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IS DIETARY DIVERSITY AN INDICATOR OF FOOD SECURITY OR DIETARY QUALITY? A REVIEW OF MEASUREMENT ISSUES AND RESEARCH NEEDS

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ABSTRACT

Although dietary diversity is universally recognized as a key component of healthy diets, there is still a lack of consensus on how to measure and operationalize it. This paper focuses on the issues of dietary diversity in developing countries. It also draws upon experience from developed countries to address the following questions:

1. How is dietary diversity conceptualized, operationalized, and measured, and how does it relate operationally to dietary quality?
2. Is there an association between dietary diversity and nutrient adequacy in developing countries? Between dietary diversity and child growth?
3. What is the relationship between household-level dietary diversity and socioeconomic factors and food security?
4. What key measurement issues need to be addressed to better operationalize and understand dietary diversity?

Dietary diversity is usually measured using a simple count of foods or food groups over a given reference period, but a number of different groupings and classification systems have been used, and reference periods have ranged from 1 to 15 days. This makes comparisons between studies difficult to interpret. The few studies that have validated dietary diversity against nutrient adequacy in developing countries confirm the well-documented positive relationship observed in developed countries. A

consistent positive association between dietary diversity and child growth is also found in a number of countries. Finally, recent evidence from a multicountry analysis suggests that household-level dietary diversity is strongly associated with per capita consumption (a proxy for income) and energy availability, suggesting that dietary diversity could be a useful indicator of household food security (defined in relation to energy availability).

A number of measurement issues still need to be addressed to improve assessment of dietary diversity. These include the selection of foods and food groupings, the consideration of portion size and frequency of intake, and the selection of scoring systems, cutoff points, and reference periods that will ensure the validity and reliability of the indicator for the purpose for which it is used.

Dietary diversity is clearly a promising measurement tool, but additional research is needed in developing countries to validate and test alternative indicators for different purposes. First, 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. Second, the potential of *household-level* dietary diversity indicators to accurately reflect household food security and overall socioeconomic status needs to be confirmed. Specific indicators will need to be developed for each of these purposes, but both will need to address the various measurement issues identified in this review. Finally, rigorous analytical approaches should be employed 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 managers and policymakers 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 between the two approaches.

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1. Introduction

Dietary diversity 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 by most dietary guidelines, in the United States (U.S. Department of Agriculture Human Nutrition Information Service 1992) as well as internationally (WHO/FAO 1996), because it is thought to ensure adequate intake of essential nutrients and thus 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.

The rationale for emphasizing dietary diversity in developing countries stems mainly from a concern related to nutrient deficiency and the recognition of the importance of increasing food and food group variety to ensure nutrient adequacy. Lack of dietary diversity is a particularly severe problem among poor populations in 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 in 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 (Popkin 1994; WHO/FAO 1996).

In spite of the well-recognized importance of dietary diversity in both developed and developing countries, there is still a lack of consensus about what dietary diversity really is and what it reflects. 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. Experience from the developing world is scant, and again, differences in methodological and analytical approaches affect the comparability and generalizability of findings.

The present paper focuses on the issue of dietary diversity in developing countries, but also draws upon some of the experience in developed countries to address the following questions:

1. How is dietary diversity conceptualized, operationalized, and measured, and how does it relate conceptually to dietary quality?
2. What is the evidence regarding the association between dietary diversity and nutrient adequacy in developing countries? And between dietary diversity and child growth?
3. What is the evidence regarding household dietary diversity and socioeconomic factors and food security?

4. What are key measurement issues that need to be addressed to better operationalize and understand dietary diversity?

The following sections address each one of these questions, and the paper concludes with a short summary of main findings and implications for research.

2. How Have Dietary Diversity and Dietary Quality Been Conceptualized, Operationalized, and Measured?

Definitions

Before discussing operational and measurement issues related to dietary diversity and dietary quality, we first define *dietary diversity, dietary variety, dietary quality,* and *nutrient adequacy.*

Dietary diversity can be 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 as synonymous to dietary diversity.

Dietary quality appears to have no official definition in the literature reviewed. Definitions vary widely, as judged by the types of measurement tools used (see Section 2 for an overview of dietary quality measurement tools). Historically, a common perception has been that dietary quality reflects “nutrient adequacy.” Nutrient adequacy, in turn, refers to a diet that meets requirements for energy and all essential nutrients. The more recent 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 (WHO/FAO 1996; U.S. Department of Agriculture Human Nutrition Information Service 1992; Chinese Nutrition Society 1990). In the United States, this has led to the incorporation of concepts of diversity, proportionality,[1] and moderation[2] in the definition of dietary quality, following the principles underlying the current Food Guide Pyramid (Haines, Siega-Riz, and Popkin 1999; Welsh, Davis, and Shaw 1992). These guidelines recommend that, in addition to including the recommended levels of energy and nutrients, a healthy, high-quality diet limits the amount of fat, saturated fat, cholesterol, sodium, and refined sugars, and incorporates many servings of fruits, vegetables, and whole grain products.

Nutrient adequacy refers to the achievement of recommended intakes of energy and other essential nutrients. Measurement tools to assess nutrient adequacy are described in Section 2. Note, however, that there is no standard list of nutrients defining nutrient adequacy, and researchers have used more-or-less exhaustive lists of nutrients when assessing nutrient adequacy.

In conclusion, it is important to emphasize that although dietary diversity is often assumed to be a proxy for nutrient adequacy, it is not synonymous to dietary quality and

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

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

the two terms (diversity and quality) should not be used interchangeably. As noted by Krebs-Smith et al. (1987), confusion in use of these terms may stem from the many nutrition and health benefits that have been attributed to dietary diversity and that are related to the concept of dietary quality. For example, dietary diversity is often promoted to enhance the chances of achieving an adequate diet, lessen the risks of developing a deficiency or excess of any one nutrient, ensure an appropriate balance of micronutrients as well as energy from fat, and reduce the likelihood of exposure to excessive amounts of contaminants. Diversity, however, is but one component of overall dietary quality and may not, in itself, ensure achievement of all dietary goals.

The description of approaches to measure dietary diversity and overall dietary quality presented below will further elaborate on the different components of dietary quality and experience with their measurement.

Experience With Measurement of Dietary Diversity, Dietary Quality, and Nutrient Adequacy

Dietary Diversity

Dietary diversity is usually measured by summing the number of foods or food groups consumed over a reference period. The reference period usually ranges from one to three days, but seven days is also often used, and periods of up to 15 days have been reported (Drewnowski et al. 1997).

Developed Countries. Common measures of dietary diversity used in developed countries include measures based on a simple count of foods (Krebs-Smith et al. 1987) or food groups (Krebs-Smith et al. 1987; Löwik, Hulshof, and Brussaard 1999), while others 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 (1981), which allocates equal weights to each of four food groups consumed in the previous 24 hours: milk products and meat/meat alternatives receive two points for each of two recommended servings, and fruits/vegetables and bread/cereals receive one point for each of four recommended servings (total = 16 points). A modification of this approach developed by Kant et al. (1991, 1993) evaluates the presence of a desired number of servings from five food groups (two servings each from the dairy, meat, fruit, and vegetable groups and four servings from the grain group) over a period of 24 hours. This score, called the serving score, allocates a maximum of four points to each food group for a total score of 20. The authors also use a simple five-point scale called the food group score, which is a simple count of food groups consumed in one day (using the same five food groups).

Finally, Krebs-Smith et al. (1987) used and compared three different types of dietary diversity measures (which they refer to as dietary variety): (1) an overall variety score (simple count of food items), (2) a variety score among major food groups (six 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 three-day recall period.

Developing Countries. Single food or food group counts have been the most popular measurement approaches for dietary diversity in developing countries, 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 (Taren and Chen 1993), Ethiopia (Arimond and Ruel 2002), and Niger (Tarini, Bakari, and Delisle 1999), researchers used food group counts, while in studies in Kenya (Onyango, Koski, and Tucker 1998), and in Ghana and Malawi (Ferguson et al. 1993), they used the number of individual foods consumed. Studies in Mali (Hatloy, Torheim, and Oshaug 1998), and Viet Nam (Ogle, Hung, and Tuyet 2001) used both single food counts (called Food Variety Score [FVS]) and a food group count (called Dietary Diversity Score [DDS]).

Studies done at the household level also used dietary diversity indicators that included either individual foods or food groups (Hoddinott and Yohannes 2002; Hatloy et al. 2000). A study in Mozambique used a weighting system, which scored foods and food groups according to their nutrient density, the bioavailability of the nutrients they contain, and typical portion sizes (Rose et al. 2002). For example, foods that were usually consumed in small amounts (e.g., condensed milk) were given a lower score than foods with similar nutrient content that were consumed in larger amounts (e.g., fluid milk).

This brief overview shows that studies in both developed and developing countries have used a variety of food and food group classification systems, different numbers of foods and food groups, and varying reference period lengths. We will come back to some of these measurement issues in Section 6.

Dietary Quality and Nutrient Adequacy

Developed Countries. Measures of dietary quality range from simple indicators such as the percentage of energy from animal sources (Allen et al. 1991) to complex indices that combine both nutrient and food components (Patterson, Haines, and Popkin 1994; Kennedy et al. 1995; Haines, Siega-Riz, and Popkin 1999). An excellent review of indices of overall dietary quality is available in Kant (1996); only some examples are highlighted here.

As indicated earlier, dietary quality has traditionally been used to reflect nutrient adequacy. Thus, commonly used measures of dietary quality have been the "nutrient adequacy ratio" (NAR) and the "mean nutrient adequacy ratio" (MAR). The concept was first developed by Madden and Yoder (1972) and has since then been used both in developed and developing countries (Guthrie and Scheer 1981; Krebs-Smith et al. 1987; Hatloy, Torheim, and Oshaug 1998). The NAR is defined as the ratio of intake of a particular nutrient to its recommended dietary intake (RDA). The MAR is the average of the NARs, computed by summing the NARs and dividing by the number of nutrients. Each NAR is usually truncated at 100 percent of the RDAs to avoid high consumption levels of some nutrients compensating for low levels of others in the resulting MAR.[3]

A number of other nutrient-based measures of dietary quality are described in the review by Kant (1996). These include food and nutritional quality indices based on the

[3] Note that this approach, although useful, does not completely eliminate interpretation problems arising from situations where very low intake of some nutrients exists in combination with high (albeit lower than 100 percent) intake of others.

nutrient density of foods or diets, and other nutritional indices scores using a fixed cutoff value of the RDA (e.g., two-thirds) (Clark and Wakefield 1975, cited in Kant 1996).

The recent trend, however, which recognizes the importance of including both concepts of nutrient deficiency and overnutrition in the definition of dietary quality, has led to the development of new measurement tools. These new tools incorporate consideration of dietary guidelines regarding the proportion of energy from fat, the ratio of polyunsaturated to saturated fat, and intake of dietary fiber, cholesterol, and alcohol (Hulshof et al. 1992; Drewnowski et al. 1997; Patterson, Haines, and Popkin 1994; Löwik, Hulshof, and Brussaard 1999). The Diet Quality Index is one example of such a measurement approach, designed to assess conformity of the diet with U.S. dietary recommendations (Drewnowski et al. 1997). The five equally weighed items included in this index are (1) that the diet contains less than 30 percent of energy from fat; (2) less than 10 percent of energy from saturated fat; (3) less than 300 milligrams of cholesterol per day; (4) less than 2,400 milligrams of sodium per day; and (5) more than 50 percent of energy from carbohydrates. This index is a simplification of a previously developed 15-point Diet Quality Index (Patterson, Haines, and Popkin 1994). A similar approach, developed for the Netherlands, also incorporates current recommendations from the Dutch dietary guidelines for a healthy diet into a five-point scale (Löwik, Hulshof, and Brussaard 1999).

A recent effort in Europe and the United States to combine both nutrient requirements and food-based dietary guidelines has resulted in yet another generation of dietary quality measures. The approach incorporates nutrient needs and food components into one measure, and thus takes into consideration intake of specific nutrients and number of servings of different food groups. Examples of these dietary quality indices include the Healthy Eating Index (Kennedy et al. 1995), the Diet Quality Index Revised (Haines, Siega-Riz, and Popkin 1999), the Healthy Diet Indicator and the Mediterranean Diet Score (Haveman-Nies et al. 2001), and the Healthy Diet Indicator (Huijbregts et al. 1997). Some of these indices specifically include a measure of dietary diversity in addition to a number of other components (Kennedy et al. 1995; Haines, Siega-Riz, and Popkin 1999). The Diet Quality Index Revised (Haines, Siega-Riz, and Popkin 1999) also includes the concepts of proportionality and moderation described previously in this section.

Developing Countries. In developing countries, dietary quality has also often been equated to nutrient adequacy. Consequently, researchers have used the NAR and MAR to measure dietary quality (Hatloy, Torheim, and Oshaug 1998).

A 1996 WHO/FAO report recommended that developing countries also start implementing measures of dietary quality that capture both problems of nutrient deficiency and dietary excess and overnutrition (WHO/FAO 1996). This is in recognition of the accelerated pace at which the nutrition transition is taking place in developing countries as a result of rapid economic development and urbanization. The resulting so-called double burden, or the co-existence of under- and overnutrition in the same country—often in the same household—requires a shift in the conceptualization of dietary quality. Pioneer efforts in China to address this double burden are highlighted in the Dietary Guidelines for Chinese Residents. These guidelines specifically include concepts of nutrient adequacy, dietary diversity, and promotion of intake of fruits, vegetables, dairy products, and foods of animal origin, while also recommending moderation in consumption of selected nutrients and foods thought to be associated with increased chronic disease (Chinese Nutrition Society 1990).

A diet quality index (DQI) was also developed for China, following the same general strategy used to develop the U.S. Diet Quality Index Revised (Haines, Siega-Riz, and Popkin 1999; Stookey et al. 2000). The Chinese DQI combined foods and nutrients and included 10 components, which were selected to represent aspects of diet quality highlighted in the Chinese dietary guidelines, and was designed to identify both problems of nutrient deficiency and overnutrition. The index was shown to be correlated with food and nutrient intakes, body mass index, urban residence, and income. Because the index was sensitive to problems of under- and overnutrition, it was suggested as a potential tool to monitor the nutrition transition and epidemiologic trends in China (Stookey et al. 2000).

This overview highlights the wealth of experience in operationalizing the measurement of dietary quality in developed countries and more recently in countries experiencing a nutrition and epidemiological transition like China. The large variability in the types of diet quality indices and the components they include comes from the fact that dietary quality measurement tools are usually—and rightly so—developed based on a specific country's dietary guidelines. These in turn respond to the country's specific nutrition and public health concerns. China provides a good example of a country that has recently gone through this process and identified the urgent need to address both problems of under- and overnutrition. These concerns were then included both in the country's dietary guidelines and in the diet quality index that was developed thereafter.

3. What Is the Association Between Dietary Diversity and Nutrient Adequacy and Child Growth in Developing Countries?

Validation studies of dietary diversity and dietary quality indicators abound in developed countries, and Kant (1996) provides an exhaustive list of the outcomes against which these indicators have been validated in research carried out up to 1996. This work is not reviewed here. Rather, we focus on validation studies of indicators of dietary diversity carried out in developing country contexts. We review studies that specifically validated dietary diversity against nutrient adequacy or intake.

We also review studies that looked at associations between indicators of dietary diversity and child nutrition and health outcomes. Although these studies are not considered "validation" studies per se, they are useful for examining the degree of association between changes in the dietary diversity indicator and the ultimate outcome of interest—child nutrition.

Table 1 presents a summary of the studies reviewed by outcome examined. Studies that have analyzed more than one outcome are listed under the different

Table 1—Summary of studies from developing countries that assessed dietary diversity and looked at associations with nutrient intake or adequacy, or with child nutritional status[a]

Author	Country	Age group	Dietary diversity approach (indicator)	Method and reference period	Descriptive dietary diversity findings	Type of validation or association study	Against which outcome?	Main findings
VALIDATION/ASSOCIATION WITH NUTRIENT INTAKE OR ADEQUACY								
Hatløy, Torheim, and Oshaug 1998	Mali	< 5 y. average age: 36 mo.	1) Food Variety Score (FVS): no. foods (n=75) 2) Dietary Diversity Score (DDS): 8 food groups: staples, vegetables, fruits, meat, milk, fish, egg, green leaves	Direct weighing for 2-3 days. Total consumed over 2-3 days.	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, % energy from fat, protein, iron, vitamin A, B1, B2, B3, calcium folic acid MAR for all nutrients: cutoff: 75% RDA	1) Correlation FVS and DDS with NAR: significant for % fat, vitamin C, 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, Hung, and Tuyet 2001	Viet Nam	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 (2 regions); DDS: mean=8 and 9 (range 5-11)	Validation against: 1) intake of 13 nutrients; 2) nutrient density Created terciles of FVS: low ≤15;high: ≥21	Measured: 1) nutrient intake; 2) nutrient intake relative to energy (density)	1) FVS>21: significantly greater intake of most nutrients than FVS≤15 2) FVS ≤15; also consumed higher variety of foods from most food groups 3) DDS ≥ 8: significantly higher MAR of energy, protein, niacin, vitamin C, zinc.
Onyango, Koski, and Tucker 1998	Kenya	12-36 mo.	No. of foods	Average daily intake from 3, 24-h recalls	Mean 5 for BF children; 6 for non-BF children	Association between low ≤ 5 and high >5 diversity and % RDA	RDA for energy, protein, vitamin A, C, B1, B2, B3, iron, calcium	Diversity >5 associated with greater intake of all nutrients;
Tarini, Bakari, and Delisle 1999	Niger	24-48 mo.	Diversity score (DS): 11 food groups over 3 days: cereals, green leafy vegetables, other vegetables, pulses/nuts, roots/tubers, fat, fruits, legumes, milk/eggs, meat, sugar	3-day modified weighed intake	DS: mean = 4.8, 5.3, 5.3 (3 seasons)	Association between DS and NQS	Nutritional quality score (NQS): energy, protein, vitamin A, and zinc	Diversity ≤ 5 significantly lower NQS in all 3 seasons compared to DS ≥ 6

Author	Country	Age group	Dietary diversity approach (indicator)	Method and reference period	Descriptive dietary diversity findings	Type of validation or association study	Against which outcome?	Main findings
Ferguson et al. 1993	Ghana and Malawi	36-72 mo.	1) No. food items consumed on average per day 2) Some analyses grouped foods into: 13 groups: citrus fruits, non-citrus fruits, kenkey, bread, banku (corn or cassava), fufu (cassava or plantain), fish, meat, bush meat, cassava, sweet potatoes, other corn, groundnuts	Average over 3-day from direct weighing	Total no. foods items recorded: Malawi: 62, Ghana: 76 Mean daily intake ranged from 6.4 to 7.1 in Malawi; 7.1 to 8 in Ghana. Seasonal variations found	Correlation between dietary diversity and nutrient densities (results only briefly reported)	Nutrient densities (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.
Rose et al. 2002	Mozambique	Adults	Mozambique Diet Assessment Tool (MDAT): **Household level:** info on all hh members, all foods consumed at all meals in 1 day. Each food receives score of 1-4 based on nutrient density, availability, size of portion. E.g.: vegetables, fruits, oils, sugars, some condiments=1 Cereals, bread, tubers=2 Beans, nuts=3 Meat, fish, milk, egg=4	Qualitative recall of all foods consumed by all individuals in 1 day	Very low scores: (0-12: 11%); average (12-19: 35%); adequate (≥ 20: 54%)	Association with quantitative dietary quality index (DQI) based on quantitative dietary assessment (24-h recall at HH level)	Diet Quality Index: 10 points, based on nutrient adequacy for: energy (2), vitamin A (2), iron (2), proteins (2) 7 other nutrients combined (2).	1) Rapid assessment tool (MDAT) associated with Diet Quality Index (DQI) for all nutrients except vitamin A. 2) Changing cutoff points that define low, average and adequate scores improved performance of MDAT
ASSOCIATION WITH CHILD NUTRITIONAL STATUS								
Arimond and Ruel 2002	Ethiopia DHS data	12-36 mo.	**1) 24-h food group** diversity: 8 groups: grains, roots/tubers, milk, vitamin A-rich fruits/vegetables, other fruits/vegetables, meat/poultry/fish/cheese/eggs/yogurt, legumes, fats/oils **2) 7-day food group** diversity: (same as above except grains combined with roots/tubers (n=7)	24-h food group recall; 7-day food group recall	Mean 24-h diversity: 2.25 Mean 7-day diversity: 2.86	Association with HAZ (controlling for SES) Created terciles of 24-h. diversity and 7-d. diversity	Height-for-age Z-scores (HAZ)	1) Both 24-hour and 7-day 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 tercile of 24-hour diversity: 0.65 Z-scores 7-day diversity: 0.67 Z-scores

Author	Country	Age group	Dietary diversity approach (indicator)	Method and reference period	Descriptive dietary diversity findings	Type of validation or association study	Against which outcome?	Main findings
Hatløy et al. 2000	Mali	6-59 mo.	1) **Household level** FVS 2) DDS (same as above: Hatløy, Torheim, and Oshaug 1998)	HH-level 24-h. food frequency (104 food items)	FVS: 19.6 (urban), 14.3 (rural) DDS: 6.7 (u), 6.1 (r)	Association with nutritional status (controlling for SES)	Stunting, underweight, wasted	In urban areas: lower FVS or DDS has twice risk of stunted or underweight; rural areas: no association (controlling for SES)
Tarini, Bakari, and Delisle 1999	Niger	24-48 mo.	Diversity score (DS): 11 food groups over 3 days (see above for details)	3-day modified weighed intake	DS: mean = 4.8, 5.3, 5.3 (3 seasons)	Association between DS and growth	Growth: mean HAZ, WAZ, WHZ	Association DS and growth not significant (low correlations, significant only for WHZ in one round)
Onyango, Koski, and Tucker 1998	Kenya	12-36 mo.	No. of foods	Average daily intake from 3, 24-h recalls	Mean: 5 for BF children; 6 for non-BF children	Association with nutritional status (multivariate analysis, but no control for SES);	HAZ, WAZ, WHZ, triceps skinfold (TS), mid-upper arm circumference (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	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-month food-frequency questionnaire	Mean no.: foods: 14.8; animal foods: 3.6	Association with length at 15 mo. (multivariate analysis, but no control for SES)	Length at 15 mo.	1) Association between no. 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	China	12-47 mo.	Food group scale (0-7): rice, egg, vegetables, fruits, soybeans, meat, other	Recall of usual intake at 12 mo.	Mean no. food groups: 4.8	Bivariate association with nutritional status	HAZ, WAZ, WHZ	Significant difference of 0.20 HAZ between children who consumed < 3 groups and rest of sample
Allen et al. 1991	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 days quant. recall data each mo. for at least 8 mo.	88% of energy intake from plant foods; 12% from animal foods	Correlation between % energy from different food groups and nutritional status	Child nutritional status (HAZ, WAZ, WHZ) at 30 months	1) Positive correlation between % energy from animal foods and HAZ. Also correlation between % energy from dairy and HAZ. 2) Negative correlation between % energy from plant foods (tortillas in particular) and HAZ

[a] Abbreviations: BF: breastfeeding; DDS: dietary diversity score; DS: dietary score; FVS: food variety score; HAZ: Height-for-age Z-scores; HH: household; MAR: mean adequacy ratio; NAR: nutrient adequacy ratio; NQS: nutritional quality score; RDA: recommended dietary allowances; SES: socioeconomic status.

outcomes. Note that all studies were carried out on preschool children; the only exception was Viet Nam, which included adult women (Ogle, Hung, and Tuyet 2001).

Association Between Dietary Diversity and Nutrient Intake or Adequacy

A study in Mali specifically validated dietary diversity against nutrient adequacy (Hatloy, Torheim, and Oshaug 1998). The study used two types of diversity scores: one based on a simple count of number of foods (food variety score [FVS]) and one based on eight food groups (dietary diversity score [DDS]). Both measures were computed from a quantitative dietary assessment using direct weighing for two–three days. Nutrient adequacy was measured using the NAR/MAR method described previously (Guthrie and Scheer 1981; Krebs-Smith et al. 1987; Schuette, Song, and Hoerr 1996). This carefully conducted 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.

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 nutrient adequacy than increasing the number of individual foods in the diet.

An additional methodological contribution of the study is the sensitivity-specificity analysis carried out to identify best cutoff points to predict nutrient adequacy for both diversity indicators. In this sample, the cutoff points of six 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 Viet Nam, which included adult women, used a similar methodology to validate the same diversity measures (FVS and DDS) against nutrient intake and nutrient density (Ogle, Hung, and Tuyet 2001). FVS and DDS were derived from a seven-day 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 a variety of nutrients. Women in the highest tercile of FVS—those who had consumed 21 or more different foods in 7 days—had a significantly higher intake of most nutrients studied than those from the lowest tercile—who had consumed 15 or fewer foods. Similarly, women with a food group diversity greater or equal to eight (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.[4]

Two other studies that have looked at the association between diversity measures and nutrient intakes confirm the positive association between dietary diversity and intake of a variety of nutrients (Onyango, Koski, and Tucker 1998; Tarini, Bakari, and Delisle 1999). An additional study, conducted in Ghana and Malawi, is probably the only one

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[4] 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.

that documents only weak, and in some cases negative, associations between diversity and certain nutrients (Ferguson et al. 1993). 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 study in Mozambique evaluated a rapid assessment tool named the Mozambican Diet Assessment Tool (MDAT) to determine whether households could be classified accurately into three categories of dietary quality (defined in this study as synonymous to dietary diversity). The tool was applied at the household level and gathered information on all individual foods consumed by all household members in one day. 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).[5] 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 Diet Quality Index (DQI) score[6] computed from data from a quantitative household-level 24-hour 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

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

[6] 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 two points, for a maximum score of 10 points.

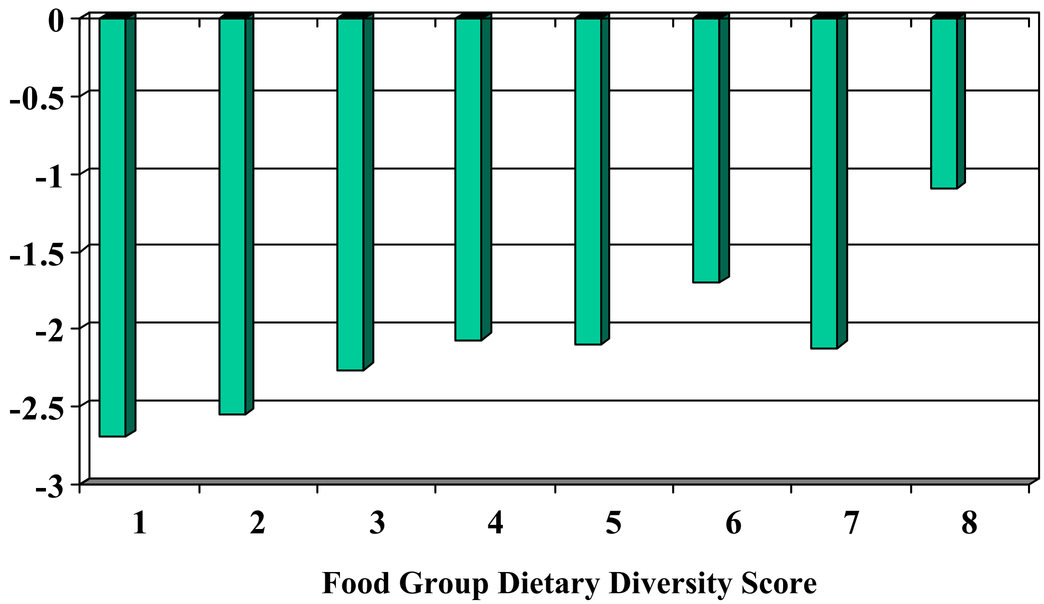
as having poor or very poor diets. Findings for vitamin A intakes, however, were in the opposite direction.

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. The results are surprisingly consistent, considering the wide differences between studies in definitions of foods, food groups, reference period, dietary assessment method, scoring systems, cutoff points used, as well as age of study subjects and general environmental and socioeconomic characteristics.

Association Between Dietary Diversity and 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 1. Our recent analysis of data from the Ethiopia 2000 Demographic and Health Survey (DHS) showed a strong and statistically significant association between food-group diversity measures based either on a 24-hour or seven-day recall and children's height-for-age Z-scores (HAZ) (Arimond and Ruel 2002). Figure 1 shows the adjusted mean HAZ of 12–36 month old children by the seven-day food group dietary diversity score. A positive, and generally linear, trend in mean HAZ is observed as food group diversity in the previous 7 days increases. A difference as large as 1.6 Z-scores is observed between children who consumed one food group in the previous seven days compared to those who consumed eight 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.[7] When terciles of dietary diversity are used, the difference in adjusted mean HAZ between children from the lowest diversity tercile compared to the highest tercile is 0.65 Z-scores. Similar findings are obtained when food group diversity in the previous 24 hours is used.

Figure 1—Mean adjusted height-for-age Z-scores, by dietary diversity score in previous 7-days (children 12-36 months of age: Ethiopia DHS 2000)



Notes: Means were adjusted 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.

A study in Mali also documents a strong association between dietary diversity and children's growth (Hatloy et al. 2000). In urban areas of Mali, lower food variety (FVS)

[7] 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.

or dietary diversity scores (DDS) were associated with twice the risk of being stunted or underweight, controlling for socioeconomic factors.[8] 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 hours (average of three, 24-hour recalls) was significantly associated with five nutritional status indicators (HAZ, WAZ, WHZ, triceps skinfolds, and mid-upper arm circumference) among 12–36 month old children (Onyango, Koski, and Tucker 1998). An interesting finding of this study is that diversity greater than five was more important for growth among children who were no longer breastfed compared to those who were still breastfed at this age. Among the non-breastfed group, the height-for-age of children with dietary diversity greater than five 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 Peru and Mexico (Marquis et al. 1997; Allen et al. 1991). In

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[8] Although the authors did control for socioeconomic factors in their analysis, we have doubts about the validity of the indicator used to reflect household socioeconomic status. Our main concern is that the indicator was based on a series of household assets, many of which were agricultural tools that may have been irrelevant to socioeconomic status in urban areas. It is well recognized that socioeconomic status indicators for urban and rural areas should be created separately (and probably based on a different set of variables) because the characteristics that define wealth in urban and rural areas are expected to be different (Ruel and Menon 2002).

Peru, animal source foods were not significantly associated with length at 15 months as a main effect, but significantly interacted with overall diversity and breastfeeding in multivariate models.[9] Animal foods were significantly associated with length at 15 months only among children who had low overall dietary diversity (measured as total number of foods consumed more than twice a week). 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 second year of life.

Again, in spite of 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 Section 4, 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

[9] 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 and diarrhea, and for breastfeeding and complementary feeding practices.

with higher dietary diversity are also children from wealthier households whose better growth is due to a combination of favorable conditions, including higher maternal education, household income, or greater availability of health and sanitation services, to name 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.

4. What Is the Association Between Household-Level Dietary Diversity and 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 tend to diversify their diets as their incomes increase, largely because greater variety makes diets generally more palatable and 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 2 for details about these studies).

Hoddinott and Yohannes (2002), in their multicountry analysis of data from 10 countries,[10] tested whether household dietary diversity was associated with household per

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

Table 2—Summary of studies from developing countries that looked at associations between household-level dietary diversity and food security and socioeconomic factors[a]

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
ASSOCIATION WITH SOCIOECONOMIC FACTORS								
Hoddinott and Yohannes 2002	10 countries	Adults	Household-level diversity measures: 1) Food diversity (individual 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 days 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) household consumption, 2) calorie availability 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) Increase by 1% of dietary diversity results in increases of: -0.65 to 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	Mali	6-59 mo.	1) Household-level FVS and 2) DDS (see above)	HH-level 24-h. food frequency (104 food items)	FVS: 19.6 (urban), 14.3 (rural) DDS: 6.7 (u), 6.1 (r)	Association with SES score	SES score based on assets (largely agriculture-related; same method used for creation of SES score in urban and rural areas)	1) Assoc. 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.

[a] Abbreviations: DDS: dietary diversity score; FVS: food variety score; HH: household; SES: socioeconomic status.

capita consumption (a proxy for household income) and energy availability (a proxy for food security).[11] 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 seven days. 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 seven days. 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-hour 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 percent increase in dietary diversity is associated with an average 1 percent increase in per capita consumption/expenditure and a 0.7 percent increase in total per capita energy availability. When separating energy from staples and nonstaples, the authors show that a 1 percent increase in household dietary diversity is associated with a 0.5 percent increase in household energy availability from staples and a 1.4 percent increase in energy availability from nonstaples. This finding indicates that as

[11] In this document, the traditional definition of household food security based on energy availability, as opposed to energy plus all other essential nutrients, is used.

households diversify their diets, they tend to increase their consumption of prestigious, nonstaple foods rather than increase 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 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 household food security, especially where resources for such measurement are limited.

Using data from Mali, Hatloy et al. (2000) also tested the association between dietary diversity and socioeconomic status. They used the same two household measures of dietary diversity as in their previous study (Hatloy, Torheim, and Oshaug 1998): the Food Variety Score (FVS: number of foods consumed in the previous 24 hours) and the Dietary Diversity Score (DDS: number of food groups). Socioeconomic status was measured by summing up assets from a list of 14 household items. Terciles of socioeconomic status were then created, where the low socioeconomic group had 0–3 assets, the middle group had 4–6 assets, and the higher group had 7–10 assets (none of the households owned more than 10 of the 14 assets). 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). Large differences in diversity between urban and rural households were found, 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 (Leatherman 1994). 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 in their study among preschool Ghanaian and Malawian children (Ferguson et al. 1993).

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 (defined in relation to energy availability), has important programmatic implications, because diversity is so much easier and cheaper to use than traditional measures of food security, which usually involve the collection of complex quantitative information.

5. What Key Measurement Issues Need To Be Addressed 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 (Hatløy, Torheim, and Oshaug 1998) and Viet Nam (Ogle, Hung, and Tuyet 2001) 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 nutrient adequacy than the simple count of individual foods.

Krebs-Smith and colleagues also compared three dietary diversity indicators with respect to their association with dietary quality and found that variety between the five major food groups studied[12] explained as much variation in the mean adequacy ratio as

[12] The five food groups were dairy, meat, grains, fruits, and vegetables.

did variety within those groups (Krebs-Smith et al. 1987). 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 the beneficial effect on reducing cancer risk beyond the advantage of high vegetable intake per se (Franceschi et al. 1995).

More validation research is needed to settle the issue of whether food or food group diversity best predicts nutrient adequacy in different contexts.

Which Food Groups?

In situations where 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. On the other hand, if diversity is to be used as an indicator of household food security or socioeconomic conditions, foods could 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, 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, and the specific focus and purpose of using the diversity indicator should drive decisions about the selection of food groups.

Again, research and validation studies are needed to elucidate these issues. In particular, research should be conducted to help determine whether a set of food groups can be developed for universal use, at least for use with a specific age or physiologic group and for a specific purpose. For example, the Demographic and Health Surveys are currently using a set of food groups that was originally developed to assess and compare the nutrient adequacy of diets of preschool children from developing countries (www.measuredhs.com). This approach has the advantage of allowing for comparability between studies, which in the case of the DHS is essential, because these surveys cover a large number of developing countries worldwide. The approach requires local adaptation, however, which involves elaborating a list of examples of local foods and preparations that pertain to the different groups. Although widely used, the diversity questionnaire developed for the DHS has not yet been validated, and the data collected in these surveys do not include the necessary quantitative dietary intake to validate the diversity indicator.

Another standard set of food groups, which was used by Hoddinott and Ysahac (2002) to measure dietary diversity at the household level, is the food groups from the FAO balance sheets. The authors applied these 12 food groups to derive household-level dietary diversity with the 10 data sets they analyzed. They do not discuss their experience with the use of these food groups with data from countries with such wide differences in dietary patterns as India and Mali, for example.

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 is sufficient to include them. This issue has been addressed in the United States and 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 (Krebs-Smith et al. 1987).

This issue was also addressed in Mozambique in the development of the Diet Assessment Tool, where foods consumed in small quantities contributed fewer points to the total score than foods of similar nutrient composition that were consumed in larger amounts (Rose et al. 2002).

Our experience in Ghana also showed that failure to take portion size into account could result in overestimates of intake of certain foods or 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, 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 consider 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 a 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 (Guthrie and Scheer 1981; Kennedy et al. 1995; Haines, Siega-Riz, and Popkin 1999).

An alternative to the simple count of foods or food groups, proposed by Hoddinott (2002), is to use a weighting system. For example, a weighted sum of the number of individual foods consumed can be computed, where the weights reflect the numbers of days the foods were consumed over a reference period (say, one week). This approach could be used with the Demographic and Health Surveys data sets, which usually include a seven-day recall of 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 (Rose et al. 2002). As described in Section 3, 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 cutoffs defining 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, and they must take 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 possibly 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 terciles 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 Hatloy and colleagues (Hatloy, Torheim, and Oshaug 1998) or receiver-operating characteristics (ROC) curves are recommended (Brownie, Habicht, and Cogill 1986).

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 U.S. adults over a 15-day period. 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 three days, suggesting that assessment of dietary diversity over a single day may significantly underestimate true variability in intake. On the other hand, they note that most curves were relatively flat between days 10 and 15, which suggests that an accurate assessment of diversity may be obtained over a period of less than two weeks.

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 three days. In contexts where two weeks 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 seven-day recall may be the longest reference period achievable from a practical point in order 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.

6. Summary and Conclusions

This review shows the extent of experience with the measurement of dietary diversity, particularly in developed countries, but also increasingly 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.

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 indicators based on food groups (a simpler approach) perform as well as those based on individual 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. The magnitude of this

effect is large, including in the few studies that have controlled for socioeconomic factors. More rigorous control of socioeconomic factors will be necessary in future research, however, in order to better understand the exact nature of the association between dietary diversity and child outcomes.

  - *Research using suitable analytical methods should 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 from 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.

In sum, dietary diversity is clearly a promising measurement tool, but considerable research is needed to continue to explore how to operationalize it and determine the purposes for which it can be most useful. Research is needed to continue to develop valid and reliable indicators of dietary diversity that 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 managers and policymakers 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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