. Despite this, the authors did not create a separate socioeconomic index for urban and rural areas.

breastfed compared to those who were still breastfed at this age. Among the nonbreastfed group, the height-for-age of children with dietary diversity >5 was 0.9 Z-scores higher than the HAZ of children with lower dietary diversity scores. The size of the difference between diversity groups among children who were still breastfed was only 0.2 Z-scores. This finding highlights the importance of diversity in complementary foods, especially among children who are no longer breastfed and therefore are entirely dependent on complementary foods for their nutrient intakes.

The importance of animal source foods as one component of dietary diversity is highlighted in studies in Mexico and Peru (26,27). In Peru, animal source foods were not significantly associated with length at 15 mo as a main effect, but significantly interacted with overall diversity and breastfeeding in multivariate models.[13] Animal foods were significantly associated with length at 15 mo only among children who had low overall dietary diversity (measured as total number of foods consumed at least more than twice a wk). The interaction with breastfeeding, on the other hand, showed that breastfeeding was positively associated with length only among children who had low intakes of animal products. This finding is similar to the one documented previously in Kenya and highlights the importance of dietary diversity (and possibly animal source foods in particular) among children who are not breastfed—or conversely the importance of continued breastfeeding for children who do not receive high quality diets during their 2nd y of life.

Again, despite the variety in measurement approaches and in environmental conditions, the results are highly consistent in showing a positive association between dietary diversity and growth in young children. One of the main weaknesses of most studies, however, is the lack of appropriate control for socioeconomic factors. It may be that the association between diversity and growth is largely confounded by socioeconomic factors because, as will be demonstrated in the next section, dietary diversity is also found to be strongly associated with household socioeconomic characteristics. Thus, it may be that dietary diversity is a good proxy for socioeconomic status and that children with higher dietary diversity are also children from wealthier households whose better growth is due to a combination of favoring conditions including higher maternal education, household income or availability of health and sanitation services, to name only a few. It will be important in future studies to disentangle the specific role of dietary diversity relative to other socioeconomic factors as a determinant of children's growth. This will require applying suitable statistical methods to accurately measure and control for socioeconomic factors in analyses of the association between dietary diversity and child outcomes.

As discussed in the previous section, an additional limitation of the research on the association between dietary diversity and growth is the lack of clarity about whether dietary diversity reflects energy intake (i.e., quantity of food) or dietary quality (i.e., nutrient density), or a combination of both. Evidence seems to suggest that energy intake tends to increase with greater dietary diversity, whereas nutrient density either remains constant (in which case intake of nutrients increases proportionally) or increases, resulting in diets of enhanced quality. This question should be explored in future research exploring the association between dietary diversity, nutrient adequacy and growth.

[13] Note that the multivariate models used did not include any indicators of socioeconomic status or maternal education. They controlled for child-level characteristics such as weight-for-length, diarrhea, breastfeeding and complementary feeding practices.

Is there evidence of an association between dietary diversity and household socioeconomic factors and food security?

Few studies have specifically addressed the association between dietary diversity and household socioeconomic characteristics and/or food security. Intuitively, however, it seems plausible that people would tend to diversify their diet as their income increases, largely because greater variety makes diets generally more palatable and more pleasant. Two recent studies have specifically looked at the linkages between household dietary diversity and socioeconomic status and food security, and their findings are summarized below (see **Table 3** for details about these studies).

Hoddinott and Yohannes, in their multicountry analysis of data from 10 countries[14] (28) tested whether household dietary diversity was associated with household per capita consumption (a proxy for household income) and energy availability (a proxy for food security). With two of the data sets for which information was available, the authors also tested whether household dietary diversity was associated with individual food intake. In this study, dietary diversity was measured as the sum of individual foods consumed in the previous 7 d. The authors also tested the findings with a food group dietary diversity indicator, which included 12 food groups (using the food groups from the FAO food balance sheets). Household per capita consumption was measured by a consumption/expenditure instrument, which estimates the value of consumption of food and nonfood goods during the previous 7 d. Household energy consumption was derived from the information on food consumption/expenditures in the same interval. The individual dietary intake was measured by a quantitative 24-h recall.

The authors use multivariate analyses and derive elasticities—i.e., the percentage increase observed in the outcome as dietary diversity increases by a fixed percentage. Their results show that a 1% increase in dietary diversity is associated with an average 1% increase in per capita consumption/expenditure and a 0.7% increase in total per capita energy availability. When separating energy from staples and nonstaples, the authors show that a 1% increase in household dietary diversity is associated with a 0.5% increase in household energy availability from staples and a 1.4% increase in energy availability from nonstaples. This finding indicates that as households diversify their diet, they tend to increase their consumption of prestigious, nonstaple foods rather than increasing variety within the category of staple foods. The authors report that the associations described above were found both in urban and rural areas, across seasons, and were not affected by the analytical approach used (multivariate analysis or correlation coefficients). The association between household diversity and individual intakes was considerably weaker but did indicate a trend.

The main objective of this study was to assess whether household dietary diversity could be used as an indicator of household food security (defined as adequate household energy availability). Based on the consistent associations found between dietary diversity and the various indicators of household food consumption and food availability used, the authors conclude that dietary diversity holds promise as a means of measuring food security, especially where resources for such measurement are limited.

Using data from Mali, Hatløy and colleagues also tested the association between dietary diversity and socioeconomic status

[14] The countries included in the analysis are: India, the Philippines, Mozambique, Mexico, Bangladesh, Egypt, Mali, Malawi, Ghana and Kenya.

TABLE 2

Characteristics of studies that looked at the association between dietary diversity and child nutritional status and growth in developing countries

Author	Country	Age group	Dietary diversity approach: (indicator)	Method and reference period	Descriptive DD finding	Type of validation/ association	Against which outcome?	Main findings
Arimond and Ruel (2002) (14)	Ethiopia DHS data	12–36 mo	*1)* 24-h food group diversity (8 groups): grains, roots/tubers, milk, vitamin A–fruits/ vegetables, other fruits and vegetables, meat/poultry/fish/ cheese/eggs/yogurt, legumes, fats/oils *2)* 7-d food group diversity: (same as above except grains combined with roots/ tubers (*n* = 7 groups)	24-h food group recall; 7-d food group recall	Mean 24-h diversity: 2.25 Mean 7-d diversity: 2.86	Association with HAZ (controlling for SES) Created tertiles of 24-h diversity and 7-d diversity	HAZ	*1)* Both 24-h and 7-d food group diversity strongly associated with HAZ, controlling for child, maternal and household socioeconomic factors *2)* Differences in adjusted mean HAZ between lowest and highest tertile of 24-h diversity: 0.65 Z-scores 7-d diversity: 0.67 Z-scores
Brown et al. (2002) (22)	Guatemala	9–11 mo	Number of single foods	12-h weighed intake + 12-h recall	Mean number of foods = 10	Bivariate association between diversity tertiles and nutritional status	Child nutritional status: HAZ and WHZ	No significant association between dietary diversity tertiles and HAZ and WHZ
Hatløy et al. (2000) (25)	Mali	6–59 mo	Household level: *1)* FVS *2)* DDS [same as above (18)]	HH-level 24-h food frequency (104 food items)	FVS: mean = 19.6 (urban), = 14.3 (rural) DDS: mean = 6.7 (urban), = 6.1 (rural)	Association with child nutritional status (controlling for SES)	Stunting, underweight wasted	*1)* In urban areas: lower FVS or DDS has twice the risk of stunted or underweight; *2)* In rural areas: no association (controlling for SES)
Tarini et al. (1999) (15)	Niger	24–48 mo	DS: 11 food groups over 3 d [same as above (15)]	3-d modified weighed intake	DS: mean = 4.8, 5.3, 5.3 (three seasons)	Association between DS and child nutritional status	Child HAZ, WAZ, WHZ	Association DS and nutritional status not significant (low correlations, significant only for WHZ in one round)
Onyango et al. (1998) (16)	Kenya	12–36 mo	Number of single foods	Average daily intake from 3, 24-h recalls	Mean number of foods: 5 (BF children); 6 (non-BF children)	Association with child nutritional status (multivariate analysis, but no control for SES)	Child HAZ, WAZ, WHZ, TS, MUAC	*1)* Diversity associated with HAZ, WAZ, WHZ, TS and MUAC; *2)* Diversity >5 more important for HAZ among non-BF children (difference between diversity groups: 0.9 HAZ among non-BF, vs. 0.2 among BF

Marquis et al. (1997) (27)	Peru	12–15 mo	*1*) 27 foods and beverages consumed more than twice/wk *2*) 5 animal food groups: cow milk, meat, organ meats, eggs, fish	Average of 3, 1-mo food-frequency questionnaire	Mean number of foods: 14.8 Mean number of animal foods: 3.6	Association with length at 15 mo (multivariate analysis, but no control for SES)	Length at 15 mo	*1*) Association between number of animal foods and length not significant as main effect *2*) Interactions: *a*) animal foods associated with length in children with low overall diversity; *b*) BF associated with length in children with low intakes of animal foods
Taren and Chen (1993) (13)	China	12–47 mo	Food group scale (0–7): rice, egg, vegetables, fruits, soybeans, meat, other	Recall of usual intake at 12 mo	Mean number of food groups: 4.8	Bivariate association with nutritional status	Child HAZ, WAZ, WHZ	Significant difference of 0.20 HAZ between children who consumed <3 groups and rest of sample
Allen et al. (1991) (26)	Mexico	18–30 mo	8 food groups: 5 plant groups: tortillas, legumes, vegetables, fruits, other 3 animal groups: dairy, eggs, meat	Mean daily intake from 2-d quantitative recall data each mo for at least 8 mo	88% of energy intake from plant foods; 12% from animal foods	Correlation between percentage of energy from different food groups and nutritional status	Child nutritional status (HAZ, WAZ, WHZ) at 30 mo	*1*) Positive correlation between percentage of energy from animal foods and HAZ *2*) Positive correlation between percentage of energy from dairy foods and HAZ *3*) Negative correlation between percentage of energy from plant foods (tortillas in particular) and HAZ

BF, breastfeeding; DD, dietary diversity; DDS, dietary diversity score; DS, diversity score; FVS, food variety score; HAZ, height-for-age Z-scores; HH, household; MAR, mean adequacy ratio; MUAC, mid-upper arm circumference; NAR, nutrient adequacy ratio; NQS, nutritional quality score; RDA, recommended dietary allowance; SES, socioeconomic status; TS, triceps skinfold; WAZ, weight-for-age Z-scores; WHZ, weight-for-height Z-scores.

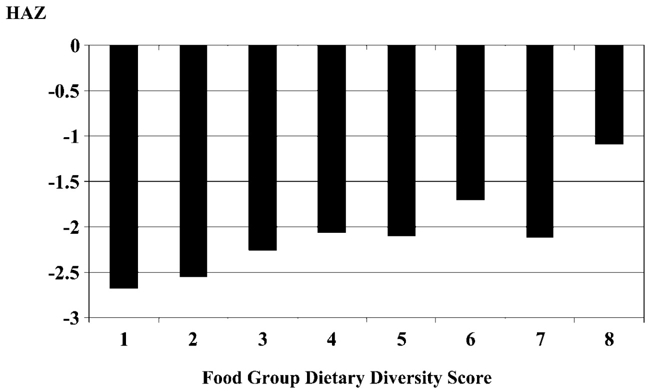

FIGURE 1 Mean adjusted height-for-age Z-scores by dietary diversity score in previous 7 d (children 12–36 mo of age: Ethiopia DHS 2000). Means were adjusted by multivariate analysis for child age and gender, maternal age, height, body mass index, education, parity, attendance at prenatal visits, partner's education, household socioeconomic factors (assets, quality of housing, availability of services), number of preschool children and area of residence. The linear trend was statistically significant at $p < 0.05$. The following food groups were used: foods made from grains, roots or tubers; milk other than breast milk; vitamin A–rich fruits and vegetables; other fruits and vegetables and juices; meat, poultry, fish, cheese, eggs, yogurt; legumes; food prepared with fat, oil or butter.

(25). They used two household measures of dietary diversity: the food variety score (number of foods consumed in the previous 24 h) and the dietary diversity score (number of food groups). Socioeconomic status was measured by summing up assets from a list of 14 household items. Tertiles of socioeconomic status were then created, where the low socioeconomic group had 0–3 assets, the middle group had 4–6 and the higher group had 7–10 assets. None of the households owned more than 10 of the 14 assets measured. The results show that dietary diversity increases with socioeconomic status both in urban and in rural areas, and irrespective of the diversity indicator used (FVS or DDS). A large difference was found in diversity between urban and rural households, where urban households had a consistently higher dietary diversity than rural households. Even the lowest socioeconomic group in urban areas had a higher dietary diversity than the highest socioeconomic group in rural areas.

The association between dietary diversity and socioeconomic factors is also suggested in a few other studies. In the Southern Andes, dietary diversity was found to be higher in urban compared to rural areas (29). Within urban areas, poorer households also consumed less diverse diets compared to wealthier households, and the differences were mainly due to their significantly lower intake of meals containing meat, dairy products and vegetables. Ferguson and colleagues also make reference to differences in dietary diversity between households from different socioeconomic status groups among preschool Ghanaian and Malawian children (17).

The strong association between dietary diversity and household socioeconomic characteristics documented here confirms the need to control for socioeconomic factors when assessing the relationship between dietary diversity and child nutrition and health outcomes. Failure to do so could lead to gross overestimations of the magnitude of this association and of the real potential of dietary diversification interventions to improve child nutrition and growth.

On the other hand, the multicountry analysis, which demonstrated the potential usefulness of household dietary diversity as an indicator of food security, has important programmatic implications because diversity is so much easier and cheaper to use than traditional indicators of food security, which usually involve the collection of complex quantitative information.

What is the contribution of animal source foods to dietary diversity and child nutritional status?

Contribution of animal source foods to dietary diversity. The importance of animal source foods for macro- and micro-nutrient intakes in developing countries is addressed in this conference by Murphy and Allen (30) and the functional importance of micronutrients for human growth and cognitive function is discussed by Rivera (31) and Black (32), respectively. This article questions what role animal source foods play in increasing dietary diversity and quality.

The specific contribution of animal source foods to dietary diversity depends to a large extent on the definition of dietary diversity. For instance, if dietary diversity is defined as the number of food groups consumed, animal source foods may all be combined together and therefore contribute only 1 point to the dietary diversity score. Most of the studies included in this review, however, separate the various sources of animal foods into two or more categories. Many studies separate dairy products from fish/meat and eggs, whereas others separate meat from fish, and yet others keep eggs in a separate category. These measurement issues will be discussed further in the penultimate section of this article, but it is important to recognize that they have important implications for the definition of dietary diversity and its association with various outcomes. For example, in the study conducted in Mali (18), the dietary diversity score was composed of 8 food groups, half of which were animal product groups (eggs, meat, milk and fish were all treated as separate categories). In Vietnam, however, animal products contributed only 3 of the 12 food groups (fish/seafood, meat and eggs) and thus, could account for no more than 25% of the total food group diversity score.

The other methodological aspect, which determines the relative contribution of animal source foods to dietary diversity is whether the diversity indicator is based on individual foods or food groups. To our knowledge, the only study in developing countries that specifically tested whether diversity between food groups was a better predictor of nutrient adequacy than diversity within food groups is the study in Mali (18). This study, which allocated 4 out of 8 points to animal source foods, showed that food group diversity was a stronger determinant of average nutrient adequacy (measured by the mean adequacy ratio) than the food variety score based on the number of individual foods consumed. It may be that this finding is strongly influenced by the selection of food groups, which in this case focused heavily on animal foods. This is an interesting finding, however, and additional work should be done to compare food group diversity scores based on various combinations of food groups to determine which ones best predict nutrient adequacy.

Only one study to our knowledge examined the association between intake of animal source foods and dietary diversity (22). Guatemalan infants in the middle and higher tertiles of animal source food intake, who received on average 15 and 40% of their energy from ASF, respectively, had significantly greater dietary diversity compared to infants in the lowest tertile of ASF intake (who received only 2% of their energy from ASF). There was, however, no difference in diversity between the two higher tertiles of ASF consumption, despite the fact that the contribution of ASF to energy intake among the higher tertile was more than double (40%) that of the

TABLE 3

Characteristics of studies that looked at the association between household-level dietary diversity and food security and socioeconomic factors in developing countries

Author	Country	Age group	Dietary diversity approach (indicator)	Reference period	Descriptive dietary diversity findings	Type of validation or association study	Against which outcome?	Main findings
Hoddinott and Yohannes (2002) (28)	10 countries	Adults	Household level diversity measures: *1*) Food diversity (single foods) *2*) Food group diversity 12 groups: Cereals, roots/ tubers, pulses/ legumes, dairy, eggs, meat and offal, fish and seafood, oils/fats, sugar/honey, fruits, vegetables, other foods	7 d for consumption and calorie availability; 24 h for individual energy intake	Wide range of food diversity scores between countries (from 8 in Mali to 48 in India)	Association with *1*) HH consumption, *2*) energy availability and *3*) individual food access (energy intake)	*1*) HH total consumption (proxy for income) *2*) HH energy availability (derived from food consumption *3*) Individual intake of food from 24-h recall	*1*) 1% increase in dietary diversity predicts an increase of: −0.65–1.1% for HH consumption −0.37–0.73% for calorie availability −0.31–0.76% for calorie availability from staples −1.15–1.57 for calorie availability from nonstaples *2*) Effects found in urban and rural areas, with both indicators, across seasons *3*) Association with individual intake of food is weaker
Hatløy et al. (2000) (25)	Mali	6–59 mo	*1*) Household level FVS and *2*) DDS [see above (33)]	HH-level 24-h food frequency (104 food items)	FVS: mean = 19.6 (urban), = 14.3 (rural) DDS: mean = 6.7 (urban), = 6.1 (rural)	Association with SES score	SES score based on assets (largely agriculture related; same approach used for urban and rural areas)	*1*) Association with SES significant both in urban and rural areas *2*) Differences in DDS between high/low SES = due to differences in some food groups: Milk (in both urban and rural areas); meat and fruits in urban areas; pulses and nuts in rural areas 3) No difference between SES groups either in urban or rural areas in staples, vegetables, oil/ sugar, fish, leaves/gathered foods, eggs

DDS, dietary diversity score; FVS, food variety score; HH, household; SES, socioeconomic status.

TABLE 4

Percentage of 12- to 36-mo-old Ethiopian children who consumed different food groups in the past 24 h, by category of food group diversity[1,2]

	Food group diversity: number of food groups consumed yesterday[3]							
Percentage of children with diversity score	1 14%	2 28%	3 26%	4 15%	5 8%	6 4%	7 2%	8 0.2%
Food groups								
Grains	73	93	93	94	98	98	100	100
Legumes	0.5	44	55	70	73	72	72	100
Roots and tubers	6.5	10	19	32	46	67	86	100
Dairy products	17	29	30	46	54	66	82	100
Vitamin A–rich fruits and vegetables	1.4	6	14	22	37	60	88	100
Other fruits/vegetables	1	3	9	25	48	73	90	100
Meat/poultry/fish	0.7	5	18	28	49	62	80	100
Foods cooked with fat/oil	0.7	10	62	82	94	97	100	100

1 Data from the Ethiopia Demographic and Health Survey (DHS), 2000 (24). Sample size = 3,109.
2 Underlined cells highlight large changes in intake of specific food groups as diversity increases by 1 point.
3 The mean and standard deviation for the food group diversity score was 2.85 (1.49) out of a maximum score of 8.

middle tertile group (15%). Infants in the upper tertile of ASF intake also had a greater intake of energy and nutrients, as well as a higher nutrient density for fat, vitamin A, niacin, riboflavin and calcium than infants in the lower and middle tertiles. Thus diets with a greater percentage of energy from ASF in this population were clearly associated with greater dietary diversity, which in turn was associated with greater energy intake and nutrient density for a number of nutrients.

Association between animal source foods and child nutritional status. The two studies (26,27) that specifically tested and confirmed the association between intake of animal products, as a component of dietary diversity, and children's growth were reviewed previously and summarized in Table 2. Research done by Brown and collaborators (22) in Guatemalan infants also showed that increased intake of animal source foods (as a percentage of energy) was associated with better height-for-age Z-scores: infants in the upper tertile of ASF were 0.51 Z-scores taller than infants in the lower ASF tertile. The analysis, however, did not control for any potentially confounding factors such as household socioeconomic status or maternal education.

Indirect evidence of the importance of animal products for growth has also been suggested in a few studies that documented that the better nutritional status of children in urban areas is paralleled by higher intakes of animal products (29,33,34). Although far from establishing a causal relationship, these studies suggest that at least part of the explanation for the better nutritional status of children in urban areas may be related to their greater dietary diversity and, in particular, their higher intake of animal source foods.

To explore some of these issues, we used two recent data sets from the Demographic and Health Surveys,[15] and looked at the contribution of different food groups to dietary diversity. The data sets used were the Ethiopia DHS 2000 (24) and the Peru DHS 2000 (35). For the Ethiopia data set, food group dietary diversity was measured using the 8 food groups available in the data set (14), and for Peru, using the 10 available food groups.

15 The DHS program is funded by the United States Agency for International Development (USAID) and coordinated by ORC/Macro International. Data collection is usually carried out in collaboration with country governments using population sampling frames, and all data sets are nationally representative. These data sets are in the public domain and are available from the DHS website (www.measuredhs.com).

Tables 4 and **5** present the distribution of food group diversity scores in Ethiopia and Peru, respectively, and the percentage of children who consume different food groups at each dietary diversity score.

The difference in the distribution of food group diversity scores between the two countries is striking. First, overall diversity is ~2 times larger in Peru (mean = 5.7) compared to Ethiopia (2.8). Similarly, in Ethiopia, only 29% of children had consumed 4 (half) or more food groups, compared to 90% having done so in Peru. These findings are not completely unexpected, considering the large differences between the two countries in levels of overall economic development and urbanization.

Another interesting aspect highlighted in Tables 4 and 5 is the difference between the two countries in the rate at which the prevalence of intake of different food groups increases with increasing dietary diversity. For example, in Ethiopia, grains and legumes are the two most commonly consumed food groups among households with low dietary diversity (scores of 1 or 2). Dairy product intake increases slowly, but gradually with dietary diversity, whereas meat products are consumed by a significant portion of children only at diversity scores of 5 or higher. By contrast, in Peru, more than half of the children with a dietary diversity score of 4 have consumed meat products in the previous day. Intakes of vitamin A–rich or other fruits or vegetables, however, remain low in Peru even at diversity scores of 4 or greater. Clearly, dietary diversity is much greater in Peru compared to Ethiopia, and the foods contributing to increased diversity also vary significantly between the two countries.

To determine the specific role of animal foods relative to overall dietary diversity for children's growth in Ethiopia, we carried out additional analyses of the Ethiopia DHS 2000 survey (24). We reported in the previous section that in this sample dietary diversity was strongly associated with child growth (HAZ) when controlling for a number of other potentially confounding influences. In the new models, we tested whether animal foods were associated with child growth, independently from dietary diversity, by including both variables in the model, along with the same child, maternal and household socioeconomic variables listed in footnote 11. The findings show that animal foods (fish/poultry/meat) were not associated with child height-for-age Z-scores in Ethiopia,

TABLE 5

Percentage of 12- to 36-mo-old Peruvian children who consumed different food groups in the past 24 h, by category of food group diversity[1,2]

	Food group diversity: number of food groups consumed yesterday[3]							
Percentage of children with diversity score	1 0.5%	2 2.2%	3 6.2%	4 11.7%	5 19.1%	6 25.4%	7 25.0%	8 9.5%
Food groups								
Grains	30	52	73	88	94	98	99	100
Legumes	0	6	16	24	31	37	48	100
Roots and tubers	9	59	70	81	83	90	97	100
Dairy products	13	6	15	25	43	69	89	100
Vitamin A–rich fruits and vegetables	13	5	16	22	36	46	54	100
Other fruits/vegetables	9	4	8	14	29	46	72	100
Meat/poultry/fish	26	35	37	54	68	87	97	100
Foods cooked with fat/oil	4	22	44	59	68	75	87	100

1 Data from the Peru Demographic and Health Survey (DHS) (35). Sample size = 4,460.
2 Underlined cells highlight large changes in intake of specific food groups as diversity increases by 1 point.
3 The mean and standard deviation of the food group diversity score was 5.7 (1.5) out of a maximum score of 8.

when overall food group dietary diversity was included in the model. Thus, animal foods did not appear to be associated with children's growth, above and beyond their contribution to dietary diversity. The same was true when similar analyses were done with dairy products rather than animal products, and irrespective of whether the 24-h or the 7-d diversity indicators were used. Interactions between animal products and dietary diversity were also tested and were not statistically significant.

This type of analysis is useful to understand the nature of the association between dietary diversity and child outcomes and to elucidate the specific role of animal foods in this association. We are currently carrying out this type of analyses with a number of recent DHS data sets.

In sum, the contribution of animal sources to dietary diversity is still not fully understood from an operational point of view, although as demonstrated by Murphy and Allen in this conference, the nutritional contribution of animal source foods to dietary quality is indisputable (30).

What are the key measurement issues that need to be addressed in the future to better operationalize dietary diversity?

A number of issues related to the measurement of dietary diversity have been raised throughout this review. These issues are summarized below and implications for research are discussed.

Food or food group diversity? The question of whether individual foods or food groups should be used to define dietary diversity has been addressed in a number of studies that compared both types of indicators. Studies in Mali (18) and Vietnam (19) compared a food variety score with a food group indicator and found that both indicators were significantly associated with nutrient adequacy. The study in Mali, however, demonstrated that food group diversity was a stronger predictor of dietary quality than the simple count of individual foods.

In a developed country context, Krebs-Smith and colleagues also compared three dietary diversity indicators with respect to their association with dietary quality and found that variety between the 5 major food groups studied[16] explained as much variation in the mean adequacy ratio as did variety within those groups (7). They conclude that, for simplicity, dietary diversity might best be assessed by measuring intake of foods from each of the major groups. By contrast, a study looking at the influence of food and food group diversity on breast cancer risk in Italy found that variety within the vegetable group had a beneficial effect on reducing cancer risk beyond the advantage of high vegetable intake per se (36).

Thus, for measurement purposes, it may be that food group diversity is the method of choice because of its simplicity. For education purposes, however, promotion of variety both between and within food groups should continue to be emphasized.

Which food groups? When food group diversity is selected as the measure of dietary diversity, the next key question is to determine the ideal level of aggregation, and the appropriate list of food groups to use. The selection of food groups should be driven by the specific purposes for which the dietary diversity indicator is to be used. For example, if the diversity indicator is expected to reflect nutrient adequacy, the food groups should be selected based on their specific nutrient content, or their unique contribution to nutrient adequacy. By contrast, if diversity is to be used as an indicator of household food security or socioeconomic conditions, foods should be aggregated based on their relative economic value.

Even with these broad guidelines, there are still many unanswered questions regarding the classification of foods into meaningful groups. One of these, which was discussed previously in this report, relates to the level of aggregation of groups with similar nutrient content, or how nutritionally homogenous the different food groups should be. For example, should fish, poultry and meat be treated as separate categories? Should dairy products and eggs be combined? What is the appropriate ratio of animal food groups relative to the total number of groups? There are clearly no definite answers to these questions. Although standardization of food group categories may be desirable for comparison purposes, it is unlikely to be useful for most other purposes and in most contexts. Because dietary patterns vary substantially between cultures, the selection of food groupings and of specific foods to include within groups should be defined locally. These food groupings should be based on the dietary patterns of the specific age groups of interest and the contribution of particular foods to nutrient adequacy in a particular context. This will depend

16 The 5 food groups are: dairy, meat, grains, fruits and vegetables.

on the types of foods available, their nutrient content, the frequency of intake and the amounts usually consumed. Methodologies similar to those used to design context- and population-specific food frequency questionnaires may be useful to develop these dietary diversity instruments.

Portion size. Another related question is whether portion size should be considered in dietary diversity measures, and more specifically, what is the minimum quantity of intake of specific foods that justifies including them. This issue has been addressed in the U.S. and in Europe and inclusion and exclusion criteria have been defined. For instance, the amount of milk in coffee or tea is usually not considered sufficiently high to count as intake of dairy products, and the slice of tomato in the hamburger is also usually not considered sufficient to contribute a portion of vegetable (7).

This issue was also addressed in Mozambique in the development of the Diet Assessment Tool, where foods consumed in small quantities contributed less points to the total score than foods of similar nutrient composition who were consumed in larger amounts (23).

Our experience in Ghana also showed that failure to take portion size into account could result in overestimates of intake of certain food groups. In Northern Ghana, for example, intake of fish among preschoolers when measured by a food group diversity indicator appeared high. Upon further investigation, however, it became clear that, although fish was consumed frequently, it was present in minute amounts as fish powder added to porridges. The same was true for dairy products in Accra, which were consumed frequently by young children, but again, in very small amounts in the form of condensed sweetened milk added to hot beverages. These examples highlight the need to take into consideration the concept of minimum amounts of specific foods when designing and using dietary diversity questionnaires. Prior knowledge of dietary patterns among selected population groups will be necessary to determine which foods are particularly susceptible to this type of problem.

Scoring system. Dietary diversity indicators are usually constructed by simply summing up number of foods or food groups, as seen in Tables 1 and 2. In developed countries, scoring systems sometimes include consideration of the number of portions of specific food groups in line with dietary guidelines. These types of indicators, however, are usually designed to reflect dietary quality, rather than diversity (5,10,37).

An alternative to the simple count of foods or food groups, proposed by Hoddinott, is to use a weighting system (38). For example, a weighted sum of the number of individual foods consumed can be computed, where the weights reflect the number of days the foods were consumed over a reference period (say, 1 wk). This approach could be used with the Demographic and Health Surveys data sets, which usually include a 7-d recall of the number of days the child consumed a variety of food groups. This approach, however, involves making decisions about the specific weights to be allocated to different frequencies of intake of the various food groups. In the absence of international recommendations on dietary diversity and on the number and types of food groups recommended for different age groups, these decisions remain arbitrary.

A weighting system was also used in Mozambique, but this time to score foods, rather than frequency of intake (23). As described previously, foods were scored based on their nutrient density and bioavailability as well as on their importance in the diet (i.e., foods of similar nutrient composition were scored lower if they were usually consumed in small amounts).

Cutoff values. What constitutes high or low diversity of foods or food groups? It is clear from this review that international cutoff points to define high and low diversity are likely to be meaningless. Cutoff points to define varying levels of diversity have to be defined in the context where they are used, taking into account local food systems and dietary patterns. As emphasized throughout this report, it is important to define in each context the set of foods and food groups that can contribute to improving dietary quality. In a similar fashion, cutoff values have to be defined locally based on this information.

The set of studies reviewed in Tables 1 and 2 show wide variations in mean food and food group diversity scores between countries (see sixth column from the left). Consequently, most studies have also rightly selected cutoff points based on the internal distribution of the diversity indicator within their sample, usually creating tertiles or quintiles. This is a suitable approach when looking at associations between diversity and health or growth outcomes. When trying to select cutoff points that best predict nutrient adequacy in a specific context, however, the sensitivity-specificity analysis used by Hatløy and colleagues (18) or receiver-operating characteristics (ROC) curves are recommended (39).

Recall period. There is no simple answer to the question regarding the optimal recall period to assess dietary diversity. As for all dietary assessment methods, this depends on the magnitude of day-to-day variability and recall error, and on whether the indicator is to be used at the individual or the population level.

An interesting analysis by Drewnowski and colleagues measured cumulative dietary variety (based on individual foods) in American adults over a period of 15 d (9). The individual curves show that, as expected, the number of different foods consumed increases with time and eventually plateaus at a point that defines a person's entire "food repertoire" over this period. Differences in individual diversity curves reflect variations in individual eating habits, between day diversity and overall dietary diversity. The authors note that the curves generally increased steeply in the first 3 d, suggesting that assessment of dietary diversity over 1 d may significantly underestimate true variability in intake. On the other hand, they note that most curves were relatively flat between d 10 and 15, which suggests that an accurate assessment of diversity may be obtained over a period of less than 2 wk.

The key message from these findings is that dietary diversity may be more accurately assessed at the individual level with a reference period of at least 3 d. In contexts where a 2-wk intake can be accurately assessed, this reference period is likely to provide even better estimates at the individual level. In most developing country contexts, however, a 7-d recall may be the longest reference period achievable from a practical point to minimize memory error.

Future validation studies of dietary diversity need to test different types of indicators, scoring systems, cutoff values and reference periods for the specific purposes for which the indicators are to be used. For example, diversity indicators aimed at reflecting household socioeconomic factors or food security will have to be constructed differently from those intended to reflect children's nutrient adequacy.

SUMMARY AND CONCLUSIONS

This review documents experience with the measurement of dietary diversity in developing countries. It emphasizes the need to pursue efforts to improve measurement approaches, to assess dietary diversity and to carry out validation studies to test the usefulness of diversity indicators for different purposes.

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The key findings of our review are summarized below and research recommendations are provided in italics.

- Most dietary diversity indicators use simple counts of foods or food groups, but a number of food or food group classification systems have been used as well as different reference periods, scoring systems and cutoff points to characterize low and high diversity. A number of measurement issues need to be addressed in the future to improve assessment of dietary diversity.

  Research should be carried out to validate and compare indicators based on alternative food and food group classification systems, scoring systems, reference periods and cutoff points. It would also be useful to continue to explore whether the indicators based on food groups (a simpler approach) perform as well as those based on single foods in predicting outcomes of interest.

- Dietary diversity has been extensively validated against dietary quality (usually measured as nutrient adequacy) in developed countries. The few validation studies in developing countries confirm previous findings from developed countries of a strong association between diversity and nutrient adequacy.

  Additional validation studies with existing data sets should be carried out to confirm these findings in a variety of contexts and population groups. These studies should also compare the performance of indicators constructed using different methodological approaches (as described in previous bullet).

- Dietary diversity has been consistently associated with child nutritional status and growth in a variety of studies in developing countries. Future research should try to elucidate the mechanisms responsible for this association—i.e., whether greater diversity is associated with intake of more food (quantity) or with a better quality diet, or even more likely a combination of both. More rigorous control of socioeconomic factors will also be necessary in future research to better understand the exact nature of the association between dietary diversity and child outcomes.

  Analyses of existing data should be done to continue to explore the association between dietary diversity indicators and dietary quantity versus quality. This can be done by looking at nutrients in relation to energy (e.g., as a percentage of energy) rather than focusing only on absolute levels of intake. Differences in the bioavailability of micronutrients such as vitamin A, iron and zinc also need to be controlled for in future validations of dietary diversity indicators.

  Research using suitable analytical methods should also be carried out to disentangle the mechanisms that underlie the association between dietary diversity and child growth. More specifically, this research should help determine whether the association between dietary diversity and child growth is independent of socioeconomic factors.

- Evidence from a 10-country analysis shows a strong association between household-level dietary diversity and per capita consumption and energy availability, suggesting that dietary diversity could be a useful indicator of food security (defined in terms of energy availability). A few additional studies also confirm the association between household dietary diversity and socioeconomic status in other contexts.

  Research should test the association between household dietary diversity and food security defined in terms of dietary quality—i.e., using adequacy of multiple nutrients as opposed to energy only, as in traditional food security measures.

  Additional research should also be conducted to relate household-level dietary diversity to individual-level dietary diversity and to examine intrahousehold processes that determine individual dietary adequacy and intake.

- The association between animal source foods and children's growth has been documented in some studies, either as main effects or in interaction with overall diversity or breastfeeding. In a study that controlled for socioeconomic factors, no association between animal foods and child growth was found, above and beyond the contribution of animal foods to dietary diversity.

  The effect of animal source foods on child growth, independent of dietary diversity, should be examined in future research. Moreover, validation studies should be carried out to test the performance of animal source food indicators in predicting nutrient adequacy, compared to indicators of dietary diversity.

In sum, dietary diversity is clearly a promising measurement tool, but considerable research is needed to continue to explore how to operationalize it and to determine the purposes for which it can be most useful. Research is needed to continue to develop valid and reliable indicators of dietary diversity, which accurately predict individual nutrient adequacy in a variety of population groups and settings. The potential of household-level dietary diversity indicators to accurately reflect household food security and overall socioeconomic status also needs to be confirmed through additional research. Appropriate analytical methods should also be used to disentangle the complex relationships observed between dietary diversity, household socioeconomic factors and child growth. It is particularly important for future programming efforts to understand whether dietary diversity has an effect on child growth, independent of socioeconomic factors. This will help program and policy makers understand what levels of reductions in childhood malnutrition they can achieve from poverty alleviation and dietary diversification interventions and whether they can expect a synergistic effect if they combine these two types of programs.

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