EVALUATION OF DIETARY DIVERSITY SCORES FOR ASSESSMENT OF MICRONUTRIENT INTAKE AND FOOD SECURITY IN DEVELOPING COUNTRIES

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ABSTRACT

Micronutrient malnutrition and food insecurity are widespread global public health problems. Micronutrient deficiencies affect one-third of the global population. Household food insecurity, often results in monotonous diets, a contributing factor to malnutrition. Consuming a varied diet is a recommended approach to achieving nutritional requirements. Many organizations promote the collection of information on dietary diversity to inform food security and nutritional assessments, but there is not an agreed upon set of indicators used for this purpose. Simple, standardized diet-based indicators are needed to assess, monitor and evaluate individual micronutrient intake and household food security. This thesis has a two-fold aim i) to examine relationships between dietary diversity and adequate intake of micronutrients and ii) to consider outstanding methodological questions. These include, determining an appropriate cut-point for (in)adequate intake of micronutrients from the diet and the effect of length of recall period on characterizing dietary patterns.

The association between probability of adequate micronutrient intake and individual dietary scores was determined by secondary analysis of data sets of non-breastfed Filipino children (n=2805, 2-5.9 y), South African children (n=2200, 1-8 y), and urban Malian women (n=102, 15-49 y). Dietary diversity scores were positively and significantly correlated with intake of micronutrients, with correlation coefficients of 0.36, 0.63, and 0.33 in the Philippines, South Africa, and Mali respectively. Using a minimum quantity for a food group to count in the score improved the correlations to 0.44 in the Philippines and 0.48 in Mali. The best score cut-off for a dichotomous indicator of inadequate intake of micronutrients was four food groups in South Africa and six in the Philippines. In Mali, five or more food groups was the best cut-off point for increased mean probability of micronutrient adequacy. In Mali dietary diversity scores using six and nine food groups had slightly higher correlations and indicator performance than scores based on thirteen or twenty-one food groups. Differences in household-level dietary patterns over one and seven day recall periods were tested through secondary analysis in Somalia (n=430 hh), Burkina Faso (n=3640 hh), Lao PDR (n=3913 hh) and Northern Uganda (n=1956 hh). In Somalia, the median dietary diversity score was four for both a one day and seven day recall period. The main food groups consumed by fifty percent or more of households in the lowest dietary diversity tertile were cereals, sugar and oil for both recall periods. The dietary patterns based on food group consumption using score tertiles in Burkina Faso, Lao PDR and Northern Uganda were similar for one or seven days.

This thesis shows that dietary diversity scores are acceptable indicators of micronutrient intake from the diet. Requiring a minimum quantity of consumption for a food group to count in the score is better, but jeopardizes simplicity. The best cut-off for a dichotomous indicator differed across studies, but fell within the range of four to six food groups for

predicting poor intake in children and five or more food groups to predict higher probability of adequate intake in women of reproductive age. Cost implications of misclassification and social unacceptability of false results are low for this indicator. For the purposes of characterizing dietary patterns of households at population level a one day recall period is sufficient. The simplicity of data collection and analysis of indicators of dietary diversity should enable more widespread and repeated collection of information on dietary intake in resource constrained, food insecure environments. Areas for further research include, the added value of assigning weights to food groups and studies in populations with higher average micronutrient intakes to better define an appropriate cut-point for a dichotomous indicator. It is recommended that dietary diversity scores be incorporated as monitoring and evaluation tools in food security and nutrition assessments at national level and below.

"If you are walking down the right path and are willing to keep walking, eventually you will make progress"

Barack Obama

CONTENTS

CHAPTER 1

INTRODUCTION

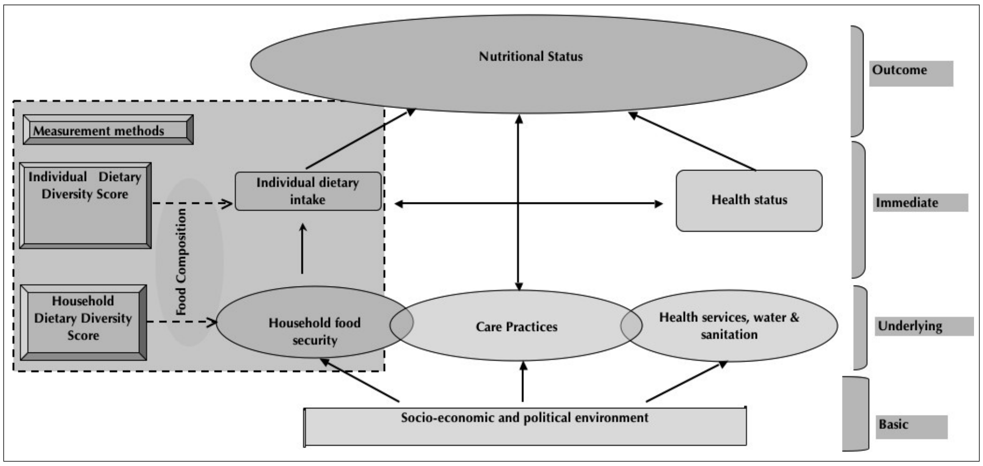
THE GLOBAL BURDEN OF MICRONUTRIENT MALNUTRITION AND FOOD INSECURITY

Micronutrient malnutrition is a global public health problem contributing directly and indirectly to morbidity and mortality of billions of persons worldwide. Vitamin and mineral deficiencies are widespread, affecting one third of the global population (1). For many years the focus of vitamin and mineral deficiencies was on vitamin A, iron and iodine. Reasons for this were justified. In extreme cases of deficiency, lack of iodine can cause irreversible brain damage while lack of vitamin A can lead to blindness. Greater attention is now being paid to less overt consequences of vitamin and mineral deficiencies, which include losses of physical and cognitive productivity in populations suffering from iron deficiency (2), reduced capacity of the immune system as a result of vitamin A deficiency (3,4) and lowered intellectual capacity resulting from iodine deficiency (5). Recent research has also highlighted insufficiency of many other micronutrients including zinc, folic acid, calcium and vitamin D (6). There is growing recognition that deficiency of multiple micronutrients is more common than one in isolation, with recommendations for programs to address deficiencies of several micronutrients in tandem (1).

Together with adequate health and sanitation services and appropriate care practices, household food security is a main contributor to nutritional well-being (Figure 1). Nearly one billion people suffer from food insecurity and the number of food insecure has been increasing recently, jeopardizing attainment of the 2015 Millennium Development Goal target for hunger reduction (7). Four broad concepts fit within the definition of food security, food availability, food access, utilization and sustainability. The definition of food security adopted at the World Food Summit in 1996 is "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (8). Food security is not only concerned with ensuring adequate supply of dietary energy, but includes a diet which is sufficient to meet all nutritional needs, thus incorporating sufficient intake of vitamins and minerals.

Micronutrient malnutrition and food insecurity are widespread public health problems

Figure 1 Conceptual Framework for measuring dietary diversity within the causal model of nutritional status. Adapted from the Nutrition Requirements and Assessment Group, FAO and UNICEF Conceptual Framework



CONSUMING A VARIETY OF FOODS FROM SEVERAL FOOD GROUPS IS A RECOMMENDED APPROACH TO ACHIEVING NUTRITIONAL REQUIREMENTS

Dietary diversification is a recommended approach to alleviate nutritional problems resulting from food insecurity and inadequate intake of micronutrients. Dietary diversity is essential to nutrient adequacy as there is no single food, other than breastmilk for the first six months of life, that contains all of the nutrients required to maintain good health and nutritional status. Consuming a wide variety of foods among and within food groups is a recommended strategy to help ensure adequate intake of micronutrients (9). Dietary diversity is therefore a key element of high quality diets and the recommendation to consume a variety of foods appears in many nutritional guidelines. Monotonous diets, based mainly on grains, roots and tubers are common in areas of high food insecurity and contribute to the burden of malnutrition (9). Dietary diversification is an element of diet-based strategies that can be used to increase intake of multiple micronutrients (9,10). Food-based strategies have been recommended as the first priority to meet micronutrient needs (11).

Consuming a diverse diet is a recommended approach to achieving nutritional requirements

DIETARY DIVERSITY AS A COMPONENT OF HOUSEHOLD FOOD SECURITY AND NUTRITION ASSESSMENTS

When the first indicators of food security were developed, their focus was primarily on national food supply, with the concept that if adequate quantities of food were available food security needs would be met (12). Over the past two decades the indicators used to measure food security have evolved along with more comprehensive definitions of food security discussed in the previous section. Dietary diversity, is considered an outcome measure of food security (13) mainly at the level of individual or household food access, but also can provide information about food availability in the community and reflect seasonal changes in dietary patterns, an aspect of the sustainability of the food supply.

The preferred measures for assessing individual dietary intake in resource poor settings, such as the quantitative twenty-four hour recall or interviewer assisted diet history are time consuming and costly to administer, require highly trained enumerators and involve complex data analysis (14). Low literacy levels, coupled with low access to computer and cell phone technology limit the types of newly developed dietary assessment tools which can be used in many areas (15). Simple measures of dietary diversity as proxy indicators of adequate intake of energy and micronutrients are useful, particularly for assessments in developing countries. Data collection and analysis is less time consuming and less costly than quantitative intake measures. Dietary diversity scores are the sum of a number of food groups consumed over a reference period. The scores are easy to construct and can be done with the aid of a simple computer package or even scored manually. Due to the constraints related to quantitative dietary assessments, there has been an effort to validate these simpler measures of dietary diversity as proxy measures of dietary intake.

There are several dietary diversity measures which can be used to proxy food consumption. Two of the most common are the household dietary diversity score (HDDS) and the individual dietary diversity score (IDDS). Figure 1 puts these indicators into the household food security and nutrition context. Both food intake and health status of an individual are the immediate contributors to nutritional status and there is interplay between the two. When measured at household level, dietary diversity scores reflect the economic ability of a household to consume a variety of foods (16) and are considered good proxy measures of household energy availability (17,18). When measured at the level of an individual, the scores reflect adequacy of energy and other nutrients (19).

Dietary diversity scores are appealing for use as measures of household and individual dietary intake

RELATIONSHIPS BETWEEN DIETARY DIVERSITY, HOUSEHOLD FOOD SECURITY AND INDIVIDUAL NUTRIENT ADEQUACY

Dietary diversity and household-level energy intake

One of the first large studies linking dietary diversity to household dietary energy intake is that of Hoddinott and Yohannes (17). In this study, the authors found a positive relationship between household-level food group diversity (using 12 food groups) and household level per capita availability of dietary energy in 10 countries. Since then, similar studies have confirmed this association. In Mali, Malawi, Bangladesh, Philippines and Sri Lanka the performance of a household-level food group diversity score as a predictor of low household level per capita dietary energy was poor to fair (AUC[1] ranging from 0.50 and 0.66) (20). Additional studies from Bangladesh, Ghana, Ethiopia and Afghanistan found positive, significant correlations between dietary diversity scores based on 12 food groups and household per capita dietary energy intake in Afghanistan (r=0.28), Bangladesh (r=0.39) and Ghana (r=0.41) and no association in Ethiopia (21). A study in Burundi, Sri Lanka and Haiti found correlations between dietary diversity based on 12 food groups and calorie consumption per adult equivalent between 0.21 in Burundi, 0.33 in Haiti and 0.11 in Sri Lanka (22). In that study the highest correlations (r=0.40, 0.50, 0.18) for Burundi, Haiti and Sri Lanka respectively were found with an indicator based on a count if individual food items (22). In Mozambique, correlations between food group scores and energy intake ranged from 0.24 for a simple count of food groups to 0.27 for a regression-based weighted food group indicator (23).

Dietary diversity and individual-level energy intake

Studies of dietary diversity and energy intake at the individual level show mostly a positive, significant relationship. A study of adolescents in Tehran, found a significant relationship between dietary diversity score and total energy (r=0.17) (24). Among Korean adults 19 years or older, a dietary diversity score based on 18 food groups was significantly correlated with energy intake (r=0.39) (25). In Vietnam, women with a dietary diversity score of eight or more had a significantly higher nutrient adequacy ratio for energy (26). Only one study of children in Mali did not find a significant correlation between either an individual count of food items consumed or a dietary diversity score based on eight food groups and nutrient adequacy ratio for energy (27).

Dietary diversity and individual-level micronutrient intake

A recent review summarized results of correlations between dietary diversity scores and individual micronutrients from six studies. Coefficients from at least four different studies are available for vitamins A and C, riboflavin, calcium, zinc and iron, three studies included

[1] Area under the receiver operating curve (AUC) of 0.50 indicates the indicator makes no distinction between groups (high or low energy intake), while 1.0 is perfect separation of groups (Zweig and Campbell, *Clin Chem* 1993;39(4): 561-577).

thiamin, vitamin B_6 and B_{12}, two or fewer results are available for other micronutrients. Correlation coefficients based on four or more studies in the review ranged from 0.19 to 0.43 for vitamin A, 0.14 to 0.44 for vitamin C, 0.02 to 0.54 for calcium, 0.16 to 0.44 for riboflavin, 0.11 to 0.40 for zinc and 0.03 to 0.26 for iron (28). No consistent pattern is seen across studies in terms of a lower or higher correlation for any individual micronutrient.

Rather than testing the relationship between a dietary diversity score and intake of each individual micronutrient of interest, composite intake measures are commonly used to summarize the association between dietary diversity and intake of numerous micronutrients. This concept is useful since numerous micronutrients are provided by each food group. Composite measures of nutrient adequacy are created by first comparing the individual's intake of a certain nutrient (energy or any micronutrient) to the estimated requirement based on age, gender and in the case of energy, body size and activity level. A simple ratio, referred to as the nutrient adequacy ratio (NAR) of intake/requirement has been used in some studies. The probability approach is a newer, recommended method for assessing adequacy (29). This approach is recommended as it takes into account distributions of both requirements and intakes (30). The summary measure, often referred to as a mean probability of adequacy (MPA) is Σ Probability of Adequacy (PA) for individual micronutrients (truncated to 1 for each micronutrient in order to avoid that a nutrient with a high intake compensates for a nutrient with a low intake) divided by the number of micronutrients in the measure. The studies reviewed in this section have used different numbers of micronutrients in the composite scores and some also incorporate intakes of energy, protein and fat in the score.

In a study of dietary intake data from children 6-23 months of age in ten countries, dietary diversity scores based on seven food groups were positively correlated with increased mean micronutrient density adequacy of complementary foods (nutrient density/100kcal of complementary foods) for breastfed (r=0.21 to 0.76[1]) and non-breastfed (r=0.26 to 0.56[2]) children in all ten locations, except among non-breastfeeding children who received fortified food products in the Philippines (31). Many other studies in children (27, 32*),* adolescents (24) and adults (25, 33, 34) have found similar positive associations.

Dietary diversity scores and nutritional status

There have been several studies of the relationship between dietary diversity scores and nutritional outcome measures such as anthropometric indicators in children under the age of five years and body mass index (BMI) in adults. Eleven Demographic and Health Surveys (DHS) were used to look at the association between dietary diversity score, based on seven

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[1] Range of correlation coefficients across studies
[2] Range of correlation coefficients across studies

food groups and height-for-age Z score in children 6-23 months of age (35). Bivariate associations were found in nine of the eleven countries. Differences in height-for-age Z score (in the nine significant countries) ranged from 0.25 to 0.51 between extreme tertiles. Dietary diversity remained significant as a main effect in seven countries in a model controlling for household wealth and welfare variables. A study in Mali found that the lowest tertile of dietary diversity (2-5 food groups), measured at the household level, was associated with higher odds ratio for stunting 2.2 (95% CI 1.1-4.2) and underweight 2.4 (95% CI 1.3-4.6) when compared to the highest dietary diversity tertile in urban, but not in rural areas. The odds ratio for low DDS and wasting was not significant in either area (36). Among children 12-36 months of age in rural Western Kenya, dietary diversity based on a count of individual foods consumed, was significantly associated with weight-for-age, height-for-age, and weight-for-height Z scores as well as triceps skinfold and mid-upper-arm circumference (37). Among children living in the Beni river lowlands of Bolivia a food diversity index, based on a weighed score of seven food groups was associated with height-for-age Z score of preschool (0-4.9 y), school age (5-9.9 y) and adolescent (> 10y) children (38).

In women in Burkina Faso, a more varied diet, based on analysis of dietary diversity tertiles using 14 food groups, was significantly associated with higher mean body mass, mean mid-upper arm circumference and mean body fat percentage index and fewer percent of women underweight. When controlling for sociodemographic and economic characteristics, there remained a significant difference between percent of women underweight in the lowest dietary diversity tertile (22.8%) compared to the highest dietary diversity tertile (9.8%) but the relationship did not remain significant for the other indicators (39). Among women living in an urban area of Burkina Faso, there was no association between dietary diversity score and BMI, body fat percentage or mid-upper arm circumference (40). In the Beni river region of Bolivia, women with a higher food diversity index, based on a weighted score of seven food groups, had a higher risk of being overweight (41). In particular, the authors conclude that women who ate more fish, bread and rice were at a higher risk of overweight than those consuming the more traditional diet consisting primarily of cassava and plantain.

Most studies show that increasing dietary diversity at both household and individual levels is related to increased dietary energy intake and individual micronutrient intake. Dietary diversity scores are also associated with anthropometric outcomes in most studies.

OUTSTANDING METHODOLOGICAL ISSUES RELATED TO THE MEASUREMENT OF DIETARY DIVERSITY

Current understanding of the relationship between dietary diversity and nutrient intake comes from studies applying several different methodologies to construct the scores. For example, there are differences in the number and type of food groups used to construct the scores and the length of recall used in the reference period. Harmonization and standardization of some of these aspects would improve the interpretation and comparability of measures of dietary diversity.

Number and composition of food groups

Scores used to measure dietary diversity have ranged in construction from a measure of four food groups to a count of individual food items consumed. A few studies have found the association between nutrient intake based on a count of food groups to be nearly the same (26) or better (27) than using scores based on counting intake of individual food items. In contrast, a review of proxy indicators for household food security found that counting the number of individual food items rather than food groups improved classifications of households falling above/below a cut-off for caloric availability per adult equivalent (20). Limiting score construction to food groups rather than a count of individual food items simplifies data analysis and interpretation and also better conforms to dietary recommendations (27). For measurement of household level diversity, guidelines developed by FANTA (16) and adopted by FAO (19) use a standardized set of 12 food groups. This construction is aimed at being able to associate household dietary diversity with household dietary energy intake. At present, there is no consensus for most individual level scores on the best number or composition of food groups to include. The decision on which food groups should be included in the score is based on the purpose of the score. When the purpose of the score is to assess micronutrient intake it was found for young children, that exclusion of the food group fats and oils provided stronger correlations (31). The food group fats and oils should always be included in scores with the goal of measuring total energy intake. Scores designed for the purpose of measuring adequate intake of micronutrients also tend to include groups rich in certain micronutrients, such as vitamin A-rich or vitamin C-rich fruits and vegetables. The evidence base for the number of and composition of food groups to include in scores tailored for different purposes needs to be increased.

An additional methodological question is whether or not to exclude foods consumed in small quantities. For example, should a dash of milk added to coffee be given a point in the score for consuming dairy? One study in children found a stronger association when small quantities are not considered in the score (42) while another study in very young children (6-34 months) found a 10g restriction did not outperform a 1g restriction (31). There is a need for more research on this question in adult population groups.

Recall period

The most appropriate recall period depends greatly on the purpose of the study as there is individual day to day variation in both food and nutrient intakes. Research on nutrient intakes has shown a range of up to twenty days are needed to estimate vitamin A intake, while five to eight days is the minimum number of days needed to estimate individual intakes of some other micronutrients, such as calcium and magnesium, and an average of four to six days required to estimate total energy intake (43). In terms of day to day variation in food items, a study undertaken in a US population showed sharp increases in diversity over three days of intake, with a plateau reached at about ten days (44). Diets of individuals in developing countries may show less day to day variation in diversity. Mean dietary diversity scores of women in a rural area of Burkina Faso increased by 0.7 food groups measured from day one to day two and by 0.2 food groups measured from day two to day three (45). Shorter recall periods ranging from one to seven days are considered acceptable for population level assessment, when the aim is to gather information on population level diet patterns and classify individuals or households into groups (46). Within the one to seven day range, longer reference periods are more prone to recall error. Longer reference periods also impose a greater burden on both the respondent and enumerator (47). For the purpose of population level assessment, the magnitude of difference in diversity scores and dietary patterns based on recall periods of one or seven days has not been well documented.

There are several outstanding questions related to number and composition of food groups to use in the score and the most appropriate length of recall period.

USING INFORMATION ON DIETARY DIVERSITY

Measurements of dietary diversity can be used for different purposes and can inform different aspects of food and nutrition security. Population level indicators can primarily be used for assessment, targeting at risk populations and monitoring and evaluation of progress and program impact (46). There is one internationally endorsed indicator for dietary diversity related to feeding practices for infants and young children. This indicator, *Minimum Dietary Diversity* is defined as the proportion of children 6-23 months of age who received foods from ≥ four food groups (out of seven) the previous day (46). There are no other internationally standardized indicators of dietary diversity for individuals in other age groups. There are currently two primary indicators used at household level, the Household Dietary Diversity Score (HDDS) and the Food Consumption Score (FCS). The FCS is primarily used by WFP, tailored to its own information needs for classifying food insecurity, while HDDS is promoted by FANTA and FAO. Both indicators are used for monitoring economic access to food and can be used for surveillance at decentralized levels (48).

For most age-groups there is no agreement on a cut-off to define a dichotomous indicator, so it is recommended to use the score as a continuous indicator (19). Mean and median scores can be used to assess changes in diet before and after an intervention or after a disaster. Mean scores of population sub-groups can also be compared to indicate vulnerability. In addition to comparing mean or median scores, consumption patterns at different score levels, based on tertiles or quartiles can be used to better understand the pattern of diversification as scores increase. Consumption of individual food groups of interest such as fish, eggs or vitamin-A rich vegetables can also be monitored.

Lack of harmonization of score construction and definition of a cut-point to define a dichotomous indicator are limiting factors in the interpretation and wide spread use of dietary diversity scores

RATIONALE AND OUTLINE

Food insecurity and micronutrient malnutrition are widespread public health problems that can be alleviated in part through increasing dietary diversity. Dietary diversity scores are appealing for use as proxy measures of household and individual dietary intake because they are less complex and costly than other traditional quantitative measures used to assess dietary intake. Many studies show increasing dietary diversity at both household and individual levels is related to increased dietary energy intake, individual micronutrient intake and anthropometric indices in children and adults. These findings come from studies using differing numbers and types of food groups to construct scores and also use different reference periods. There are several outstanding questions related to the recall period, number and composition of food groups to include in the score and best cut-off for creating a dichotomous indicator. These unanswered questions are impeding development of standardized indicators, which would be of global use in comparing dietary diversity across populations and over time.

The main aim of this research is two-fold, i) to explore relationships between dietary diversity and adequate intake of micronutrients and ii) to consider outstanding methodological questions. These include, determining an appropriate cut-point for (in)adequate intake of micronutrients from the diet and the effect of length of recall period on characterizing dietary patterns. The specific research questions were:

I. What is the relationship between micronutrient intake and individual dietary diversity scores (chapters 2, 3 and 4) including the effect of eliminating foods consumed in small quantities? (chapters 2 and 4)

II. Which food groups are the most strongly correlated to mean probability of adequate micronutrient intake?(chapter 5)

III. What is the most appropriate cut-off point to create a dichotomous indicator of inadequate or adequate micronutrient intake? (chapters 2, 3 and 4)

IV. What difference does a one or seven day recall period make in characterizing household level dietary patterns? (chapters 5 and 6)

Secondary analysis of data sets from the Philippines (chapter 2), South Africa (chapter 3) and Mali (chapters 4 and 5) were used to provide answers to the above questions related to the use of individual dietary diversity scores. Household level information from food security assessments in Somalia (chapter 6) and Burkina Faso, Lao PDR and Northern Uganda (chapter 7) were used to examine household dietary diversity score performance and dietary patterns using recall periods of one and seven days. Study areas comprise emergency and acute food security crisis contexts as well as urban and rural areas.

REFERENCES

1. Mason J, Lofti M, Dalmiya N, Sethuraman K, Deitchler M. The Micronutrient Report: Current progress and trends in the control of Vitamin A, Iodine and Iron Deficiencies. Ottawa, Canada: Micronutrient Initiative; 2001.
2. Horton S, Ross J. The economics of iron deficiency. *Food Policy* 2003;28:51-75.
3. Semba R, Muhilal, Scott A, Natadisastra G, Wirasasmita S, Mele L, Ridwan E, West K, Sommer A. Depressed immune response to tetanus in children with Vitamin A deficiency *J Nutr* 1992.;122:101-107.
4. International Vitamin A Consultative Group (IVACG). IVACG Policy Statement on Vitamin A status and childhood mortality. Washington, DC: IVACG; 1997.
5. Qian M, Wang D, Watkins W, Gebski V, Yan Y, Li M, Chen Z. The effects of iodine on intelligence in children: a meta-analysis of studies conducted in China *Asia Pac J Clin Nutr* 2005;14(1):32-42.
6. Black R, Allen LH, Bhutta ZA, de Onis M, Ezzati M, Mathers C, Rivera J. Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* 2008;371:243-260.
7. FAO. The State of Food Insecurity in the World, 2008. Rome: FAO; 2008.
8. FAO. World Food Summit: Rome Declaration and Plan of Action. [Internet] FAO; October 1996. [cited May 20 2009]. Available from: www.fao.org/wfs
9. FAO/WHO. Vitamin and mineral requirements in Human Nutrition. Rome: FAO; 2002.
10. Boy E, Mannar V, Pandav C, de Benoist B, Viteri F, Fonatine O, Hotz C. Achievements, challenges and promising new approaches in vitamin and mineral deficiency control. *Nutrition Reviews* 2009;67(Suppl. 1): S24-30.
11. Allen L. To what extent can food-based approaches improve micronutrient status? *Asia Pac J Clin Nutr* 2008;17(S1):103-105.
12. Maxwell S, Smith M. Household food security: A conceptual review. In: Maxwell S Frankenberger T. editors. Household food security: concepts, indicators and measurements. A technical review. NewYork and Rome: UNICEF and IFAD; 1992.
13. Hoddinott J. Choosing outcome indicators of Household Food Security. Technical Guide #7. Washington, DC: International Food Policy Research Institute; 1999.
14. Ferro Luzzi A. Individual food intake survey methods. In: Measurement and Assessment of Food Deprivation and Undernutrition. Proceedings from the International Scientific Symposium on Measurement and Assessment of Food Deprivation and Undernutrition. Rome: FAO; 2003.
15. Solomons N, Valdés-Ramos R. Dietary assessment tools for developing countries for use in multi-centric, collaborative protocols. *Public Health Nutr* 2002;5(6A): 955-968.
16. Swindale A, Bilinsky P. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (v.2). Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2006.
17. Hoddinott J, Yohannes Y. Dietary diversity as a food security indicator. Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2002.
18. Ruel M. Is Dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. FCND Discussion Paper # 140. Washington, DC: International Food Policy Research Institute; 2002.
19. FAO. Guidelines for measuring household and individual dietary diversity (version 4) [Internet]. Rome: FAO; 2008. [cited 12 January 2009]. Available from: http:/ www.foodsec.org/tr/nut/ guidelines.pdf
20. IFPRI. Review and validation of dietary diversity, food frequency and other proxy indicators of household food security. Rome: World Food Programme, Vulnerability Analysis and Mapping Branch; 2006.
21. Coates J, Rogers B, Webb P, Maxwell D, Houser R, McDonald C. Dietary Diversity Study. Rome: World Food Programme, Emergency Needs Assessment Service; 2007.
22. Wiesmann D, Bassett L, Benson T, Hoddinott J. Validation of the World Food Programme's Food Consumption Score and Alternative Indicators of Household Food Security. IFPRI Discussion paper 00870. Washington, DC: International Food Policy Research Institute (IFPRI); 2009.
23. Rose D, Chotard S, Oliveira L, Mock N, Libombo M. Comparative Evaluation of Dietary Indicators used in Food Consumption Assessments of at-risk populations *Food Nutr Bull* 2008;29(2):113-122.
24. Mirmiran P, Azadbakht L, Esmaillzadeh A, Azizi F. Dietary diversity score in adolescents- a good indicator of the nutritional adequacy of diets: Tehran lipid and glucose study. *Asia Pac J Clin Nutr* 2004;13(1):56-60.
25. Ahn BC, Engelhardt K, Joung H. Diet variety is associated with socio-economic factors. *Ecol Food Nutr* 2006;45:417-430.
26. Ogle B, Hung P, Tuyet H. Significance of wild vegetables in micronutrient intakes of women in Vietnam: an analysis of food variety. *Asia Pac J Clin Nutr* 2001;10(1):21-30.
27. Hatloy A, Torheim L, Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr* 1998;52(12):891-8.

28. Roman-Vinas B, Ribas Barba L, Ngo J, Martinez-Gonzalez MA, Wijnhoven T, Serra-Majen L. Validity of dietary patterns to assess nutrient intake adequacy. *Br J Nutr* 2009;101(S2):S12-S20
29. Murphy S. Impact of the new Dietary Reference Intakes on nutrient calculation programs. *J Food Comp Anal* 2003;16:365-372.
30. Barr S, Murphy S and Poos M. Interpreting and using the Dietary Reference Intakes in dietary assessment of individuals and groups. *J Am Diet Assoc* 2002;102(6):780-788.
31. Working Group on Infant and Young Child Feeding Indicators. Developing and validating simple indicators of dietary quality and energy intake of infants and young children in Developing Countries: Summary of findings from analysis of 10 data sets. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2006.
32. Ruel M, Graham J, Murphy S, Allen L. Validating simple indicators of dietary diversity and animal source food intake that accurately reflect nutrient adequacy in developing countries. Report submitted to GL-CRSP. 2004.
33. Sodjinou R, Agueh V, Fayomi B, Delisle H. Dietary patterns of urban adults in Benin: relationship with overall diet quality and socio-demographic characteristics. *Eur J Clin Nutr* 2009;63:222-228.
34. Torheim LE, Ouattara F, Diarra M, Thiam F, Barikmo I, Hatloy A, Oshaug, A. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. *Eur J Clin Nutr* 2004;58(4): 594-604.
35. Arimond M, Ruel M. Dietary diversity is associated with child nutritional status: Evidence from 11 Demographic and Health Surveys. *J Nutr* 2004;134:2579-2585.
36. Hatloy A, Hallund J, Diarra M, and Oshaug A. Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). *Public Health Nutr* 2000;3(1):57-65.
37. Onyango A, Koski K, Tucker K. Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. *Int J Epidemiol* 1998;27:484-489.
38. Benefice E, Monroy S, Jimenez S, Lopez R. Nutritional status of Amerindian children from the Beni River (lowland Bolivia) as related to environmental, maternal and dietary factors. *Public Health Nutr* 2006;9(3):327-335.
39. Savy M, Martin-Prével Y, Sawadogo P, Kameli Y, Delpeuch F. Use of variety/ diversity scores for diet quality measurement: relation with nutritional status of women in a rural area in Burkina Faso. *Eur J Clin Nutr* 2005;59:703-716.
40. Savy M, Martin-Prével Y, Danel P, Traissac P, Dabire HB, Delpeuch F. Are dietary diversity scores related to the socioeconomic and anthropometric status of women living in an urban area in Burkina Faso? *Public Health Nutr* 2008;11(2):132-141.
41. Benefice E, Lopez R, Monroy S, Rodriguez S. Fatness and overweight in women and children from riverine Amerindian communities of the Beni River (Bolivian Amazon). *Am J Hum Biol* 2007;19:61-73.
42. Daniels M, Adair L, Popkin B, Truong Y. Dietary diversity scores can be improved through the use of portion requirements: an analysis in young Filipino children. *Eur J Clin Nutr* 2009;63:199-208.
43. Nelson M, Black A, Morris J, Cole T. Between and within-subject variation in nutrient intake from infancy to old age: estimating the number of days required to rank dietary intakes with desired precision. *Am J Clin Nutr* 1989;50:155-67.
44. Drewnowski A, Renderson S, Driscoll A, Rolls B. The Dietary Variety Score: Assessing diet quality in healthy young and older adults. *J Am Diet Assoc.* 1997; 97(3):266-271.
45. Savy M, Martin-Prével Y, Traissac P, Delpeuch F. Measuring dietary diversity in rural Burkina Faso: comparison of a 1 day and a 3-day dietary recall. *Public Health Nutr* 2007;(10)1:71-78.
46. World Health Organization. Indicators for assessing infant and young child feeding practices. Part 1 Definitions. Geneva, Switzerland. 2008.
47. Falciglia G, Horner S, Liang J, Couch S, Levin L. Assessing dietary variety in children: Development and Validation of a Predictive Equation *J Am Diet Assoc* 2009;109:641-647.
48. World Food Programme. Comprehensive Food Security and Vulnerability Analysis Guidelines. Rome: WFP; 2009. pp.356.

CHAPTER 2

DIETARY DIVERSITY SCORE IS A USEFUL INDICATOR OF MICRONUTRIENT INTAKE IN NON-BREAST-FEEDING FILIPINO CHILDREN

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ABSTRACT

Micronutrient malnutrition remains a problem of public health concern in most developing countries, partly due to monotonous, cereal-based diets that lack diversity. The study objective was to assess whether dietary diversity score (DDS) based on a simple count of food groups consumed and DDS using a 10-g minimum intake for each food group (DDS 10g) are good indicators of adequate micronutrient intake in 24–71-month-old non-breast-feeding Filipino children. Pearson's correlation and linear regression were used to assess the utility of DDS and DDS 10g as indicators of micronutrient intake. Sensitivity and specificity analysis were used to determine the most appropriate cut-off point for using DDS to categorize children with high probability of adequate micronutrient intake. The average diet of the sample population consisted of 4–5 food groups. The mean probability of adequate nutrient intake (MPA) of 11 micronutrients was 33%. The Pearson's correlation coefficient between MPA and DDS was 0.36 ($P < 0.001$) and for DDS 10g it increased to 0.44 ($p < 0.001$). Intake of individual micronutrients was correlated to DDS for most nutrients. When maximizing sensitivity and specificity, the best cut-off points for achieving 50 and 75% probability of adequate micronutrient intake were 5 and 6 food groups, respectively. DDS and DDS 10gwere both significant predictors of adequate micronutrient intake. This study demonstrates the utility of indicators of dietary diversity to predict adequate intake of micronutrients in the diets of young non-breast-feeding children.

INTRODUCTION

Micronutrient malnutrition remains a serious nutritional concern in developing countries. In the Philippines, 40% of children 6 m to 5y of age have low or deficient serum retinol levels and 29% of children 1–5 y of age are anemic (1). The prevalence of low serum retinol and anemia in Filipino children has increased over the past decade. The increase in low serum retinol has occurred despite Department of Health biannual vitamin A capsule supplementation program for young children, most probably as a result of low coverage and poor compliance with biannual doses. The continuing high prevalence of anemia is attributed to low birth weight, low dietary iron intake, and helminth infections (1).

Evidence from dietary intake research in the Philippines shows that the diets of a large percentage of young children are deficient in iron, vitamin A, and calcium. Intakes of vitamin C, niacin, riboflavin, and thiamin were found to be adequate. Average energy intake of preschool age children was also below recommended levels (2). Moving from a monotonous diet to one containing a more diverse range of foods has been shown to increase intake of energy as well as micronutrients in developing countries (3–7). Intake of a diverse variety of foods has been a recommendation for achieving adequate nutrient intake and the recommendation appears in the dietary guidelines of many countries. The nutritional guidelines for the Philippines include a number of recommendations on dietary diversity; 2 recommendations specify daily intake; 1) eat a variety of foods every day and 2) consume milk, milk products, and other calcium rich foods such as small fish and dark green leafy vegetables every day (8). Other recommendations encourage greater consumption of certain food groups but do not specify how often these should be consumed (fish, lean meat, poultry, dried beans, vegetables, fruits, and root crops). The precise number of foods or food groups that one should strive to consume over any given period is not commonly mentioned in most dietary guidelines. Japan advises consumption of 30 different food items per day (9) and the US advocates consumption of a variety of nutrient-dense foods and beverages within and among 5 basic food groups, with an item from each food group consumed daily [the 5 USDA food groups are: cereals, vegetables, fruit, dairy, and protein source foods (meat, fish, poultry, eggs, nuts, beans)] (10).

Despite many national nutritional guidelines recommending consumption of a variety of foods to meet nutritional needs, including those in the Philippines, the question remains how to operationalize this message for use as an indicator in the public health setting. The use of dietary diversity as an indicator of adequate nutrient intake remains under evaluation, particularly in developing countries. In those settings where the importance of dietary diversity to adequate nutrient intake has been assessed, researchers have used different food group classification systems, as well as diverse reference periods, cut-off points, and age groups (11). There is need for a set of comparable validation studies using the same methodology for creating a dietary diversity score (DDS) to predict adequate micronutrient intake.

The purpose of this study is to validate dietary diversity as an indicator of micronutrient adequacy in the diet of Filipino children 24–71 m to quantify the appropriate DDS cut-off point for use as an indicator of inadequate micronutrient intake. The results of this study will aid in the development and promotion of rapid assessment tools for measuring diversity of the diet and further understanding of the utility of a measure of dietary diversity as part of a set of indicators used to monitor food and nutrition security.

MATERIALS AND METHODS

Data were from non-breast-fed children 24–71 months of age in the Philippines 1993 National Nutrition Survey. The survey used a stratified 2-stage sampling design including a total of 4050 households and 3164 children 24–71 months of age. All surveyed households provided informed consent prior to participation. Ethical consent for the study was obtained from the Philippines Food and Nutrition Research Institute. Detailed information on the 1993 survey methodology has been published elsewhere (12).

The food intake data of the preschool children was collected by individual 24-h food recall. The mother or caregiver was the respondent. The interviews included a detailed description of the foods eaten, the cooking method, and brand names (e.g. for milk consumed or other processed snack foods). The amount consumed by the child was estimated by the respondent, expressed in terms of cups, spoons, matchbox pieces, and other common household utensils. The respondents were shown visual aids to assist them in accurately reporting food intake. For mixed recipes, the respondent was asked how the food was prepared and how much of the visible components (e.g. pieces of meat, vegetables, etc.) were eaten by the child.

To compute nutrient values, the cooked weight was converted to raw weight using the Filipino Food and Nutrition Research Institute's Individual Dietary Evaluation Software. The software also contains a library of food composition values in their raw form. Nutrient values for energy, protein, fat, calcium, iron, vitamin A, vitamin C, thiamin, riboflavin, and niacin are from the 1997 food composition tables of the Philippines (13) and from food labels, particularly for iron and vitamin A, for fortified foods. For this study, nutrient values for vitamin B_6 vitamin B_{12}, folate, zinc, and phytate were obtained from the World Food Dietary Assessment System, version 2.0 (14). Nutrient retention values, from the USDA Table of Nutrient Retention Factors, Release 5 (2003), were added to account for nutrient losses during cooking process (15).

The data were cleaned for the purposes of this study. The average per capita daily energy requirement (kcal/d) for children 12–47 months of age in the Philippines was calculated using the Population Energy Requirements software (16). The average per capita energy requirement was estimated at 4707 kJ/d (1125 kcal/d). The 5th and 95th percentiles, corresponding to intakes below 1607 kJ/d (384 kcal/d) and above 6632 kJ/d (1585 kcal/d) were discarded, leaving a total of 2805 records used in the analysis.

For the analysis using anthropometric data, only records with complete information on age, gender, weight, and height were included. WHO fixed exclusion ranges were used as criteria for cleaning outlying anthropometric Z scores (17).

DDS were calculated for each child using a set of 10 food groups (cereals and tubers; meat, poultry and fish; dairy; eggs; pulses and nuts; vitamin A-rich fruits and vegetables; other fruit; other vegetables; oils and fats; and other). The choice of the 10 food groups was based on the outcome of discussions held during a workshop on validation methods for dietary diversity held in Rome, Italy in October 2004. The decision was based on previous experience and testing of the usefulness of different food groupings (5) and is reflected in a set of basic guidelines for validating DDS in non-breast-feeding children 24–83 months of age (18) and also in validation guidelines for children 0–24 months of age (19). The food group "other," consisting of sugar, non-juice or dairy beverages, and condiments and spices, was used in descriptive statistics but was not used for tests of correlation, because this group does not contribute substantially to micronutrient intake. The majority of the analysis presented is based on the 9 food groups, excluding the "other" category.

DDS were calculated by summing the number of unique food groups consumed by the child in the 24-h period. An all inclusive DDS was calculated without a minimum intake for the food group. A second DDS was calculated applying a 10g minimum intake for all food groups (DDS 10g) except fats and oils.

Bioavailability adjustments were made for calcium, iron, and zinc. The purpose of making the bioavailability adjustments was to derive estimates of absorbed calcium, absorbed iron, and absorbed zinc to more accurately reflect concurrence between dietary intake and requirements. Bioavailability factors for calcium were 25% for roots, tubers, and legumes; 45% for fruits and vegetables; 5% for high oxalate vegetables (amaranth, cassava root and leaves, and spinach); and 32% for all other foods, based on Weaver et al. (20). Bioavailability factors for iron were estimated at 6% for plant foods and 11% for animal source foods, based on a synthesis of sources, including FAO/WHO and Tseng et al. (21,22).

Bioavailability factors for zinc were calculated based on the phytate to zinc molar ratio. A ratio of ≤18 was considered to have 30% bioavailability, whereas for a phytate to zinc ratio >18, a bioavailability factor of 22% was used based on calculations derived from Hotz and Brown (23).

The estimated average requirements (EAR) were used to assess the probability of adequate nutrient intake (PA). The EAR approach has been recommended as an improvement over using recommended nutrient intakes (RNI) for nutrient assessment of groups (24) as it allows for calculation of the probability that the individual's intake is adequate given the requirement distribution. The assumptions of the probability approach are that: 1) the requirement and intakes are independent; 2) the mean and variance of the requirement is known; and 3) the shape of the requirements distribution is known or can be assumed (25). The Institute of Medicine (IOM) report on applications of dietary reference intakes indicates that for all nutrients except energy, intakes and requirements are independent (24). The mean, variance, and distribution of requirements are known or calculated and assumed normal for all nutrients, with the exception noted in the IOM document of iron, where the distribution of requirements is skewed (24).

PA was calculated by the equation PA = PROBNORM [(estimated child intake – EAR)/SD], where PROBNORM is the statistical function that calculates the probability that a child's intake is above the EAR. The mean probability of adequate micronutrient intake (MPA) for each child is the average of the PA for the 11 micronutrients in the analysis. The mean PA and mean MPA were then calculated for the entire sample. The probability approach to assess adequacy of intake has been used in recent studies with a similar aim (5,26) and is also now part of the World Food Dietary Assessment System, version 2.0 (14). More information about the application of the probability approach can be found in the IOM report on applications in dietary assessment (24).

To derive EAR based on international requirements set by the United Nations, the EAR was back calculated from FAO/WHO RNI (Table 1). The RNI is defined as $EAR + 2SD_{EAR}$ (21). The CV used to perform the calculations was based on IOM recommendations, set at 10% for all nutrients except 15% for niacin, 20% for vitamin A, and 25% for zinc (27–29).

Due to the fact that bioavailability adjustments were made to calcium, iron, and zinc, the requirement was adjusted to reflect the amount of absorbed nutrient required. An EAR for absorbed calcium was calculated from the recommended dietary allowance used in the Dietary Reference values for the United Kingdom using a CV of 10% (30). An EAR for absorbed zinc requirement was based on FAO/WHO using a CV of 25% (21).

Because iron requirements are not normally distributed, calculation for iron requirement and probability of adequate intake were derived from IOM iron requirements (29). Table 1-5 in that document was used as the basis for constructing a matrix for probability of adequate iron intake for children in age ranges 12-47 mo and 48-107 mo. We converted data in that table from 18% bioavailability to 10% bioavailability, which is more realistic of a high phytate, primarily vegetable-based diet (21) as typically consumed by children in the Philippines (Supplemental Table 1).

Statistical analysis was performed using SPSS version 11.5. PA and MPA were calculated separately for children 12-47 and 48-71 months of age using respective EAR. Pearson's correlations were run by age group to verify the linear association for MPA and individual PA for each micronutrient. Linear regression models have been estimated separately for DDS and DDS 10g. DDS was evaluated for sensitivity and specificity using MPA as the gold standard. Sensitivity and specificity analysis were performed to quantify the accuracy of DDS to correctly classify children with high MPA values and then to determine the DDS cut-off point that maximized sensitivity and specificity. Two MPA cut-off values (0.50 and 0.75) were used in the analysis to categorize the children with low or high nutrient intakes.

Table 1 Estimated average requirements and standard deviations used for calculating probability of adequate micronutrient intake for non-breastfeeding Filipino children 24-71 months of age[1]

Nutrient	Children 12-47 mo		Children 48-83 mo	
	EAR	SD	EAR	SD
Vitamin A, µg RE[2]	200	40	200	40
Vitamin C, mg	25	2,5	25	2,5
Thiamin, mg	0,4	0,04	0,5	0,05
Riboflavin, mg	0,4	0,04	0,5	0,05
Niacin, mg	4,6	0,69	6,2	0,92
Vitamin B_6, mg	0,4	0,04	0,5	0,05
Vitamin B_{12}, µg	0,8	0,08	1	0,1
Folate, µg	133	13,33	167	16,7
Absorbed calcium, mg	220	22	220	22
Absorbed Zinc, mg	0,83	0,083	0,97	0,097

1 Data for absorbed iron are in Supplemental Table 1. Probability of adequate absorbed iron intake back calculated by multiplying the values in table I-5 p.701 (29). These values are higher than the FAO/WHO, 2002 values and thus may lead to overestimation of inadequate intake.

2 The Philippines FCT calculates RE as 1 RE = 1 µg retinol or 6 µg ß-carotene. This is compatible with FAO/WHO calculations for RE's. The EAR for vitamin A was not back calculated from the RNI value, but was interpreted as the mean requirement µg RE/day reported in FAO/WHO, 2002 (21). The mean requirement is described as "the minimum daily intake of vitamin A as presented in µg retinol equivalents to prevent xerophthalmia in the absence of clinical or sub-clinical infection. The required level of intake is set to prevent clinical signs of deficiency, allow for normal growth and reduce the risk of vitamin A-related severe morbidity and mortality on a population basis" p. 97.

RESULTS

The mean age of the children was just under 4 y. One-half of the children in the study were male and one-half were female. Over one-third of the children in the sample suffered from undernutrition. The mean DDS was close to 5 and decreased to 4 when a 10-g minimum was applied (Table 2).

Table 2 Descriptive statistics of non-breastfeeding Filipino children 24-71 months of age [1, 2]

Characteristic	Value
Child age, mo	46.5 ±13.7
Gender (% male)	50.9
HAZ	-1.59 ±1.17
WAZ	-1.51 ±0.91
WHZ	-0.67 ±0.81
Stunting (%)	37.5
Underweight (%)	32.2
Wasting (%)	4.2
DDS	4.91 ±1.57
DDS 10g	4.05 ±1.54

[1] Values are means ± SEM or percentages where indicated
[2] Abbreviations used only in table: height-for-age Z score (HAZ), weight-for-age Z score (WAZ), weight-for height Z score (WHZ).

Nearly all children consumed a cereal/tuber; meat, fish, or poultry; and an item from the food group "other" (Table 3). Median energy intake was 3736 kJ (893 kcal). Cereals/tubers represented 68% of total energy intake. Meat, fish, and poultry accounted for 10% and fruits and vegetables accounted for another 8% of total energy intake. Energy intake from the "other" category accounted for 7% of total intake. Additional food intake data are presented in Supplemental Table 2.

As DDS increased, a larger percentage of children consumed items from 1 or more of the 3 fruit and vegetable groups or fats/oils. Only at a DDS of 7 or more were more than 50% of children consuming a food from the dairy, egg or legumes, pulses and nuts food group (Table 4).

Table 3 Summary of food group intakes by non-breastfeeding Filipino children 24-71 months of age [1]

Food Group	Children consuming, (%)	Food intake g	Energy intake kcal [2]
Cereals/tubers	99,9	182(133:239)	593(439:767)
Meat, poultry, fish	95,8	46(23:76)	61(30:116)
Other	87,1	12(4:42)	40(12:88)
Other fruit	51,9	8(0:53)	5(0:75)
Vitamin A rich fruits and vegetables	47,6	0(0:6)	0(0:5)
Other vegetables	47,2	0(0:5)	0(0:5)
Oils and fats	47,1	0(0:3)	0(0:22)
Dairy	38,3	0(0:8)	0(0:32)
Eggs	35,0	0(0:9)	0(0:15)
Pulses/nuts	28,4	0(0:4)	0(0:9)
Total		351(266:459)	893(687:1116)

[1] Values are medians (25^{th}, 75^{th} percentiles) n=2805.
[2] Multiply by 4.184 to convert kcal to kJ.

In general, median micronutrient intake was lower than the EAR (Table 5) and did not increase with increasing age of the child (data not shown). The mean MPA was 0.33. Only niacin had an average probability of adequate intake above 50%. The next highest intakes were for vitamin B_6, iron, and vitamin A. Intakes of absorbed calcium, absorbed zinc, and folate had the lowest probability of adequacy. Pearson's correlation coefficient for DDS and mean PA and mean MPA were significant for all nutrients except calcium and vitamin B_{12}. Results of correlations using the 10-g cut-off point were similar to the no-gram minimum. Mean MPA increased with DDS and DDS 10g (Figure 1).

DDS and child age in months were significant determinants of MPA in all 4 models tested (Table 6). In particular, higher values of DDS correspond to higher values of MPA, whereas age was negatively associated with MPA. When not controlling for energy, higher child weight values also increased the MPA. Energy intake was significantly and positively associated with MPA. Finally, the 2 models including energy seemed to perform better than the other 2 models, resulting in higher adjusted r^2 coefficients.

Sensitivity indicates the percentage of children truly at risk (low MPA) who are correctly classified by low DDS. Specificity maximizes the percentage of children not at risk of nutrient inadequacy (high MPA) and who are correctly classified by high DDS. Using an MPA of 0.50, the best DDS cut-off point (where the sensitivity and specificity curves meet) is 5 food groups. Increasing the MPA to 0.75 increased the DDS cut-off point to 6 food groups (Figure 2).

Table 4 Percent consumption of different food groups by DDS (no gram minimum) for non-breastfeeding Filipino children 24-71 months of age (n=2805)

DDS	Cereal/ Tuber	Meat, poultry, fish	Other fruit	Vitamin A rich fruits and vegetables	Other Vegetable	Oils & fats	Dairy	Eggs	Legumes, pulses & nuts
1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	100.0	89.2	0.6	4.5	1.3	1.3	2.5	0.6	0.0
3	100.0	90.7	26.1	19.5	16.0	19.7	14.7	7.2	6.1
4	100.0	94.5	45.0	36.6	35.6	31.1	21.1	19.8	16.1
5	99.9	97.1	52.6	50.6	52.2	50.2	38.0	33.6	25.7
6	100.0	98.4	64.7	63.7	64.3	64.9	54.2	49.4	40.3
7	100.0	99.7	82.1	72.1	72.4	80.0	70.0	69.3	54.5
8	100.0	100.0	88.4	87.0	86.2	87.0	86.2	87.7	77.5
9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5 Median micronutrient intake, mean probability of adequacy and correlation between mean PA and mean dietary diversity scores for non-breastfeeding Filipino children 24-71 months of age

	Intake[1]	PA[2]	Correlations[3]	
			DDS	**DDS 10 g**
Vitamin A, µg RE	142 (77:235)	0.34 ±0.41	0.37*	0.43*
Vitamin C, mg	13 (3.6:31.2)	0.31 ±0.45	0.25*	0.29*
Thiamin, mg	0.3 (0.2:0.5)	0.29 ±0.41	0.25*	0.31*
Riboflavin, mg	0.3 (0.2:0.4)	0.25 ±0.39	0.33*	0.40*
Niacin, mg	7.9 (5.7:10.6)	0.80 ±0.33	0.19*	0.23*
Vitamin B_6, mg	0.4 (.29:.56)	0.44 ±0.45	0.10*	0.13*
Vitamin B_{12}, µg	0.5 (0.2:1.0)	0.30 ±0.44	0.02	0.06*
Folate, µg	90 (61:1305)	0.19 ±0.35	0.30*	0.35*
Absorbed zinc, mg	0.6 (0.4:0.8)	0.21 ±0.37	0.08*	0.11*
Absorbed calcium, mg	61 (38:105)	0.13 ±0.33	0.001	0.02
Absorbed iron, mg	0.3 (0.2:0.5)	0.37 ±0.28	0.11*	0.15*
Mean MPA		0.33 ±0.19	0.36*	0.44*

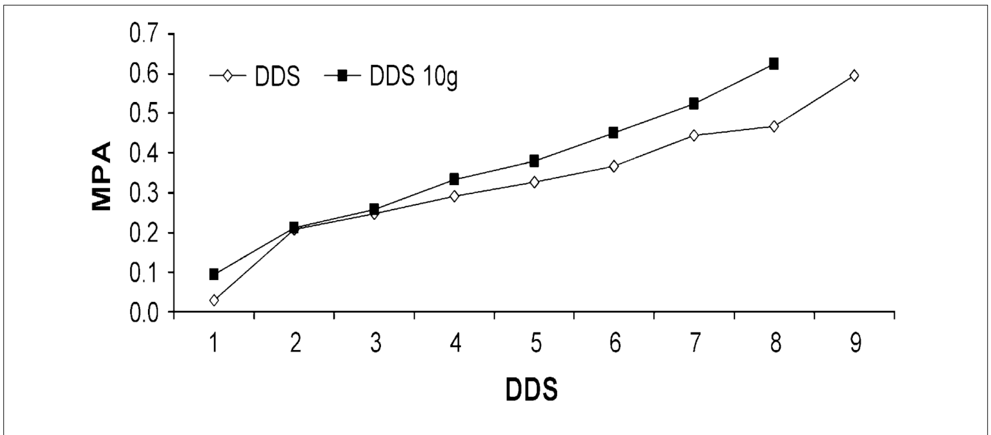
1 Values are medians (25th, 75th percentiles) n=2805.
2 Values are means +/- SEM n=2805.
3 * indicates p<0.05.

DISCUSSION

Overall, the diet of the Filipino children is based on differing combinations of rice, meat or fish, oil, vegetables, and fruit. Using 9 food groups, children had a mean DDS of nearly 5 (4.9) and a mean MPA of 33%. Using the DDS10g indicator, children consumed a mean of 4 (4.05) food groups. Both the DDS and DDS10g were significantly correlated with MPA, illustrating the potential of simple scores of dietary diversity for use as indicators of micronutrient adequacy of the diet. These findings are similar to those of other studies testing the utility of dietary diversity as an indicator of nutrient adequacy in the diet of preschool and school age children (4–7).

In a study of school-aged children in Kenya, the mean DDS was 5.18 (based on 7 food groups) and mean MPA was 70% (5). In Kenya, the highest probability of inadequate intake for individual nutrients was zinc, vitamin B_{12}, calcium, vitamin E, and vitamin A. The results from our study were similar, with calcium, folate, and zinc having the lowest PA.

Figure 1 MPA by DDS in non-breastfeeding Filipino children 24-71 months of age (n=2805)



There are 2 similar validation studies on children of roughly the same age group in developing countries, 1 from South Africa and another from Mali. These studies used recommended dietary allowance instead of EAR to validate adequate intake of micronutrients and calculated nutrient adequacy ratios and a mean nutrient adequacy ratio (MAR) for each child. The study in South Africa found a mean DDS of 3.58 (based on the same 9 food groups used in this study) with a mean MAR of 50% (6).

The nutrients with the lowest adequacy ratios were iron, calcium, and zinc. In Mali, the mean DDS was 5.8 (based on 8 food groups), with a mean MAR of 0.77 (4). The nutrients with the lowest nutrient adequacy ratio were riboflavin, calcium, vitamin A, and vitamin C.

The low intake of thiamin and riboflavin in this study was somewhat surprising, because these nutrients are present in most staple foods. Low PA of these nutrients in this study also differed from the results in Kenya (5). Rice has the lowest amount of thiamin and riboflavin per 100 g compared with wheat and maize, with maize being the staple food in Kenya, whereas the Filipino diet is based on rice. The practice of milling rice into highly polished white kernels removes an additional large percentage of thiamin. Highly milled polished rice contains roughly 0.06 mg thiamin/100 g, or only 12% of the EAR for a young child. Another explanation for the low intakes of thiamin and riboflavin in Filipino children comes from low milk consumption, particularly in children over the age of 1 y (1).

Our Pearson's correlation (0.36) between DDS and MPA was significant. The studies in Kenya, South Africa, and Mali also found significant correlations between DDS and nutrient intake: 0.39 (Mali), 0.32 (Kenya), and 0.64 (South Africa). In this study, using DDS 10g improved the correlation with MPA to 0.44, indicating that the performance of dietary diversity as an indicator of adequate micronutrient intake is improved when a minimum intake for each food group can be assessed. This finding has important implications for field use of the indicator, as collecting information on quantities of food consumed is more time consuming than simply recording the number of food groups consumed.

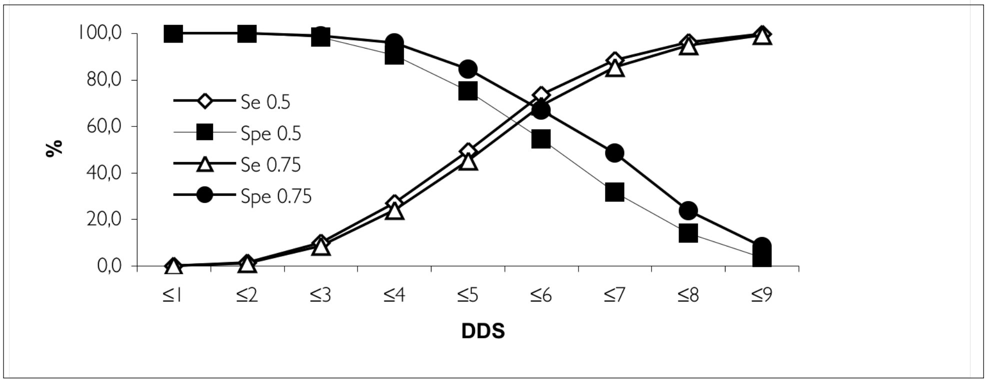
In our study, two nutrients, calcium and vitamin B_{12}, were not significantly correlated with DDS. Vitamin B_{12} is found only in animal source foods, particularly liver, dairy products, and eggs. The best sources of calcium are dairy products, some legumes, green leafy vegetables, and small fish species, particularly if the bones are consumed. Dairy, eggs, and legumes were the least consumed food groups in the study population and lack of these groups could explain the poor correlation with DDS. Green leaves and fish were more commonly consumed, although the portion size consumed tended to be small. The lack of consumption of any foods from the dairy, egg, or legume, pulses, nuts group is the more likely explanation of poor correlation, as small portion sizes were common for most food groups except cereals/tubers.

TABLE 6 Linear regression of determinants of MPA in non-breastfeeding Filipino children 24-71 months of age

	Unadjusted[1,3]				Adjusted for energy[2,3]			
Variable	**Coeff**	**SD**	**Coeff**	**SD**	**Coeff**	**SD**	**Coeff**	**SD**
DDS/ DDS 10g	0.0451*	0.0022	0.0618*	0.0024	0.0219*	0.0019	0.0333*	0.0021
Male	0.0107	0.0069	0.0102	0.0067	-0.0023	0.0056	-0.0019	0.0054
Age, mo	-0.0026*	0.0005	-0.0025*	0.0004	-0.0030*	0.0004	-0.0029*	0.0004
Weight, kg	0.0104*	0.0032	0.0093*	0.0031	-0.0000	0.0026	-0.0000	0.0025
Height, m	0.0008	0.0010	0.0007	0.0010	0.0011	0.0008	0.0010	0.0008
Energy, kcal					0.0004*	0.0000	0.0004*	0.0000
Constant	0.0084	0.0585	-0.0022	0.0565	-0.1195	0.0469	-0.1219	0.0460
Adj. R^2	0.150		0.205		0.460		0.475	

[1] Results in first two columns for DDS and second two columns DDS 10g.
[2] Results in first two columns DDS and second two columns DDS 10g.
[3] * indicates p<0.05.

Figure 2 Sensitivity and specificity of DDS for two different cut-off points of MPA for non-breastfeeding Filipino children 24-71 months of age.



Se = Sensitivity, Spe = Specificity. Sensitivity indicates the percentage of children truly at risk of inadequate micronutrient intake identified as at risk. Specificity identifies the percentage of children correctly identified as not at risk of inadequate micronutrient intake.

A final aim of the study was to determine cut-off points for DDS, which can be used to classify children who are at greater risk of inadequate micronutrient intake. Similar to the Kenya study and using the 50th percentile of MPA, our results (not shown) found the best cut-off point to maximize sensitivity and specificity is a DDS of 5. However, the 50th percentile of our population corresponded to a mean MPA of 0.31, which may not be considered a sufficiently high enough cut-off to achieve an adequate improvement in population micronutrient intake. The results in Figure 2 test the sensitivity and specificity cut-off points using MPA of 0.50 and 0.75, a methodology previously applied by Hatloy et al. using MAR (4). Using MPA of 0.50 and 0.75, the best cut-off point for maximizing both sensitivity and specificity is between DDS of 5 and 6. Determining a fixed cut-off point where children can be defined as having greater or less risk of inadequate micronutrient intake has potential application in both immediate population nutritional assessment and continued monitoring of improvement in micronutrient intake. The ultimate decision as to which is the most appropriate MPA to use to define the DDS cut-off point, as well as whether it is more desirable to maximize sensitivity or specificity or find the point that optimizes both, will depend on the desired use of the DDS indicator. For example, if the goal of the indicator is to maximize identification of at-risk children, one would aim to maximize sensitivity; however, this would reduce specificity, thereby including more children who are not truly at risk in the target group.

One potential use of the DDS is as an international indicator of risk of inadequate micronutrient intake. To realize this objective, additional validation studies using the same methodology for datasets from different geographic and cultural settings should be replicated.

One limitation of the study is that only one 24-h recall was available per child; therefore, it was not possible to correct for within-person variation of intake. Not accounting for this variation could affect the MPA as well as perhaps the DDS cut-off point. Future studies should test the use of the indicator after adjusting for within-person variation in intake.

The aim of this study was to determine how well a simple score of food groups can be used to predict adequate micronutrient intake. The results have shown that DDS is correlated with MPA and also that DDS is a significant determinant of MPA. Using the more rigorous measure of DDS 10g did improve the correlation and regression model. Additionally, energy intake had a strong influence on MPA.

Current methods used to assess micronutrient deficiencies primarily rely on biochemical diagnostic tests of blood or urine, which, although considered the gold standard, are often difficult, time consuming, and expensive to collect and analyze, and are thus not generally widely used in community settings for monitoring and evaluation of nutrition improvement programs. There is a need to develop convenient, cost efficient indicators that can measure changes in the micronutrient status of vulnerable populations. This paper demonstrates that a simple count of food groups can be used to predict the probability of adequate micronutrient intake in young non-breast-feeding Filipino children. Indices that include additional information such as quantities of food consumed or total energy intake should enhance the performance of the indicator. The decision about the level of detail to incorporate into a survey will depend on the time available for data collection, overall study budget, and purpose or objective for which the indicator will be used.

REFERENCES

1. Pedro MRA, Cerdena CM, Molano WL, Constantino A, Perlas LA, Palafox FF, Patalan L, Chavez M, Madriaga J, et al. The current state of nutrition in the Philippines: children in focus [Internet]. Manila: Food and Nutrition Research Institute; 2005 [cited 2006 March 29]. Available from: http:// www.fnri.dost.gov.ph/.
2. Pedro MRA, Benavides RC, Barba CVC. Dietary changes and their health implications in the Philippines. In: The double burden of malnutrition: case studies from six developing countries. Rome: FAO; 2006.
3. Hoddinott J, Yohannes Y. Dietary diversity as a food security indicator. Washington, DC: International Food Policy Research Institute, Food Consumption and Nutrition Division; 2002. Discussion paper no. 136.
4. Hatloy A, Torheim LE, Oshaug A. Food variety: a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr* 1998;52(12):891–8.
5. Ruel M, Graham J, Murphy S, Allen L. Validating simple indicators of dietary diversity and animal source food intake that accurately reflect nutrient adequacy in developing countries. Report submitted to GL- CRSP; 2004.
6. Steyn N, Nel J, Nantel G, Kennedy G, Labradarios D. Food variety and dietary diversity scores; are they good indicators of dietary adequacy? *Public Health Nutr* 2006;9:644–50.
7. Onyango A, Koski K, Tucker K. Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. *Int J Epidemiol* 1998;27:484–9.
8. FNRI (Food and Nutrition Research Institute). Nutritional guidelines for Filipinos. Revised ed. Manila (Philippines): FNRI; 2000.
9. Truswell S. Evolution of dietary recommendations, goals and guidelines. *Am J Clin Nutr* 1987;45:1060–72.
10. USDA. Dietary guidelines for Americans 2005 [Internet]. Washington, DC: USDA; [cited March 1, 2006]. Available from: http://www.healthierus.gov/dietaryguidelines/.
11. Ruel M. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr*. 2003;133:S3911–26.
12. Villavieja G, Cerdena C, Molano W, Lana R, Boquecosa J, Raymundo B, Nones C, Abaya H, Palafox E, et al. Fourth National Nutrition Survey, Philippines, 1993. Part A. Food consumption survey. *Philipp J Nutr* 1997;44:1–33.
13. Food and Nutrition Research Institute. The Philippine food composition tables. Revised ed. Manila (Philippines): FNRI; 1997.
14. User's Guide to the World Food Dietary Assessment System. [Internet] [cited 2005 June 28]. Accessed as a Word document from the International Network of Food Data Systems (INFOODS). Available from: http://www.fao.org/ infoods/.
15. USDA, Agricultural Research Service. USDA National Nutrient Database for Standard Reference, Release 18. USDA Nutrient Retention Factors, Release 5. 2003 Nutrient Data Laboratory [Internet]. Washington, DC: USDA; [cited 2006 July 17]. Available from: http://www.nal.usda.gov/fnic/foodcomp
16. FAO. Human energy requirements. Rome: FAO; 2004. FAO Food and Nutrition Technical Report Series 1. Report of a Joint FAO/WHO/UNU expert consultation.
17. WHO. Physical status: the use and interpretation of anthropometry. Geneva: WHO; 1995. WHO Technical Report Series 854.
18. Kennedy G, Nantel G. Basic guidelines for validating dietary diversity score as an indicator of adequate micronutrient intake [Internet] FAO; 2006 [cited 2006 April 15]. Available from: ftp://ftp.fao.org/ag/agn/ nutrition/dds_validation.pdf
19. Arimond M, Cohen R, Dewey K, Ruel M. Developing and validating simple indicators of complementary food intake and nutrient density for infants and young children in developing countries: protocol for data analysis. Washington, DC: IFPRI/UC Davis; 2005. Report submitted to the Food and Nutrition Technical Assistance Project, Academy for Educational Development.
20. Weaver CM, Proulx WR, Heaney R. Choices for achieving adequate dietary calcium with a vegetarian diet. *Am J Clin Nutr* 1999;70:S543–548.
21. FAO/WHO. Human and vitamin mineral requirements. Rome: FAO; 2002. Report of a Joint FAO/WHO expert consultation.
22. Tseng M, Chakraborty H, Robinson D, Mendez M, Kohlmeier L. Adjustments of iron intake for dietary enhancers and inhibitors in population studies: bioavailable iron in rural and urban residing Russian women and children. *J Nutr* 1997;127:1456–68.
23. Hotz C, Brown K, editors. Assessment of the risk of zinc deficiency in populations and options for its control. International Zinc Nutrition Consultative Group. Technical Document No. 1. *Food Nutr Bull* 2004;25(S2):S94–203.

24. Institute of Medicine. Dietary reference intakes: applications in dietary assessment. Washington, DC: National Academy Press; 2000.
25. Carriquiry AL. Assessing the prevalence of nutrient inadequacy. *Public Health Nutr* 1999;2:23–33.
26. Foote J, Murphy S, Wilkens L, Basiotis P, Carlson A. Dietary Variety increases the probability of nutrient adequacy among adults. *J Nutr* 2004;134:1779–85.
27. Institute of Medicine. Dietary reference intakes for vitamin c, vitamin e, selenium, and carotenoids. A report of the Panel on Dietary Antioxidants and Related Compounds and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Washington, DC: National Academy Press; 2000.
28. Institute of Medicine. Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B_6, folate, vitamin B_{12}, pantothenic acid, biotin and choline. A report of the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Washington, DC: National Academy Press; 2000.
29. Institute of Medicine. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium and zinc. Washington, DC: National Academy Press; 2001.
30. UK Department of Health. Dietary reference values for food energy and nutrients for the United Kingdom. London: Department of Health; 1991.

Supplemental
TABLE 1 Probability of adequate iron intake based on ranges of iron intakes for children 12-47 and 48-107 months[1]

Children					
12-47 mo			48-107 mo		
PA[2]	Iron intake, mg/d		PA	Iron intake, mg/d	
		0.18	0		0.2394
0.04	0.198	0.2232	0.04	0.2412	0.2952
0.07	0.225	0.2772	0.07	0.297	0.369
0.15	0.279	0.3528	0.15	0.3726	0.4734
0.25	0.3546	0.4176	0.25	0.4752	0.5634
0.35	0.4194	0.4788	0.35	0.5652	0.6516
0.45	0.4806	0.5418	0.45	0.6534	0.7398
0.55	0.5436	0.6102	0.55	0.7416	0.8352
0.65	0.612	0.6876	0.65	0.837	0.9486
0.75	0.6894	0.7884	0.75	0.9504	1.0944
0.85	0.7902	0.945	0.85	1.0962	1.3158
0.92	0.9468	1.0908	0.92	1.3176	1.521
0.96	1.0926	1.2258	0.96	1.5228	1.7136
1		1.2258	1		1.7136

[1] Table adapted from IOM 2002 table I-5, p.701 (29).
[2] Values in table I-5 multiplied by 0.18 and PI converted to PA.

Supplemental

TABLE 2 Top three individual foods for each food group contributing to energy intake by non-breastfeeding Filipino children 24-71 months of age

Food Group	Mean energy, kcal	% contribution to total energy intake
Cereals/tubers	365	67.8
Rice	60	40
Bread		6.6
Milled corn	30	3.3
Meat, poultry and fish	89	9.7
Pork	31	3.4
Chicken	6	0.7
Processed meat	6	0.7
Other	63	6.9
Sugar	47	5.2
Beverages (non-fruit juice)	14	1.5
Soup	1	0.1
Other fruit	59	6.5
Banana	50	5.5
Star apple	2.2	0.3
Other fruit[1]	1.8	0.2
Vitamin A rich fruit/vegetables	7	0.8
Mango	5.2	0.6
Squash	0.8	0.1
Malungay leaves	0.4	0.04
Other vegetables	5	0.5
Other vegetables[2]	1.4	0.2
Stringbean	0.8	0.08
Eggplant	0.6	0.06
Oils and fats	15	1.7
Cooking oil	12	1.3
Coconut milk	2.2	0.2
Margarine	0.7	0.08
Dairy	30	3.3
Filled milk	15	1.7
Whole full cream	7	0.8
Other milk products	2	0.3
Eggs	11	1.2
Hen egg	9.4	1
Duck egg	1.8	0.2
Other egg	0.05	0.006
Pulses/nuts/legumes	14	1.5
Mung beans	8	0.8
Peanuts	2	0.2
Other beans/nuts	2	0.2

1 Other fruit is a consolidated coding category, consisting of a variety of fruit not individually itemized during data collection(apple, pear, peach).

2 Other vegetables is a consolidated coding category, consisting of a variety of vegetables not individually itemized during data collection (mushrooms, celery, radish).

CHAPTER 3

FOOD VARIETY AND DIETARY DIVERSITY SCORES IN CHILDREN: ARE THEY GOOD INDICATORS OF DIETARY ADEQUACY?

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ABSTRACT

Objective: To assess whether a food variety score (FVS) and/or a dietary diversity score (DDS) are good indicators of nutrient adequacy of the diet of South African children.

Methods: Secondary data analyses were undertaken with nationally representative data of 1–8 year-old children (n = 2200) studied in the National Food Consumption Study in 1999. An average FVS (mean number of different food items consumed from all possible items eaten) and DDS (mean number of food groups out of nine possible groups) were calculated. A nutrient adequacy ratio (NAR) is the ratio of a subject's nutrient intake to the estimated average requirement calculated using the Food and Agriculture Organization/World Health Organization (2002) recommended nutrient intakes for children. The mean adequacy ratio (MAR) was calculated as the sum of NARs for all evaluated nutrients divided by the number of nutrients evaluated, expressed as a percentage. MAR was used as a composite indicator for micronutrient adequacy. Pearson correlation coefficients between FVS, DDS and MAR were calculated and also evaluated for sensitivity and specificity, with MAR taken as the ideal standard of adequate intake. The relationships between MAR and DDS and between anthropometric Z-scores and DDS were also evaluated.

Results: The children had a mean FVS of 5.5 (standard deviation (SD) 2.5) and a mean DDS of 3.6 (SD 1.4). The mean MAR (ideal = 100%) was 50%, and was lowest (45%) in the 7–8 year-old group. The items with the highest frequency of consumption were from the cereal, roots and tuber group (99.6%), followed by the 'other group' (87.6%) comprising items such as tea, sugar, jam and sweets. The dairy group was consumed by 55.8%, meat group by 54.1%, fats by 38.9%, other vegetables by 30.8%, vitamin-A-rich by 23.8%, other fruit by 22%, legumes and nuts by 19.7% and eggs by 13.3%. There was a high correlation between MAR and both FVS ($r = 0.67$; $p<0.0001$) and DDS ($r = 0.63$; $p<0.0001$), indicating that either FVS or DDS can be used as an indicator of the micronutrient adequacy of the diet. Furthermore, MAR, DDS and FVS showed significant correlations with height-for-age and weight-for-age Z-scores, indicating a strong relationship between dietary diversity and indicators of child growth. A DDS of 4 and an FVS of 6 were shown to be the best indicators of MAR less than 50%, since they provided the best sensitivity and specificity.

Conclusion: Either FVS or DDS can be used as a simple and quick indicator of the micronutrient adequacy of the diet.

INTRODUCTION

Micronutrient malnutrition remains one of the largest nutritional problems worldwide, affecting people in both developed and developing countries (1). Children are particularly vulnerable to micronutrient deficiency owing to their high nutrient requirements for growth and susceptibility to infectious diseases such as diarrhea and respiratory infections, which can inhibit nutrient absorption as well as decrease appetite (2). The nutrient density of the diet given to young children is often insufficient to meet their nutrient requirements, and increasing the diversity of foods provided to young children, particularly meat, poultry, fish, eggs, fruits and vegetables, is recommended to improve micronutrient intakes (3).

Despite the intuitive link between increasing diversity of the diet and increased nutrient intake, the relationship between dietary diversity and adequate micronutrient intake has not yet been sufficiently validated across different cultural settings and in different age groups. Progress towards developing an indicator of dietary diversity for use in public health settings has been slow due to a lack of consistent methodology and differences in the correlations of interest, which range from the relationship with energy intake to food security, child anthropometry and micronutrient adequacy. The few studies which have focused on the relationship between dietary diversity and micronutrient intake from the diet have mainly shown positive correlations (4-9).

In a summary of seven studies reviewed by Ruel, five found a positive association between dietary diversity score and nutrient adequacy (10). Of the studies focusing on young children, a positive correlation was found between dietary diversity score and nutrient adequacy in Mali (4), Kenya (6) and Niger (7), while inconsistent results or no correlation were found in Guatemala (11), Ghana (12) and Malawi (12). Greater dietary diversity was associated with improved nutrient adequacy in children 4 - 8 years of age in Kenya (13). Analysis of children aged 6 - 13.9 months from four developing countries concluded that there was promising evidence for the utility of dietary diversity as an indicator of inadequate nutrient intake (14).

Designing a simple and easy-to-use indicator reflective of the nutrient adequacy of the diet has become a priority for many working in the field of public health nutrition. Much of the preliminary work on this subject, including developing a validation protocol and conducting the first validation studies using the protocol, was conducted by the World Health Organization (WHO), the International Food Policy Institute (IFPRI) and the University of California at Davis. To further efforts towards development of an indicator of micronutrient adequacy of the diet, the Food and Agricultural Organization of the United Nations (FAO), WHO and IFPRI convened a workshop in October 2004 to refine and disseminate a methodology for validating indicators of dietary diversity for different age groups. The analysis in the present paper is based on the protocol refined during the workshop.

MATERIALS AND METHODS

Subjects

Secondary data analyses were undertaken of the National Food Consumption Survey (NFCS), which took place in 1999. The NFCS population comprised children aged 1 to 8.9 years (12 - 108 months) in South Africa and was a nationally representative sample (n = 2200, weighted for provincial representativeness), which was randomly selected. A detailed description of this process is given elsewhere (15,16).

Dietary Intake

The NFCS collected data by 24-hour recall, a method which has been used by numerous other researchers (6,8,17). A 24-hour recall was conducted with the caregiver of each child by trained interviewers who visited the homes of the participants. Dietary aids comprising household utensils and wax food models were used to determine portion sizes. Relative validity was determined by comparison with data obtained from the same participants using a food-frequency questionnaire. Furthermore, three 24-hour recalls were repeated in 10% of the sample. The dietary results are available elsewhere (18).

Anthropometry

Height and weight of each participant were determined according to recommended techniques. Anthropometric results have been published elsewhere (18).

Diet diversity and food variety scores

The evaluation of dietary adequacy used in the present analysis is based on the method described by Hatloy et al. (4) in Mali. The dietary diversity score (DDS) is defined as the number of food groups consumed over a period of 24 h. The diet was classified according to nine food groups as recommended by FAO, which included: 1. cereals, roots and tubers; 2. vitamin-A-rich fruits and vegetables; 3. other fruit; 4. other vegetables; 5. legumes and nuts; 6. meat, poultry and fish; 7. fats and oils; 8. dairy; and 9. eggs. Other remaining items such as tea, sugar and sweets were not used in DDS and food variety score (FVS) calculations. The FVS is defined as the number of food items consumed over a 24 h period, from a possible total of 45 items (4). The possible total (n = 45) reflects all the different types of food items eaten by this sample of children.

In order to determine the nutrient adequacy of the diet, the nutrient adequacy ratio (NAR,%) was calculated for each of 11 micronutrients (vitamins A, B_6, B_{12} and C, niacin, thiamin, riboflavin, folate, calcium, iron and zinc) and energy and protein. NAR was calculated as the intake of a nutrient divided by the recommended intake for that nutrient (RNI), using WHO/FAO recommended intakes (19) which are set at two standard deviations above the average requirements. In the case of iron and zinc, the category for moderate bioavailability was used. The mean adequacy ratio (MAR, %) was calculated as a measure of the adequacy of the overall diet, where MAR is the sum of each NAR (truncated at 100%) divided by the number of nutrients (excluding energy and protein). For both NAR and MAR a value of 100% is the ideal since it means that the intake is the same as the requirement.

Pearson correlation tests were done between DDS (and NARs) and MAR and between FVS and MAR to test for a significant relationship, while controlling for energy. Finally, the DDS and FVS cut-off points optimizing sensitivity, specificity and positive predictive values for MAR were determined.

RESULTS

The anthropometric characteristics of the sample are summarized in Table 1. The high negative Z-scores for height and weight show that the values are skewed to the left, i.e. there is a large degree of stunting and underweight prevalent in the group.

Table 1 Summary of South African children's anthropometric characteristics determined in the National Food Consumption Survey, 1999

Variable	1-3 y (n=795)[1]	4-6 y (n=861)[1]	7-8 y (n=544)[1]	All (n=2200)[1]
Age (m)	29.8 (8.5)	65.2 (9.7)	95.9 (8.4)	60.0 (25.3)
Weight (kg)	12.6 (2.1)	18.3 (3.3)	23.9 (5.8)	17.6 (5.3)
Height (m)	0.87 (0.07)	1.08 (0.08)	1.23 (0.09)	1.04 (0.15)
HAZ[2]	-0.95 (1.33)	-0.85 (1.34)	-0.71 (1.41)	-0.85 (1.35)
WAZ[3]	-0.50 (1.09)	-0.44 (1.16)	-0.50 (1.29)	-0.48 (1.15)
WHZ[4]	0.16 (1.05)	0.12 (1.23)	0.01 (1.47)	0.11 (1.19)

1 Values are expressed as mean (standard deviation).
2 HAZ height-for-age Z score.
3 WAZ weight-for-age Z score.
4 WHZ weight-for-height Z score.

Table 2 shows the MAR and the NARs of individual nutrients in the children's diet. MAR was lowest (57.3%) in the 7 – 8-year-old children and averaged 63.3% for the group as a whole. FVS and DDS were similar in all age groups, being 5.5 and 3.6, respectively, for the whole group. Nutrients which had an average NAR of at least 100% were protein, zinc, vitamin B_{12}, vitamin C, riboflavin and thiamin. Those with an average NAR greater than or equal to 90% were energy, iron, vitamin A and vitamin B_6. The average NARs for calcium and folate were too low, being less than 56% for calcium and less than 65% for folate.

Table 2 Mean adequacy ration (MAR), nutrient adequacy ratios (NAR) food variety score (FVS) and dietary diversity score (DDS) of South African children in the National Food Consumption Survey, 1999

Variable	1-3 y (n=795)[1]	4-6 y (n=861)[1]	7-8 y (n=544)[1]	All (n=2200)[1]
MAR (%)	64.7 (17.0)	65.8 (18.8)	57.3 (25.2)	63.3 (19.4)
FVS	5.37 (2.23)	5.58 (2.56)	5.67 (3.24)	5.52 (2.54)
DDS	3.51 (1.18)	3.60 (1.41)	3.64 (1.74)	3.58 (1.37)
NAR (%) vitamin A	92.4 (146.9)	96.9 (243.3)	90.4 (277.3)	93.7 (210.7)
NAR (%) vitamin B_6	100.1 (60.2)	108.2 (75.3)	68.6 (58.4)	95.5 (67.6)
NAR (%) vitamin B_{12}	238.4 (610.7)	243.0 (888.3)	167.4 (753.4)	222.6 (750.1)
NAR (%) vitamin C	104.2 (194.4)	108.9 (207.1)	157.1 (960.4)	119.1 (417.4)
NAR (%) calcium	66.4 (51.8)	52.0 (40.7)	46.1 (44.5)	55.7 (47.3)
NAR (%) folate	60.9 (41.4)	72.8 (51.7)	54.5 (51.8)	63.9 (47.7)
NAR (%) iron	81.4 (48.8)	107.8 (65.3)	77.5 (66.3)	90.8 (59.6)
NAR (%) niacin	94.1 (56.7)	96.4 (61.8)	70.8 (58.2)	89.3 (59.6)
NAR (%) riboflavin	139.2 (118.5)	128.6 (135.6)	89.4 (121.6)	122.8 (126.9)
NAR (%) thiamin	118.4 (51.4)	120.6 (55.1)	86.8 (50.6)	111.5 (54.1)
NAR (%) zinc	103.6 (49.2)	104.0 (54.9)	103.2 (75.1)	103.7 (56.0)
NAR (%) energy	96.2 (33.7)	91.4 (35.3)	81.8 (37.9)	90.7 (35.3)
NAR (%) protein	133.6 (58.0)	137.7 (62.9)	127.1 (74.3)	133.6 (62.7)

[1] Values expressed as mean (standard deviation).

Pearson correlation coefficients between adequacy ratios and different micronutrients revealed that all correlations were significant ($p<0.05$) with the exception of DDS with vitamin C in the group as a whole (Table 3). MAR showed a strong positive correlation (all $r >0.6$) with both DDS and FVS in all age groups.

Pearson correlation coefficients were also determined between anthropometric values and NAR, MAR, DDS and FVS (Table 4). The most striking finding was the significant positive correlations between anthropometric Z scores and FVS, DDS and MAR for the group as a whole and all age groups, with the exception of weight-for-height Z score in the 1-3 y group. Nutrients which showed little or no correlation with mean Z-scores were vitamin A, vitamin C and vitamin B_{12}.

Table 3 Pearson correlation coefficients between nutrient adequacy ratio (NAR) of certain nutrients and food variety score (FVS) and dietary diversity score (DDS) of South African children in the National Food Consumption Survey, 1999[1]

Variable	All (n=2200)		1-3 y (n=795)		4-6 y (n=861)		7-8 y (n=544)	
	FVS	DDS	FVS	DDS	FVS	DDS	FVS	DDS
NAR (%) vitamin A	0.19	0.20	0.23	0.25	0.16	0.17	0.21	0.20
NAR (%) vitamin B_6	0.58	0.48	0.61	0.51	0.62	0.51	0.60	0.46
NAR (%) vitamin B_{12}	0.11	0.13	0.13	0.16	0.10	0.11	0.12	0.11
NAR (%) vitamin C	0.18	0.15	0.36	0.32	0.34	0.31	0.11	0.06 (ns)
NAR (%) calcium	0.29	0.25	0.23	0.19	0.39	0.35	0.35	0.30
NAR (%) folate	0.34	0.30	0.33	0.28	0.40	0.34	0.30	0.24
NAR (%) iron	0.29	0.26	0.26	0.24	0.33	0.29	0.27	0.23
NAR (%) niacin	0.56	0.49	0.54	0.49	0.59	0.52	0.61	0.52
NAR (%) riboflavin	0.42	0.36	0.42	0.36	0.44	0.40	0.42	0.33
NAR (%) thiamin	0.27	0.22	0.23	0.19	0.33	0.28	0.30	0.22
NAR (%) zinc	0.45	0.40	0.44	0.40	0.47	0.42	0.44	0.39
NAR (%) energy	0.47	0.38	0.44	0.36	0.52	0.44	0.48	0.35
NAR (%) protein	0.49	0.45	0.45	0.42	0.54	0.49	0.49	0.44
MAR (%)	0.67	0.63	0.65	0.62	0.70	0.66	0.71	0.66

1 Correlation significant at p<0.5 unless indicated ns.

Table 4 Pearson correlation coefficients between nutrient adequacy ratio (NAR) of certain nutrients with height-for-age Z score (HAZ), weight-for-age Z score (WAZ) and weight-for-height Z score (WHZ) of South African children in the National Food Consumption Survey, 1999

	All (n=2200)			1-3 y (n=795)			4-6 y (n=861)			7-8 y (n=544)		
NAR (%)	HAZ	WAZ	WHZ	HAZ	WAZ	WHZ	HAZ	WAZ	WHZ	HAZ	WAZ	WHZ
Vitamin A	0.04	0.04	0.01	0.02	0.01	-0.01	0.05	0.06	0.02	0.04	0.04	-0.01
Vitamin B_6	0.15*	0.18*	0.09*	0.16*	0.13*	0.04	0.18*	0.21*	0.10*	0.18*	0.25*	0.14*
Vitamin B_{12}	0.02	0.01	0.00	-0.01	-0.03	-0.02	0.04	0.04	0.01	0.03	0.02	-0.01
Vitamin C	0.02	0.03	0.02	0.06	0.05	0.01	0.14	0.11*	0.01	-0.04	-0.00	0.03
Calcium	0.08*	0.12*	0.07*	0.05	0.09*	0.07	0.16*	0.16*	0.04	0.08	0.17*	0.13
Folate	0.11*	0.13*	0.05*	0.08*	0.10*	0.06	0.15*	0.15*	0.05	0.13*	0.13	0.03
Iron	0.10*	0.08*	-0.00	0.10*	0.07	-0.01	0.09*	0.06	-0.03	0.12	0.15*	0.05
Niacin	0.15*	0.15*	0.05	0.15*	0.09*	-0.01	0.16*	0.17*	0.06	0.18*	0.25*	0.13
Riboflavin	0.09	0.12*	0.07*	0.08*	0.08*	0.03	0.12*	0.12*	0.05	0.13	0.24*	0.18*
Thiamin	0.08*	0.09*	0.04	0.03	0.07	0.06	0.14*	0.10*	-0.00	0.15*	0.15*	0.03
Zinc	0.13*	0.13*	0.04	0.10*	0.09*	0.02	0.13*	0.11*	0.01	0.18*	0.22*	0.10
Energy	0.15*	0.16*	0.06*	0.08*	0.11*	0.08*	0.23*	0.18*	0.01	0.19*	0.22*	0.09
Protein	0.14*	0.15*	0.05*	0.10*	0.09*	0.03	0.17*	0.16*	0.04	0.19*	0.23*	0.10
FVS	0.21*	0.23*	0.10*	0.21*	0.14*	0.01	0.23*	0.26*	0.11*	0.20*	0.35*	0.25*
DDS	0.19*	0.21*	0.10*	0.15*	0.10*	-0.01	0.23*	0.25*	0.10*	0.17*	0.32*	0.25*
MAR (%)	0.17*	0.19*	0.08*	0.13*	0.11*	0.03	0.21*	0.20*	0.05	0.25*	0.33*	0.17*

1 * indicates p <0.01.

Figure 1 shows the relationship between DDS and NARs of energy, protein and minerals. For all nutrients there was an increase in NAR as DDS increased. For energy, NAR reached 100% at a DDS of 4.5, while NAR reached 100% at a DDS of 2 for protein. NAR increased above 100% at a DDS of 4 for zinc and at a DDS of 5 for iron. Calcium remained below 100% of NAR (Figure 1). All NARs for vitamins increased as DDS increased (Figure 2). NAR reached 100% at a DDS of 6 for folate; at a DDS of 4 for vitamins A, C and B_6; and at a DDS of 3 for riboflavin. Figure 3 presents the relationship between DDS and Z-scores. The Z-score rose above zero at a DDS of 4, 7.5 and 8 for weight-for-height, weight-for-age and height-for-age, respectively.

Figure 1 Mean nutrient adequacy ratio (NAR, expressed as %) of energy and nutrients at different levels of dietary diversity score (DDS)

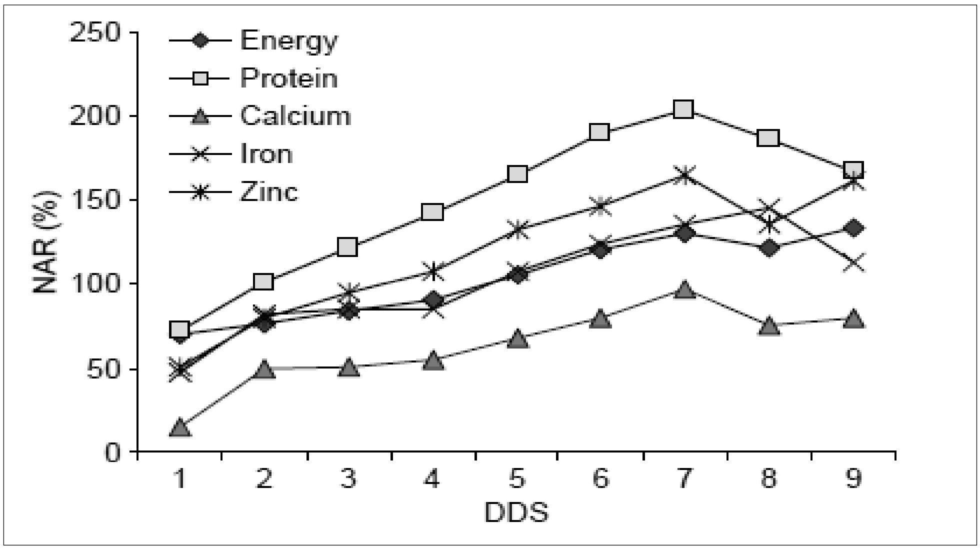
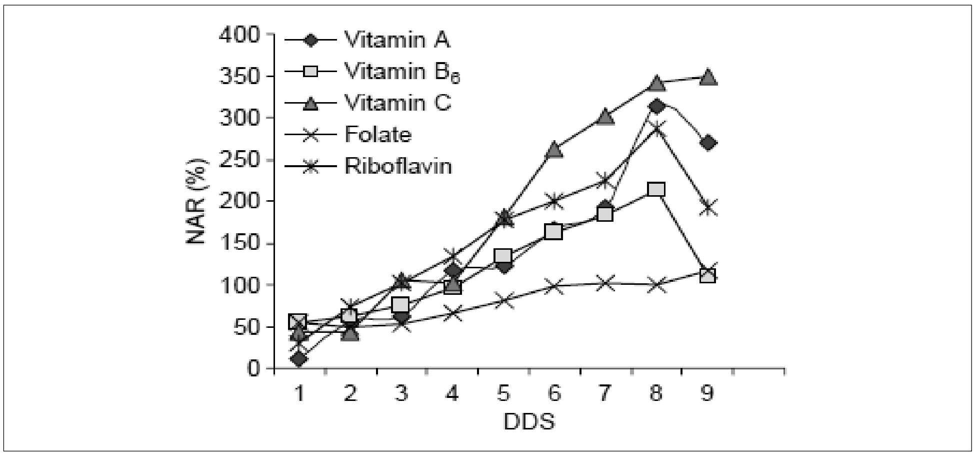


Figure 2 Mean nutrient adequacy ratio (NAR, expressed as %) of vitamins at different levels of dietary diversity score (DDS)



Mean MAR values for different levels of DDS and FVS are presented in Table 5. If one evaluates levels having an MAR of at least 70%, FVS is above 11 with a DDS of at least 4. Another alternative is to have a DDS of at least 8 with an FVS of 6 – 10. No child had MAR of 100%. Those having a DDS of less than 4 and an FVS of less than 5 had MAR of less than 50%.

Figure 3 Mean anthropometric Z-scores (WAZ – weight-for-age; HAZ – height-for-age; WHZ – weight-for-height) at different levels of dietary diversity score (DDS)

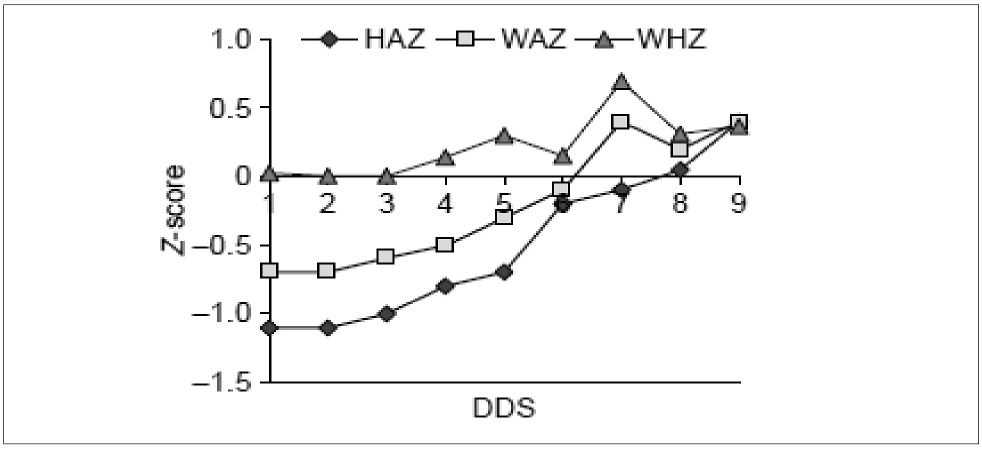


Table 5 Mean adequacy ratio (MAR) (%) for different levels of food variety score (FVS) and dietary diversity score (DDS) of South African children in the National Food Consumption Survey, 1999

	FVS				
DDS	**0-5**	**6-10**	**11-15**	**16-20**	**≥ 21**
0	1.4 (n=1)				
1	26.4 (n=114)				
2	38.0 (n=494)	53.1 (n=6)			
3	44.9 (n=469)	56.8 (n=73)			
4	50.4 (n=194)	55.3 (n=279)	73.4 (n=2)		
5	45.4 (n=8)	62.3 (n=269)	74.0 (n=24)		
6		67.2 (n=115)	75.9 (n=51)	79.9 (n=2)	
7		66.7 (n=26)	77.6 (n=36)	85.8 (n=5)	
8		75.5 (n=3)	75.0 (n=23)	81.7 (n=2)	86.9 (n=1)
9		69.9 (n=1)	83.0 (n=1)		

Figures 4 and 5 indicate the sensitivity and specificity of the receiver – operator characteristic curves for MAR using DDS and FVS. If one selects < 50% MAR as a cut- off for sensitivity and >50% MAR for specificity, then a DDS of 4 is most appropriate. It gives a sensitivity of 75% and a specificity of 70%. Using the same cut-off points for FVS makes an FVS of 6 the most appropriate since the sensitivity is 82% and the specificity is 65%.

Figure 4 Sensitivity (sens) and specificity (spec) (%) for different cut-off points of diet diversity score (DDS)

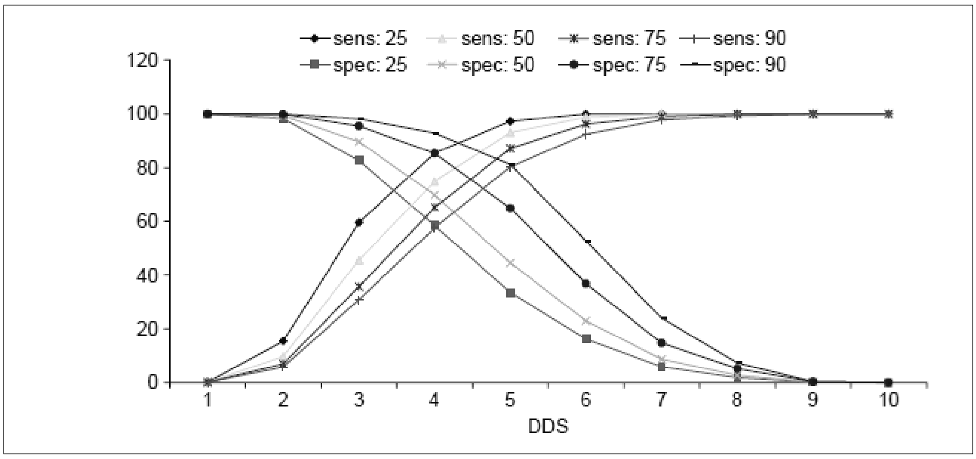
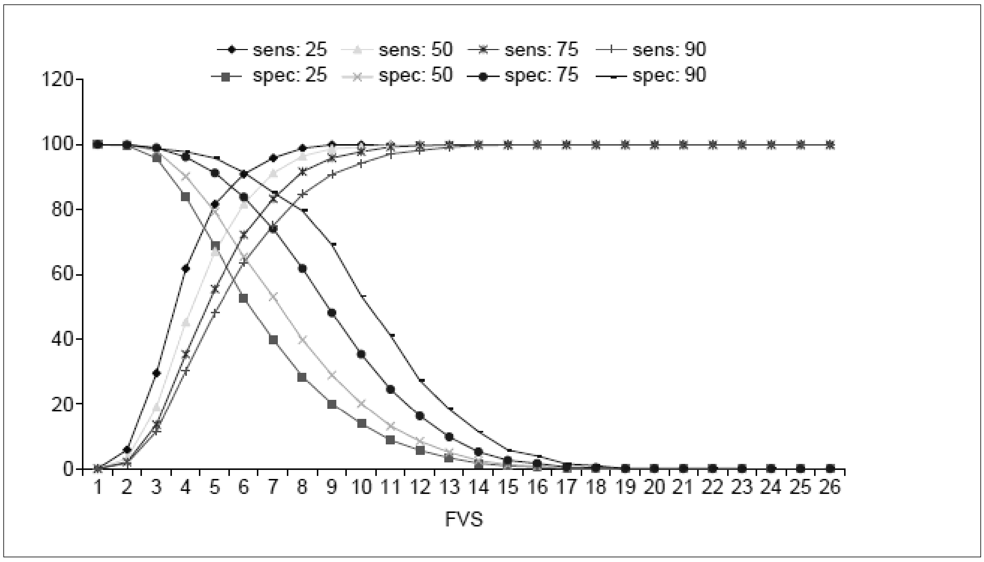


Figure 5 Sensitivity (sens) and specificity (spec) (%) for different cut-off points of food variety score (FVS)



DISCUSSION

Since 1990 researchers in the USA have been promulgating a variety of foods in the diet (20), the underlying principle being that variety will ensure an adequate intake of essential nutrients and hence promote good health (7, 21, 22).

But there has been much speculation about what dietary variety encompasses and how it should be measured. In South Africa there is a food-based dietary guideline (23) which advocates: 'Enjoy a variety of foods'. However, this has not been quantified to date and health workers might not be sure how to interpret it.

Overall, the diet of South African children as measured in the NFCS in 1999 was found to have low mean FVS and DDS of 5.5 and 3.6, respectively, compared with some other developing countries. Although this might be due in part to the different dietary methods used, it should be recognized that dietary variety is very limited in the majority of children's diets in South Africa (18). In Guatemala, Brown et al.(11) measured an FVS of 10 in 9 - 11-month-old children. In four African countries, Kenya (6), Niger (7), Ghana and Malawi (12), DDS was found to be 6, 4.8, 7.1 and 8, respectively. In Mali (4) MAR was found to be 0.77 for pre-school children, while in South Africa it was only 0.63. Thus it appears that South African children have a diet with little dietary variety. Furthermore, it was found that certain micronutrients were particularly deficient in the diet, these being calcium and folate. Although iron and zinc intakes appeared to be reasonable, bioavailability was based on the RNI for a moderate intake. Not all studies have taken this into consideration when calculating variety indicators.

It is difficult to compare countries on the basis of DDS and FVS because of the different ways in which these indicators have been defined and calculated in different countries (4). Some have counted food groups, some food codes or even food ingredients. Thus, in an attempt to overcome this, some researchers have developed other ways of classifying dietary quality such as the Healthy Eating Index and Dietary Quality Index (24-27). The disadvantages of these indices, however, are that the methods become more complex and time-consuming and hence can deflect from the very purpose for which they were designed.

Individual dietary diversity scores have promise as a rapid and efficient means to estimate nutrient adequacy of the diet. For example, health professionals can do a quick 24-hour recall with a caregiver to ascertain a child's DDS over the previous 24h. Children who have a DDS value less than 6 will most probably have weight-for-age and weight-for-height Z-scores less than zero and should be regarded as being at risk of undernutrition. This measure can also be useful as an indicator to assess improvement in diets over time. Recent applications of such measures include, for example, the use of DDS as an indicator in the Knowledge, Practice and Coverage Surveys used to monitor progress in child survival projects (28) and as part of Demographic and Health Surveys.

Health workers require simple, quick and reasonably accurate indicators to evaluate the dietary intake of children. In the fast-paced primary health-care setting, it is not feasible to use lengthy dietary intake methods to establish whether the diet is adequate in terms of micronutrient quality; they want something fast which can assist them in classifying children according to the quality of their diet. This would be one specific use of the DDS and/or FVS, particularly since it has been shown to correlate significantly with MAR (14) and with weight-for-age, height-for-age and weight-for-height Z-scores in the present study. Furthermore, in eight studies in children, six showed significant associations between an indicator of dietary variety and nutritional status (10).

Hence, health-care workers in the South African context can simply question the caregivers of children regarding the number of food groups they usually give to their children on an average day. A DDS of less than or equal to 7 may result in weight-for-age and/or weight-for-height Z-sore of less than zero, while a DDS of less than 3 is associated with height-for-age Z-score of a less than zero. Furthermore, a DDS of 4 and an FVS of 6 were shown to be the best indicators of MAR less than 50%, since they provided the best sensitivity and specificity.

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REFERENCES

1. World Health Organization. World Health Report, 2002. Geneva: WHO; 2002.
2. Ochoa TJ, Salazar-Lindo E, Cleary TG. Management of children with infection-associated persistent diarrhea. *Seminars in Pediatric Infectious Diseases* 2004; 15: 229 – 36.
3. Pan American Health Organization (PAHO)/World Health Organization (WHO). Guiding Principles for Complementary Feeding of the Breastfed Child. Washington, DC: PAHO/WHO; 2003.
4. Hatloy A, Torheim LE, Oshaug A. Food variety – a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr* 1998; 52: 891 – 8.
5. Ogle BM, Hung PH, Tuyet HT. Significance of wild vegetables in micronutrient intakes of women in Vietnam: an analysis of food variety. *Asia Pac J Clin Nutr* 2001; 10: 21 – 30.
6. Onyango A, Koski KG, Tucker KL. Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. *Int J Epidmiol* 1998; 27: 484 – 9.
7. arini A, Bakari S, Delisle H. The overall quality of the diet is reflected in the growth of Nigerian children. *Sante* 1999; 9: 23– 31.
8. Foote JA, Murphy SP, Wilkens LR, Basiotis PP, Carlson A. Dietary variety increases the probability of nutrient adequacy among adults. *J Nutr* 2004; 134: 1779 – 85.
9. Bernstein MA, Tucker KL, Ryan ND, O'Neill EF, Clements KM, Nelson ME, et al. Higher dietary variety is associated with better nutritional status in frail elderly people. *J Am Diet Assoc* 2002; 102: 1096 – 104.
10. Ruel MT. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr* 2003; 133: S3911 – 26.
11. Brown KH, Peerson JM, Kimmons JE, Hotz C. Options for achieving adequate intake from home-prepared complementary foods in low income countries. In: Black RE, Fleischer Michaelsen K, editors. Public Health Issues in Infant and Child Nutrition. Nestle Nutrition Workshop Series, Pediatric Program Vol. 48. Philadelphia, PA: Vevey/Lippincott Williams and Wilkins; 2002. p. 10 – 22.
12. Ferguson E, Gibson R, Opare-Obisaw C, Osei-Opare C, Lamba C, Ounpuu S. Seasonal food consumption patterns and dietary diversity of rural preschool Ghanaian and Malawian children. *Ecol Food Nutr* 1993; 29: 219 – 34.
13. Ruel M, Graham J, Murphy S, Allen L. Validating simple indicators of dietary diversity and animal source food intake that accurately reflect nutrient adequacy in developing countries. University of California at Davis: Report for Global Livestock CRSP; 2004.
14. Dewey K, Cohen R, Arimond M, Ruel M. Developing and Validating Indicators of Feeding Frequency and Nutrient Density of Complementary Foods for the Breastfed Child in Developing Countries. Washington, DC/Davis, CA: International Food Policy Research Institute and University of California at Davis; 2004.
15. Steyn NP, Labadarios D, Maunder E, Nel J, Lombard C, MacIntyre U, et al. Secondary anthropometric data analyses of the National Food Consumption Survey in South Africa: the double burden. *Nutrition* 2005; 21: 4 – 13.
16. Labadarios D, Steyn NP, Maunder E, MacIntyre U, Gericke G, Swart R, et al. The National Food Consumption Survey (NFCS): South Africa, 1999. *Public Health Nutr* 2005; 8: 533 – 43.
17. Rose D, Meershoek S, McEwan M. Evaluation of a rapid field tool for assessing household diet quality in Mozambique. *Food Nutr Bull* 2002; 23: 181 – 9.
18. Labadarios D, Steyn NP, Maunder E, MacIntyre U, Swart R, Gericke G, et al. The National Food Consumption Survey (NFCS): Children aged 1 - 9 years in South Africa, 1999. Pretoria: Department of Health; 2000
19. Food and Agriculture Organization (FAO) /World Health Organization (WHO). Human Vitamin and Mineral Requirements. Rome: FAO; 2002. Report of a Joint FAO/WHO Expert Consultation.
20. Hahn NI. Variety is still the spice of life. *J Am Diet Assoc* 1995; 95: 1096 – 7.
21. Food and Agriculture Organization/International Life Sciences Institute (ILSI). Preventing Micronutrient Malnutrition: A Guide to Food-based Approaches. Washington, DC: ILSI Press; 1997.
22. Tucker K, Mayer J. Eat a variety of healthful foods: old advice with new support. *Nutr Reviews* 2001; 59: 156 – 8.
23. Maunder EMW, Matji J, Hlatshwayo-Molea T. Enjoy a variety of foods – difficult but necessary in developing countries. *South African J Clin Nutr* 2001; 14(Suppl. 3): S7 – 11.
24. Kennedy ET, Ohls J, Carlson S, Fleming K. The healthy eating index: design and applications. *J Am Diet Assoc* 1995; 95: 1103 – 8.
25. Kant AK. Indexes of overall diet quality: a review. *J Am Diet Assoc* 1996; 96: 785 – 91.
26. Drewnowski A, Henderson SA, Shore AB, Fischler C, Preziosi P, Hercberg S. Diet quality and dietary diversity in France: implications for the French paradox. *J Am Diet Assoc* 1996; 96: 663 – 9.

27. Feskanich D, Rockett HRH, Colditz GA. Modifying the healthy eating index to assess diet quality in children and adolescents. *J Am Diet Assoc* 2004; 104: 1375 – 83.
28. Espeut D. Knowledge, Practices and Coverage Survey 2000+ Field Guide [Internet]. Calverton, MD: The Child Survival Technical Support Project; 2001 [cited 5 June 2005]. Available from: http://www.childsurvival.com/kpc2000/FldGuide_Sept_2003.doc.

CHAPTER 4

PERFORMANCE OF EIGHT FOOD GROUP DIVERSITY INDICATORS TO PREDICT PROBABILITY OF ADEQUATE INTAKE OF MICRONUTRIENTS IN WOMEN OF REPRODUCTIVE AGE IN URBAN MALI

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Submitted

FORWARD

The results in this paper were excerpted from one of a series of technical reports produced under the Women's Dietary Diversity Project (WDDP) an initiative funded through the Food and Nutrition Technical Assistance II Project (FANTA-2), managed by the Academy for Educational Development (AED). The WDDP is a collaborative research initiative to assess the potential of simple indicators of dietary diversity to function as proxy indicators of the micronutrient adequacy of women's diets in resource-poor areas. Work carried out under the WDDP includes the development of a standard analysis protocol and application of that protocol to five existing data sets meeting the analytic criteria established by the project. Indicator performance in just one site is not sufficient to address the broader objective of developing indicators for global use. A portion of these results in combination with those from the other collaborator sites; including Bangladesh, Burkina Faso, Mozambique and the Philippines will be prepared for publication as a Journal supplement.

ABSTRACT

Micronutrient malnutrition is a public health problem in many developing countries, including Mali. A diet dominated by staple foods with little variety can contribute to the burden of micronutrient deficiencies. Two rounds of twenty-four hour weighed dietary recall records from a sample of 102 women for round one and 96 women for round two from Bamako Mali were used to assess the potential of indicators of dietary diversity as predictors of micronutrient intake. Eight food group diversity scores were constructed from six, nine, thirteen and twenty one food groups and applying a 1g or 15g restriction to count in the score. The probability of adequacy for eleven micronutrients was calculated taking into account inter and intra individual variations in intakes. A summary measure of dietary quality, the mean probability of micronutrient adequacy (MPA) was constructed based on micronutrient adequacy across the eleven micronutrients. Mean food group diversity scores ranged from 4.3 (0.9) to 7.1 (1.5). Correlations with food group diversity scores and total energy intake ranged from 0.17 to 0.26. Correlations between food group diversity scores and MPA ranged from 0.25 to 0.48 and were all significant both with and without controlling for energy. The fifteen gram restricted scores based in six and nine food groups had the highest area under the curve (0.75) at an MPA cut-off of 50 percent. A cut-off of five or more food groups maximized the balance between sensitivity and specificity for these two scores. These results demonstrate that dietary diversity scores are useful proxy indicators of adequate intake across a range of key micronutrients, particularly when food consumed in small amounts are excluded from counting in score construction.

INTRODUCTION

Micronutrient malnutrition is a serious public health concern in developing countries. Women of reproductive age are disproportionately affected due to higher vulnerability to nutrient deficiencies throughout the reproductive years. In Bamako, Mali it is estimated that 54 percent of women 15-49 years of age with one child under five years, suffer from anemia (1) and that the national GDP in Mali is decreased by 2.7 percent due to vitamin and mineral deficiencies (2). Iodine deficiency is also a public health problem in Mali (3).

Despite the widespread presence of several micronutrient deficiencies, women's dietary intake has received insufficient attention. In Mali, there are no nationally representative data on women's food intake. Collecting quantitative data on dietary intake can be logistically complicated, costly and requires well-trained staff (4). Available dietary intake information is often fragmented and due to diverse data collection methodologies, cannot be compared internationally or over time within the same country. Simple, standardized indicators are needed in developing countries to characterize diet quality, to assess key diet problems and to identify sub-groups particularly at risk of nutrient inadequacy. These indicators are also needed to monitor and evaluate intervention programs.

Dietary diversity scores are often constructed as the number of foods consumed across and within food groups over a reference period. Diversification of the diet is widely recognized as a key dimension of diet quality (5). In developing countries, dietary diversity has been associated with nutrient adequacy in several studies in children (6-10) and also in adults in Bangladesh (11) Korea (12) and Mali (13).

This study will assess the potential of simple indicators of food group diversity to function as proxy indicators of diet quality. Relationships between food group diversity indicators, energy intake and micronutrient adequacy will be explored and the performance of eight different indicators will be tested.

METHODS

A total of 108 women were selected for the study using a three-stage cluster sampling method, involving cluster selection using probability proportional to size, household selection within the cluster using the random walk method and random selection of one eligible woman per household. In the case of unavailability or refusal, the selected women were not replaced, which left a sample size of 103. The record of one woman was deleted from the analysis as being a statistical outlier, leaving a total sample size of 102.

Data collection took place over three months: February, March and April 2007. Two 24-h recalls were collected on separate days with a minimum of two days and a maximum of 11 days between the two recall days. Weekends and special event days were excluded. Daily food intake was assessed by a quantitative 24-h recall method adapted to shared plate eating. Respondents were asked to use known-weight utensils on the recall day to help them visualize the amount of food consumed. The amounts of all foods, beverages, ingredients of mixed dishes consumed were estimated either in household units or in monetary value. The total amount of the cooked food and the amount consumed by the respondents were measured in household units to derive the proportion consumed by the respondent from the total volume of the dish. When a monetary value was used to represent the portion size, price was converted into weight in grams by averaging across nine to 15 vendors selected from the three most frequented markets in the study area. Food weights were measured to the nearest two grams using digital dietary scales (Soehnle, Plateau maximum weight 10 kg).

A food composition table (FCT) was developed for the purposes of a larger project. A detailed description of the development of the food composition table is provided elsewhere (14). The food composition values used in the present study are based on this food composition table, which relied primarily on the *Table de Composition des aliments du Mali (TACAM)* (15). The nutrients for all staple foods[1] are expressed as cooked. To account for nutrient losses during cooking in other foods, such as fish, meat and vegetables, USDA Retention factors release 6 (16) were applied to the nutrient values of the raw foods. In the case of missing values in *TACAM* for any of the eleven micronutrients values were first obtained from USDA release 20 (17) and, if necessary, from the International Mini List (IML), (18). Retinol equivalents (RE) were calculated as the sum of retinol and beta-carotene, using the following conversions: 1mcg retinol = 1 mcg RE and 1 mcg beta-carotene = 0.167 mcg RE, as recommended by FAO/WHO (5). Nutrient values taken from sources other than the TACAM were adjusted to account for differences in moisture content[2].

Eight food group diversity indicators (FGIs) based on four sets of food groupings (6, 9, 13 and 21 food groups, see Annex one for food groupings) and each applying a 1g or 15g minimum intake criteria were constructed based on the 24-h recall from the first observation day. The probability of adequacy (PA) for 11 micronutrients was constructed taking into account nutrient requirement distributions and inter- and intra-individual variation in intake. The mean probability of micronutrient adequacy (MPA) was constructed as a summary indicator using the average of the eleven PA. MPA_{pop} represents the mean probability of adequacy for the total sample, which is equivalent to a population level estimate of prevalence of adequacy. MPA_{ind} represents that individual's mean probability of adequate

1 Vitamin B_6 values reported for cooked staples in TACAM were very low, so vitamin B_6 values for cooked staples from USDA and IML were used.

2 IML tables do not report moisture content. The moisture content for foods taken from IML was estimated based on the closest food match from USDA.

intake of micronutrients. Diversity scores are from a single observation day, while MPA is calculated based on both observation days.

Food intake was computed using the VBS Food Calculation system (19). Statistical analysis was performed in STATA-IC (20). Pearson's correlation, linear regression and receiver-operator characteristics (ROC) analysis were used to test the performance of each indicator. Indicator qualities (sensitivity, specificity, and misclassification) for several cutoffs of MPA, at various diversity cutoffs were analyzed. For all statistical tests, values of $p < 0.05$ were considered significant. Regression diagnostics were performed, including assessment of normality of residuals and heteroskedasticity tests.

RESULTS

Table 1 provides descriptive statistics for the sample. Mean age in the sample was 31.5y. Two-thirds of the women were literate. Mean BMI for the sub-sample with BMI measured was 23.6, with 17 percent classified as underweight and nearly one-third as overweight or obese. Average dietary energy intake was 2054 kcal (± 717).

Table 1 Sample characteristics

Characteristic	n	Mean	SD
Age (yr)	102	31.5	10.5
Height (cm)	64	166	5.9
Weight (kg)	64	65.0	14.8
BMI	64	23.6	5.6
Energy (kilocalories)	102	2054.0	716.5
	n	Percent	
BMI ≤18.49	64	17.2	
BMI ≥ 25.0	64	28.1	
Education (% literate)[1]	102	65.1	

[1] Percent of women who reached at least primary school level or went to Islamic school.

Mean FGI scores applying a 1g restriction, ranged from 5.1 (FGI-6) to 7.1 (FGI-21) (Table 2). Means were lower for 15g restricted scores, ranging from 4.3 (FGI-6R) to 5.6 (FGI-21R). The highest number of food groups consumed within each FGI increased incrementally with disaggregation, but did not reflect consumption of the full range of food groups after FGI-6 and FGI-6R. In FGI-21 six food groups, cheese, soy/soy products, organ meat, poultry, insects/rodents and all other fruits were not consumed by any women. Using six food groups, the food groups most affected by the 15g restriction were all legumes and nuts and Vitamin A-rich fruits and vegetables, which fell from 73 to 39 and 92 to 47 percent consumption respectively. Disaggregating into twenty-one food groups, helps isolate more precisely the food groups effected. Nuts and seeds fell from 70 to 36 percent consuming, while Vitamin A-rich deep yellow/orange/red vegetables dropped from 82 to 17 percent consuming. There were no women who consumed more than 15g of small fish eaten whole with bones, which dropped from five to zero percent of women consuming. The food groups large whole fish/dried fish/shellfish/other seafood, vitamin A-rich dark green leafy vegetables and All other vegetables were also impacted, to a lesser degree by the 15g minimum.

Full results of micronutrient intakes, probability of adequacy for individual micronutrients and mean probability of adequacy (MPA) are presented in detail elsewhere (21). Intakes of riboflavin, niacin, vitamin B_{12}, folate, vitamin A were below the Estimated Average Requirement and intakes of calcium were below the acceptable intake (AI). The MPA_{pop} for the 11 micronutrients was 0.47.

Table 2 Summary of food group diversity scores

Indicator	Mean	SD	Median	Range
FGI-6	5.1	0.7	5.0	3-6
FGI-6R	4.3	0.9	4.0	2-6
FGI-9	5.5	1.0	6.0	3-8
FGI-9R	4.4	1.1	4.0	2-7
FGI-13	6.4	1.3	6.0	3-10
FGI-13R	4.9	1.3	5.0	2-9
FGI-21	7.1	1.5	7.0	3-11
FGI-21R	5.6	1.6	5.0	2-10

Table 3 shows the correlation between the eight dietary diversity indicators and estimated intake of individual nutrients. In general, there was a trend for more significant relationships when not controlling for energy intake. The most consistent relationships were seen for riboflavin, folate, vitamin B_{12}, vitamin A and calcium. For these nutrients, the correlations with all dietary diversity indicators were positive and significant, and remained so after controlling for energy intake. After controlling for energy, correlations became smaller and so energy in part explains the relationship between dietary diversity and micronutrient intakes. Estimated intakes for all micronutrients except iron were significantly correlated with FGI-21 and FGI-21R when energy intake was not controlled. After controlling for energy, correlations remained significant for riboflavin, folate, vitamin B_{12}, vitamin A, calcium and vitamin C for FGI-

21R and for all those micronutrients except vitamin C for FGI-21. Zinc was positively correlated with all dietary diversity indicators when not controlling for energy and with FGI-6, FGI-6R and FGI-9 when controlling for energy. Vitamin C was negatively correlated with FGI-6 and FGI-9. The correlation became positive and significant, when food groups were more disaggregated into 21 groups. Estimated iron intake was significantly correlated only with FGI-9 when not controlling for energy. Vitamin B_6 correlations were significant for FGI-6R, FGI-13R, FGI-21 and FGI-21R when not controlling for energy.

Total energy intake by dietary diversity indicator and the correlation between those two parameters appear in Table 4. Dietary energy intake increased rather consistently with increasing dietary diversity scores for each dietary diversity indicator; however, there was no entirely linear relationship at either extreme end of the scores. This is likely due in part to the smaller sample sizes at the tails of the distribution. The correlation coefficients between energy intake and the dietary diversity indicators ranged from 0.17 to 0.26, with significant coefficients for FGI-6, FGI-6R, FGI-9, FGI-13R and FGI-21R. The relationship between the dietary diversity scores and MPA demonstrated a general linear relationship (Figure 1). All coefficients between the dietary diversity scores and MPA were positive and significant (Table 4). The coefficients ranged from 0.30 (FGI-13) to 0.50 (FGI-6R) when not controlling for total energy intake and decreased to 0.25 (FGI-6) to 0.48 (FGI-6R and FGI-9R) when total dietary energy intake was controlled.

The relationships between the dietary diversity indicators and MPA were also analyzed by different linear regression models. These analyses are presented in Table 5. The dietary diversity indicators were significant predictors of MPA in all regressions when not controlling for energy. When controlling for energy, five dietary diversity indicators were significant: FGI-6R, FGI-9, FGI-9R, FGI-13R and FGI-21R. Neither a woman's age nor height was significantly associated with MPA. The regression results controlling for energy were higher. Adjusted r^2 ranged from 0.36 for FGI-13 to 0.42 for both FGI-6R and FGI-9R.

Sixty six percent of women had an MPA >40 percent, 46 percent had MPA > 50 percent, 25 percent had MPA > 60 percent and 11 percent had an MPA > 70 percent. The percentages of women above MPA cutoffs of 70 percent and higher are low enough, particularly given this study's small sample size, to indicate that MPA cutoffs of 70 percent and higher should be excluded from an analysis of indicator performance.

Table 3 Correlation between Food Group Diversity Scores and the PA of Individual Micronutrients, With and Without Controlling for Total Energy [1,2]

	FGI-6		FGI-6R		FGI-9		FGI-9R	
Nutrients	**Not controlling for energy**	**Controlling for energy**	**Not controlling for energy**	**Controlling for energy**	**Not controlling for energy**	**Controlling for energy**	**Not controlling for energy**	**Controlling for energy**
Total energy	0.21 *		0.26 **		0.20 *		0.19	
Thiamin	0.19	0.02	0.26 **	0.06	0.21 *	0.06	0.19	0.04
Riboflavin	0.44 ***	0.42 ***	0.51 ***	0.46 ***	0.44 ***	0.41 ***	0.48 ***	0.47 ***
Niacin	0.20 *	0.09	0.39 ***	0.30 **	0.26 **	0.17	0.28 **	0.21 *
Vitamin B_6	0.07	-0.12	0.25 *	0.1	0.09	-0.07	0.19	0.08
Folate	0.29 **	0.22 *	0.50 ***	0.44 ***	0.34 ***	0.29 **	0.47 ***	0.44 ***
Vitamin B_{12}	0.38 ***	0.33 ***	0.38 ***	0.31 **	0.38 ***	0.33 ***	0.39 ***	0.35 ***
Vitamin C	-0.05	-0.12	0.09	0.00	-0.02	-0.09	0.09	0.03
Vitamin A	0.46 ***	0.43 ***	0.61 ***	0.58 ***	0.54 ***	0.51 ***	0.65 ***	0.64 ***
Calcium	0.47 ***	0.45 ***	0.51 ***	0.46 ***	0.44 ***	0.40 ***	0.47 ***	0.45 ***
Iron	0.12	-0.00	0.17	0.01	0.24 *	0.15	0.11	-0.01
Zinc	0.29 **	0.21 *	0.34 ***	0.22 *	0.29 **	0.21 *	0.24 *	0.15

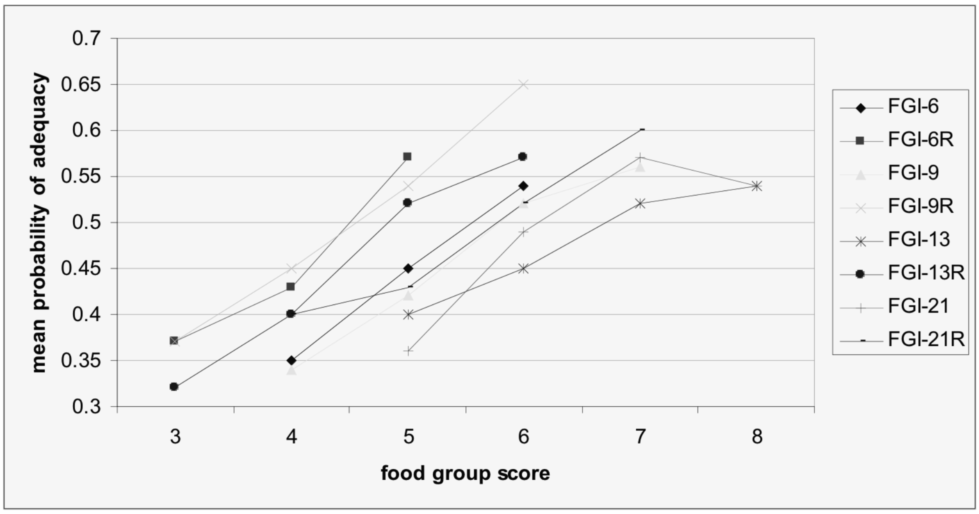
Table 3 (cont.)

	FGI-13		FGI-13R		FGI-21		FGI-21R	
Total energy	0.17		0.17		0.17		0.17	
Thiamin	0.15	-0.00	0.15	-0.00	0.15	-0.00	0.15	-0.00
Riboflavin	0.36 ***	0.33 ***	0.36 ***	0.33 ***	0.36 ***	0.33 ***	0.36 ***	0.33 ***
Niacin	0.19	0.11	0.19	0.11	0.19	0.11	0.19	0.11
Vitamin B_6	0.15	0.05	0.15	0.05	0.15	0.05	0.15	0.05
Folate	0.30 **	0.26 **	0.30 **	0.26 **	0.30 **	0.26 **	0.30 **	0.26 **
Vitamin B_{12}	0.30 **	0.26 **	0.30 **	0.26 **	0.30 **	0.26 **	0.30 **	0.26 **
Vitamin C	0.11	0.06	0.11	0.06	0.11	0.06	0.11	0.06
Vitamin A	0.50 ***	0.48 ***	0.50 ***	0.48 ***	0.50 ***	0.48 ***	0.50 ***	0.48 ***
Calcium	0.34 ***	0.31 **	0.34 ***	0.31 **	0.34 ***	0.31 **	0.34 ***	0.31 **
Iron	0.16	0.07	0.16	0.07	0.16	0.07	0.16	0.07
Zinc	0.21 *	0.13	0.21 *	0.13	0.21 *	0.13	0.21 *	0.13

1 Usual intake of energy and individual nutrients are estimated by the best linear unbiased predictor (BLUP) following the method described in Arimond et al. 2008. Diversity scores are from first round data; BLUP calculation incorporates information from both rounds.

2 A * indicates a coefficient that is statistically significant at $p < 0.05$; ** indicates $p < 0.01$, and *** indicates $p < 0.001$.

Figure 1 Mean Probability of Adequacy by Food Group Scores for Various Diversity Indicators [1]



[1] Only scores with 10 or more observations are plotted.

Table 4 Pearson correlations between food group diversity scores, total energy intake and MPA

FGI	Total energy intake[1]	MPA [1]	
		Unadjusted	Adjusted for total energy intake
FGI-6	0.21*	0.32*	0.25 *
FGI-6R	0.26*	0.50 *	0.48*
FGI-9	0.20*	0.36*	0.33 *
FGI-9R	0.19	0.45*	0.48 *
FGI-13	0.17	0.30*	0.27 *
FGI-13R	0.23*	0.42*	0.38 *
FGI-21	0.18	0.34*	0.32 *
FGI-21R	0.20*	0.41*	0.41 *

[1] * indicates Pearson correlation coefficient that is statistically significant at $p < 0.05$.

For the purpose of assessing an indicator's potential, an area under the curve (AUC) of ≥ 0.70 derived from receiver-operating characteristic (ROC) analysis can be considered to have potential, while an AUC of 0.50 indicates "no predictive power". At an MPA cut off of > 40 percent all AUC results were above 0.70 except for FGI-6, FGI-9 and FGI-13, at an MPA > 50 percent, all were above 0.7 except FGI-6 and FGI-13, using the MPA cut-off of 60 percent, only FGI-6R had an AUC above 0.70 (Table 6). Overall AUCs were within a narrow range. From 0.63 to 0.74 at MPA > 40 percent, with FGI-6 significantly lower than FGI-6R. At MPA > 50 percent the range was 0.67 to 0.75, with no significant differences. The range for MPA > 60 percent was 0.59 to 0.71 with FGI-6R, FGI-9R and FGI-13R significantly higher than FGI-13.

Based on the AUC results, FGI-6 and FGI-13 could be considered the weakest indicators and FGI-6R and FGI-9R marginally stronger than the rest.

In addition to the AUC, the best balance of sensitivity, specificity and total misclassification can be studied. Sensitivity indicates the proportion of those with better MPA identified correctly by the chosen cutoff applied to the score. Specificity is the proportion of those with a lower MPA who are correctly identified using the cutoff for each score. For the purposes of the WDDP – to develop indicators to assess diet quality for women at a population level – it is reasonable to aim for a balance between sensitivity and specificity, but to favor specificity when trade-offs must be made.[1] This would err on the side of classifying women with lower MPA correctly, with fewer false positives (low MPA classified as 'good') than false negatives (high MPA classified as 'poor').

For both FGI-6R and FGI-9R, the best cut-off point was five or more food groups for all MPA thresholds selected. For these two indicators, the lowest combination of false positives and total misclassified was at MPA > 60 percent, however using MPA > 50 percent resulted in fewer women classified incorrectly as having a higher MPA. FGI-21R also performed well at a cutoff of ≥ 6 food groups with a sensitivity of 72 percent, specificity of 71 percent and a total of 28 percent misclassified at an MPA of > 50 percent.

[1] Arimond et al. 2009a.

Table 5 Ordinary Least Squares Regression Analysis of the Determinants of MPA[1,2]

	FGI-6			FGI-6R			FGI-9			FGI-9R		
	B		**SE**	**B**		**SE**	**B**		**SE**	**B**		**SE**
Constant	0.15		0.14	0.11		0.07	0.18		0.12	0.20	*	0.09
Age	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Dietary diversity score	0.08	**	0.03	0.10	***	0.02	0.07	***	0.02	0.08	***	0.02
Adjusted R^2	0.11	**		0.25	***		0.13	***		0.20	***	
	B		**SE**	**B**		**SE**	**B**		**SE**	**B**		**SE**
Constant	0.05		0.12	0.01		0.09	0.00		0.11	0.03		0.08
Age	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Dietary diversity score	0.04		0.02	0.06	***	0.02	0.04	*	0.02	0.05	***	0.01
Total energy intake[3]	0.14	***	0.02	0.12	***	0.02	0.14	***	0.02	0.13	***	0.02
Adjusted R^2	0.37	***		0.42	***		0.39	***		0.42	***	

Table 5 (cont.)

	FGI-13			FGI-13R			FGI-21			FGI-21R		
	B		**SE**	**B**		**SE**	**B**		**SE**	**B**		**SE**
Constant	0.29		0.11	0.25	**	0.09	0.02	*	0.11	0.28		0.09
Age	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Dietary diversity score	0.04	**	0.01	0.06	***	0.01	0.00	**	0.01	0.05	***	0.01
Adjusted R^2	0.09	*		0.17	***		0.11	**		0.16	***	
	B		**SE**	**B**		**SE**	**B**		**SE**	**B**		**SE**
Constant	0.10		0.10	0.08		0.08	0.08		0.10	0.1		0.08
Age	0.00		0.00	0.00		0.00	0.00		0.00	0.00		0.00
Dietary diversity score	0.02		0.01	0.03	**	0.01	0.02	*	0.01	0.03	*	0.01
Total energy intake[3]	0.14	***	0.02	0.13	***	0.02	0.14	***	0.02	0.13	***	0.02
Adjusted R^2	0.36	***		0.39	***		0.37	***		0.39	***	

1 Food group diversity scores are from first observation day, MPA is based on the first observation day and repeat observations for a subset of the sample.

2 A * indicates a coefficient that is statistically significant at $p < 0.05$; ** indicates $p < 0.01$; and *** indicates $p < 0.001$.

3 Total energy intake (kcal)/10.

Table 6 Area under the Curve for each Food Group Diversity Indicator and different MPA cutoffs

Food group indicator	AUC	95% CI [1]	p-value [2]
	MPA >40%		
FGI-6	0.63	0.53-0.73	0.03
FGI-6R	0.74	0.64-0.83	0.00
FGI-9	0.67	0.57-0.77	0.01
FGI-9R	0.73	0.63-0.82	0.00
FGI-13	0.69	0.59-0.79	0.00
FGI-13R	0.72	0.62-0.82	0.00
FGI-21	0.72	0.62-0.82	0.00
FGI-21R	0.71	0.61-0.82	0.00
	MPA >50%		
FGI-6	0.67	0.58-0.77	0.00
FGI-6R	0.75	0.67-0.84	0.00
FGI-9	0.74	0.64-0.83	0.00
FGI-9R	0.75	0.67-0.84	0.00
FGI-13	0.68	0.58-0.78	0.00
FGI-13R	0.74	0.64-0.83	0.00
FGI-21	0.72	0.62-0.82	0.00
FGI-21R	0.74	0.65-0.84	0.00
	MPA >60%		
FGI-6	0.62	0.51-0.74	0.06
FGI-6R	0.71	0.61-0.81	0.00
FGI-9	0.65	0.54-0.77	0.02
FGI-9R	0.70	0.60-0.80	0.00
FGI-13	0.59	0.47-0.71	0.18
FGI-13R	0.68	0.58-0.80	0.01
FGI-21	0.62	0.50-0.74	0.08
FGI-21R	0.68	0.57-0.79	0.01

[1] Confidence interval.
[2] P-value for test of null hypothesis that area=0.5 (“neutral” diagonal line on ROC graph).

DISCUSSION

Main Findings

All of the dietary diversity scores constructed for this analysis were positively and significantly correlated to the composite indicator of micronutrient adequacy. The indicators using a 15g restriction had slightly better overall performance than those with only a 1g restriction.

Differences between the indicators were small, with few significant differences in AUC. Taking into consideration the combination of results, including correlations, regressions and ROC analysis, there was a consistent tendency across all tests for the strongest results using FGI-6R and FGI-9R. In ROC analysis, FGI-6R and FGI-9R seemed to show a slight advantage over the rest. Though, the results for all FGI-R indicators were quite similar and that there were no significant differences among the AUCs for these four indicators.

Study Limitations

Random and systematic error can both be associated with 24 hour recall surveys. Increasing sample size can help to correct for some of the bias inherent in dietary intake studies (22), however, the sample size in this study was relatively small.

Systematic error can occur in dietary studies as a result of misreporting on the part of the respondent or misrecording on the part of the enumerator (23) Systematic error is more of concerning as this type of error is not be mediated through increased sample size. Systematic errors can occur on the part of the interviewer, in terms of estimating portion sizes or coding food items. The interviewee can over or under report intakes of certain food groups or provide a poor memory record of variety and quantities of food consumed. Food composition data are another source of potential error as nutrients/100g of food may be over or under estimated depending on analytical method used and there may be a mismatch between foods actually consumed and those with available nutrient information.

The average MPA and overall distribution were clustered around a probability of fifty percent adequacy. The ROC analysis in this study was based on using MPA cut-offs of 40, 50 and 60 percent since indicator performance can only be assessed for cutoffs that are possible within observed distributions. These MPA levels are not ideal for characterizing high levels of adequate intake. We were obliged in this study to consider a lower than desirable MPA cut-point for assessing indicator performance.

Table 7 Summary of AUC and ROC analysis for all Food Group Diversity Indicators and three different MPA cut-offs

FGI	Food group cut point [1]	Sensitivity	Specificity	False positives (%)	False negatives (%)	Total misclassified (%)
			MPA > 40%			
FGI-6	≥ 5	89	25	26	7	33
FGI-6R	≥ 5	53	83	6	30	36
FGI-9	≥ 6	61	68	12	26	37
FGI-9R	≥ 5	53	78	8	30	38
FGI-13	≥ 7	53	78	8	30	38
FGI-13R	≥ 5	71	68	12	19	30
FGI-21	≥ 7	79	56	16	14	30
FGI-21R	≥ 6	62	75	9	24	33
			MPA > 50%			
FGI-6	≥ 6	43	84	9	27	35
FGI-6R	≥ 5	62	78	12	18	29
FGI-9	≥ 6	72	67	18	13	30
FGI-9R	≥ 5	62	75	14	18	31
FGI-13	≥ 7	57	71	16	20	35
FGI-13R	≥ 5	79	60	22	10	31
FGI-21	≥ 8	53	82	10	22	31
FGI-21R	≥ 6	72	71	16	13	28
			MPA > 60%			
FGI-6	≥ 6	44	77	18	14	31
FGI-6R	≥ 5	64	68	25	9	33
FGI-9	≥ 6	72	56	33	7	40
FGI-9R	≥ 5	64	65	27	9	35
FGI-13	≥ 7	52	61	29	12	41
FGI-13R	≥ 6	48	75	19	13	31
FGI-21	≥ 8	48	70	23	13	35
FGI-21R	≥ 6	68	57	32	8	40

[1] Food group cut-point which maximizes sensitivity and specificity.

Applying portion size restrictions to dietary diversity scores

In Mali, the indicators based on a 15g restriction in order to count in the score performed slightly better than those based on only a 1g restriction. This was a consistent finding throughout all other WDDP project sites (24). The highest site specific correlations for FGI and MPA when total energy intake was controlled were 0.48 for FGI-6R and FGI-9R in Mali, 0.46 for FGI-9R in Bangladesh, 0.29 to 0.39 for FGI-21R in Burkina Faso, Mozambique and the Philippines (24). Additional studies in children have also concluded that a portion size restriction in order to count in the score provided higher correlations with total nutrient adequacy (8,9).

Which number of food groups

The number of food groups to include in dietary diversity scores remains an outstanding research question that this and the other WDDP site papers tried to address. In the Mali site there was no significant difference in indicator performance for any of the restricted indicators, in the other WDDP sites, the restricted indicators based on nine, thirteen and 21 food groups outperformed FGI-6R. In several sites, FGI-21R had higher AUC and better performance of sensitivity, specificity and total misclassification.

Best cut-off point for creating a dichotomous indicator

In Mali five food groups was the best cut-off point for FGI-6R and FGI-9R indicators. This cut-off held across all MPA levels tested, indicating that five or more food groups was a robust threshold for predicting higher, but not ideal, probabilities of adequate micronutrient intake. Summary results are presented in the other site reports only for FGI-9R at MPA levels of 0.5 and 0.6. The best cut-off points were four food groups in Mozambique and the Philippines and five food groups in Burkina Faso and Bangladesh. As in Mali, the best cut-off point did not change whether based on MPA > 50 or MPA > 60 percent.

Wider significance of these findings

Restricted scores were found overall in this project and in other studies, to provide stronger associations with MPA than non-restricted scores. Ideally methods to exclude small portion sizes could be incorporated into questionnaire design. Recommendations to exclude foods consumed in small quantities already appear in operational guidance provided by different organizations (25,26) however, more research needs to be undertaken on questionnaire construction in order to validate the ability of questionnaires to truly exclude foods consumed in small amounts. Invariably there is a trade-off between questionnaire simplicity and score precision.

In Mali all restricted indicators performed at about the same level, so in terms of pure statistical performance, there is no reason to choose one above the other. Considering ease of data collection, the indicator based on only six food groups is the simplest, both in terms of identifying the local foods which go into each of the six food groups and also in terms of time spent on data collection. However there are advantages to collecting information, at least up to the level of nine food groups which should also be considered. In the more disaggregated food group indicators, there are several food groups which may be of particular interest in terms of nutrient density. For example in the nine food group indicator information is collected on consumption of organ meat, eggs and dark green leafy vegetables, whereas in the six food group indicator the food groups are Animal source foods and Vitamin A-rich fruits and vegetables. There are also statistical advantages to having a wider score distribution.

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REFERENCES

1. Cellule de Planification et de Statistique du Ministère de la Santé (CPS/MS), Direction Nationale de la Statistique et de l'Informatique du Ministère de l'Économie, de l'Industrie et du Commerce (DNSI/MEIC) et Macro International Inc. Enquête Démographique et de Santé du Mali 2006 Calverton, Maryland : CPS/DNSI et Macro International Inc ; 2007.
2. UNICEF and the Micronutrient Initiative. Vitamin and Mineral Deficiency. A global damage assessment report. [internet] (cited January 2009) Available from: http://www.micronutrient.org/CMFiles/PubLib/Report-67-VMD-A-Global-Damage-Assessment-Report1KSB-3242008-9634.pdf
3. Zimmermann M, Jooste P, Pandav C. Iodine-deficiency disorders. *Lancet* 2008;372:1251-62.
4. Ferro Luzzi A. Individual food intake survey methods. In: Measurement and Assessment of Food Deprivation and Undernutrition. Proceedings from the International Scientific Symposium on Measurement and Assessment of Food Deprivation and Undernutrition. Rome: FAO; 2003.
5. FAO/WHO. Human and vitamin mineral requirements. Rome: FAO; 2002. Report of a Joint FAO/WHO expert consultation.
6. Working Group on Infant and Young Child Feeding Indicators. Developing and Validating Simple Indicators of Dietary Quality and Energy Intake of Infants and Young Children in Developing Countries: Summary of findings from analysis of 10 data sets. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2006.
7. Steyn NP, Nel JH, Nantel G, Kennedy G Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Pub Health Nutr* 2006;9(5):644-650.
8. Kennedy G, Pedro MR, Seghieri C, Nantel G, Brouwer I. Dietary diversity is a useful indicator of micronutrient intake in nonbreast-feeding Filipino children. *J Nutr* 2007;137:1-6.
9. Daniels M, Adair L, Popkin B, Truong Y. Dietary diversity scores can be improved through the use of portion requirements: an analysis in young Filipino children. *Eur J Clin Nutr* 2009; 1-10.
10. Hatloy A, Torheim LE, and Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr*. 1998;52(12):891-8.
11. Arimond M, Torheim LE, Wiesmann D, Joseph M, Carriquiry A. Dietary Diversity as a Measure of Women's Diet Quality in Resource-Poor Areas: Results from rural Bangladesh site. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project/Academy for Educational Development (AED); March, 2008.
12. Ahn BC, Engelhardt K, Joung H. Diet variety is associated with socio-economic factors. *Ecol Food Nutr* 2006;45:417-430.
13. Torheim LE, Ouattara F, Diarra M, Thiam F, Barikmo I, Hatloy A, Oshaug A. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. *Eur J Clin Nutr* 2004;58: 594-604.
14. Koreissi Y, Fanou N, Brouwer I. Development of the fonio food composition table. INCO FONIO Project; 2007.
15. Barikmo I, Ouattara F, Oshaug A. Table de composition des aliments du Mali. Oslo: Akershus University College; 2004.
16. USDA, Agricultural Research Service. USDA Table of Nutrient Retention Factors, Release 6. [Internet]. Nutrient Data Laboratory Home Page, Available from: http://www.ars.usda.gov/ba/ bhnrc/ndl. 2007.
17. USDA, Agricultural Research Service. USDA National Nutrient Database for Standard Reference, Release 20. [Internet]. Available from Nutrient Data Laboratory Home Page, http://www.ars. usda.gov/ba/bhnrc/ndl. 2008.
18. World Food Dietary Assessment System (no date). Users Guide to the World Food Dietary Assessment System, version 2.0. [Internet]. [cited 6 August, 2008]. Available from: http://www.fao.org/infoods/ software/wfood2.doc.
19. BaS Nutrition Software. VBS Food Calculation System, 2004. Available from www.bbware.nl
20. StataCorp. Stata Statistical Software: Release 10-IC. College Station, Texas: StataCorp LP. 2007.
21. Kennedy G, Fanou N, Seghieri C and Brouwer ID. Dietary Diversity as a Measure of the Micronutrient Adequacy of Women's Diets: Results from Bamako, Mali Site. Washington, DC: Food and Nutrition Technical Assistance II Project, Academy for Educational Development; 2009.
22. Block G, Hartman M. Issues in reproducibility and validity of dietary studies. *Am J Clin Nutr* 1989;50:1133-8.
23. Gibson R, Ferguson E. An interactive 24-hour Recall for Assessing the Adequacy of Iron and Zinc Intakes of Developing Countries. Washington, DC: Harvest Plus; 2008. Technical Monograph 8.
24. Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels M, Deitchler M, Fanou N, Ferguson E, Joseph M, Kennedy G, Martin-Prével Y, Torheim LE. Dietary diversity as a measure of the micronutrient adequacy of women's diets in resource-poor areas: Summary of results from five sites. Washington, DC: Food and Nutrition Technical Assistance II Project, Academy for Educational Development; 2009.

25. FAO. Guidelines for Measuring Household and Individual Dietary Diversity version 4. Rome: FAO Nutrition and Consumer Protection Division Rome: with support from the EC/FAO Food Security Information for Action Programme and the Food and Nutrition Technical Assistance (FANTA) project; 2008.

26. WFP. Comprehensive Food Security & Vulnerability Analysis Guidelines. Rome: WFP; 2009.

Annex 1 Food Groups Summed in Diversity Indicators [1,2]

6-group indicators	9-group indicators	13-group indicators	21-group indicators
All starchy staples	All starchy staples	All starchy staples	Grains and grain products All other starchy staples
All legumes and nuts	All legumes and nuts	All legumes and nuts	Cooked dry beans and peas Soybeans and soy products Nuts and seeds
All dairy	All dairy	All dairy	Milk/yogurt Cheese
Other animal source foods	Organ meat Eggs Flesh foods and other miscellaneous small animal protein	Organ meat Eggs Small fish eaten whole with bones All other flesh foods and miscellaneous small animal protein	Organ meat Eggs Small fish eaten whole with bones Large whole fish/dried fish/shellfish and other seafood Beef, pork, veal, lamb, goat, game meat Chicken, duck, turkey, pigeon, guinea hen, game birds Insects, grubs, snakes, rodents and other small animals
Vitamin A-rich fruits and vegetables	Vitamin A-rich dark green leafy vegetables Other vitamin A-rich vegetables and fruits	Vitamin A-rich dark green leafy vegetables Vitamin A-rich deep yellow/orange/red vegetables Vitamin A-rich fruits	Vitamin A-rich dark green leafy vegetables Vitamin A-rich deep yellow/orange/red vegetables Vitamin A-rich fruits
Other fruits and vegetables	Other fruits and vegetables	Vitamin C-rich vegetables Vitamin C-rich fruits All other fruits and vegetables	Vitamin C-rich vegetables Vitamin C-rich fruits All other vegetables All other fruits

[1] Vitamin A-rich fruits and vegetables are defined as those with ≥ 120 RE/100 g as eaten.
[2] Vitamin C-rich fruits and vegetables are defined as those with ≥ 9 mg/100 g as eaten.

CHAPTER 5

WHICH FOOD GROUPS ARE ASSOCIATED WITH PROBABILITY OF ADEQUATE INTAKE OF 11 MICRONUTRIENTS IN THE DIETS OF WOMEN IN URBAN MALI?

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ABSTRACT

Micronutrient malnutrition undermines the health, development and economic potential of millions of persons worldwide. The prevalence of micronutrient deficiency and BMI outside of normal range is high among women of reproductive age living in urban Mali. Despite this, there is very little data on dietary intake of women of reproductive age and the relationships between dietary intake and intake of micronutrients. This research tested the relationship between a grouping of twenty-one possible food groups and probability of adequate intake of a composite group of eleven micronutrients, constructed from 24-hour recall data in an urban sample of Malian women. The majority of women consumed the food groups grains, nuts and seeds, red meat, large fish, vitamin A-rich yellow, orange and red vegetables, vitamin-C rich vegetables and other vegetables. The probability of adequate intake of micronutrients was lowest for folate, B_{12}, calcium and riboflavin. The overall mean probability of adequacy (MPA) for the composite score of eleven micronutrients was below fifty percent. Grams of intake from the food groups nuts and seeds, milk and yogurt, dark green leafy vegetables and vitamin C-rich vegetables were significantly correlated ($r = 0.20$ to 0.36) with MPA. Increasing intakes from the food groups nuts and seeds and dark green leafy vegetables, increased by five and six times, respectively, the odds of an MPA > 0.5.

INTRODUCTION

Women of reproductive age suffer disproportionately from micronutrient deficiencies due to physiologically higher micronutrient requirements during the reproductive life stage. The impact of poor maternal micronutrient status is transmitted inter-generationally, from mother to child, resulting in less optimal fetal growth and development (1). In Bamako, Mali it is estimated that 54 percent of women 15-49 years of age with one child under five years, suffer from anemia (2) and that the national GDP in Mali is decreased by 2.7 percent due to vitamin and mineral deficiencies (3). In a recent survey, ten percent of women in Bamako had low BMI (<18.5), while 31 percent were overweight or obese (2).

Despite these nutritional problems, women's dietary intake has received insufficient attention in many developing countries. In Mali, there is no nationally representative data on women's food intake. Available dietary intake information is often fragmented and due to diverse data collection methodologies, cannot be compared internationally or over time within the same country. This is partly due to the fact that collection of information on dietary intake is costly and time consuming. Challenges of collecting accurate quantitative information on dietary intake can be even greater in developing country contexts where literacy levels are low, restricting the types of survey instruments which can be used. In addition, shared plate eating requires adaptation of survey instruments and requires additional data collection time (4,5).

Because of the challenges and cost of quantitative dietary data collection, simpler methods yielding information on diet and food group patterns are needed. Previous studies found that association between nutrient intake based on counting the number of food groups consumed was nearly the same (6) or stronger (7) than when using scores based on counting intake of individual food items. Dietary diversity scores, which are generally defined as a simple count of the number of food groups consumed, have been shown in developing country settings to be adequate proxy indicators of micronutrient intake in children (7-11) and also in adults in Bangladesh (12) Korea (13) and Mali (14). While the use of dietary diversity scores has shown promise in a variety of settings, methodologies for score construction and analytical methods used to establish relationships between the scores and measures of nutritional well being have varied (15). For infants and young children 6-23 months of age, WHO (16) has defined a food group diversity indicator that sums seven food groups. For older children and adults, there is currently no standard indicator and no consensus on level of aggregation of foods, or number of food groups to sum when creating dietary diversity indicators.

This paper will look at which food groups were most strongly correlated to higher probability of adequate micronutrient intake. These results can help advance knowledge on food group composition for the purpose of constructing dietary diversity scores. Addressing this issue will also help identify specific food groups to promote in order to improve micronutrient intakes of women of reproductive age in Mali.

MATERIALS AND METHODS

The data used in this study are from a cross-sectional food consumption survey undertaken as part of the FP6/EU/INCO/STREP[1] funded FONIO project. Results presented in this paper were part of a multi-country analysis funded through Food and Nutrition Technical Assistance (FANTA). A standardized protocol provided guidance on the use of four combinations of food groups, and the application of the probability of adequacy method for determining the adequacy of micronutrient intake of each woman. Full detail on the analytical research protocol can be found elsewhere (17).

Study site and sample size

The research was carried out in Bamako, the capital city of Mali. The sample was designed to provide an estimate of iron intake. A total of 108 women were selected based on the formula (N=s2/e2) (5) where s is an anticipated standard deviation, and e is the desired standard error. For this study, s was 5.08 based on previously estimated mean±sd of iron intake of women (12.15±5.08 mg/day). With an assumed margin error of $\varepsilon = \pm 1$, the desired standard error (e) is 0.5, at 95% confidence interval. The calculated sample size was 103, using [(5.08)2/(0.5)2]), with an additional drop-out factor of five percent added, for a total sample size of 108 (103*0.05/100). Women were selected using a three-stage cluster sampling method (17). From the initial sampling frame consisting of the 72 quarters in Bamako, nine quarters were excluded due to over-representation of expatriates and international industries. Twelve of the remaining 63 quarters were selected for sampling using probability proportional to size. In each selected quarter, nine households[2] were randomly selected using the random walk method (5). All women aged 15-49 years-old living in the selected households were listed. From the list, one apparently healthy non-pregnant, non-lactating woman, belonging to a Malian sociolinguistic group and preferably a food preparer, was randomly selected from eligible women in each household. Forty-seven percent of the households had only one eligible woman, the remaining households had from two to eight eligible women. In the case of unavailability or refusal, the selected women were not replaced. During round one five women dropped out, leaving 103 women. During analysis one woman was considered a severe outlier and was deleted from analysis, leaving a total sample of 102 women with one day of intake, with a sub sample of 96 women completing two non-consecutive days of recall.

Dietary intake data collection

Two 24-hour dietary recalls were performed on non-consecutive days from February to April, 2007, during the post-harvest season. Six female interviewers were trained for ten days,

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1 Project number 0015403.

2 The household is considered as a group of consumers and may be defined as any person or group of persons who share the same living accommodation, who pool some or all of their income and wealth and who take food prepared from a common kitchen or cooking.

and then completed a pretest in two households that were not included in the sample. Weekend and special events days were excluded. The daily food intake of the subjects was assessed by a quantitative 24-hour recall method adapted to the context of shared plate eating, which involved asking the respondent to use known-weight utensils on the recall day to help them visualize the amount of food consumed (5). Participants were asked to name all the food and drinks consumed during the preceding day, including snacks and any food or beverages consumed outside the home. Then they were asked to describe ingredients and cooking methods of mixed dishes, and the place and the time of consumption. Finally, the amounts of all foods, beverages, and ingredients of mixed dishes were estimated either in household units or in monetary value. For meals consumed within the household, the total amount of the cooked food and the amount consumed by the respondent were measured in household units to derive the proportion consumed by the respondent from the total volume of the dish. Food weights were measured using digital dietary scales (Soehnle, Plateau Art, Germany, Model number 65086, maximum weight 10 kg), to nearest 2g (0.1oz). When a monetary unit was used to describe a portion, foods and ingredients were converted from monetary value to weight equivalent. Information on consumption of fortified food products was not included in original data collection. However, it is unlikely that this affected the results of the study as most of the fortified foods commonly available in the study area are designed for infants and preschool children[1].

Anthropometric measurements

Anthropometric measurements were performed on approximately two-thirds of the sample (n=65). Measurements were made according to WHO standardized procedures (19). Weight was measured using a SECA platform spring balance model 761, graduation 0.5kg, measuring range up to 150kg. Measures were recorded to the nearest 0.1kg. Height was measured using a body measuring tape label MZ10017, measuring range 2200 mm, graduation 1mm. Measurement was recorded to the nearest 0.1 cm. Body mass index (BMI) was calculated as [weight/height^2 (kg/m^2)]. Chronic energy deficiency and overweight/obesity were assessed using BMI cut-offs of <18.5 and ≥25.0, respectively.

Food Composition Data

A food composition table (FCT) was developed for the purposes of a larger project. A detailed description of the development of the food composition table is provided elsewhere (20). The food composition values used in the present study are based on this food composition table, which relied primarily on the *Table de Composition des aliments du Mali*

[1] Lactating women often eat the leftovers of their babies' porridges. But no lactating women were selected for this study. Although it cannot be stated conclusively, the impact of consumption of fortified children's porridge in our sample of non-pregnant, non-lactating women is expected to be minimal.

(TACAM) (21). The nutrients for all staple foods[1] are expressed as cooked. To account for nutrient losses during cooking in other foods, such as fish, meat and vegetables, USDA Retention factors release 6 (22) were applied to the nutrient values of the raw foods. In the case of missing values in *TACAM* for any of the eleven micronutrients values were first obtained from USDA release 20 (23) and, if necessary, from the International Mini List (IML), (23). Retinol equivalents (RE) were calculated as the sum of retinol and beta-carotene, using the following conversions: 1mcg retinol = 1 mcg RE and 1 mcg beta-carotene = 0.167 mcg RE, as recommended by FAO/WHO (24). Nutrient values taken from sources other than the TACAM were adjusted to account for differences in moisture content[2].

Food group combinations

Four different food group combinations based on six, nine, 13 or 21 food groups, with two levels of minimum intake (1g or 15g) were analyzed. The food group combinations, along with their abbreviations are described in Annex 1. The decision on appropriate combinations of food groups was undertaken by a small group of experts guided by the following principles; collection of the information required to construct the food groups should be available in simple surveys, there should be relevant nutritional distinctions between groups and lastly, disaggregation was guided by more nutrient-dense food groups and those providing a wider range of micronutrients (17). Vitamin A-rich fruits and vegetables were defined as those with ≥ 120 RE/100g as eaten. Vitamin C-rich fruits and vegetables were defined as those with ≥ 9 mg/100g as eaten. For simplicity of presentation, results from the most disaggregated set of food groups is presented in tables and figures. Notable results based upon the other combinations are described in the text.

Assessing probability of adequacy

Estimated average requirements (EAR) were used to assess the probability of adequacy of thiamin, riboflavin, niacin, B_6, B_{12}, vitamin C, vitamin A, zinc, folate, iron and the adequate intake (AI) for calcium. Intake distributions and intra-individual standard deviation distributions for most micronutrients were skewed, and were transformed prior to analysis. The probability of adequacy (PA) for eleven micronutrients was then calculated by means of the best linear unbiased predictor (BLUP) taking into account nutrient requirement distributions and inter- and intra- individual variation in the transformed intake variables (17). Iron and zinc requirements were based on bioavailability of ten percent for iron and 34 percent for zinc, determined on the basis of the population level dietary pattern of the sample (25). The mean probability of micronutrient adequacy (MPA) was constructed as a summary indicator using the average of the eleven PA's. MPA_{pop} represents the mean probability of adequacy for the

[1] Vitamin B_6 values reported for cooked staples in TACAM were very low, so vitamin B_6 values for cooked staples from USDA and IML were used.

[2] IML tables do not report moisture content. The moisture content for foods taken from IML was estimated based on the closest food match from USDA.

total sample, which is equivalent to a population level estimate of prevalence of adequacy. MPA_{ind} represents that individual's mean probability of adequate intake of micronutrients.

Statistical methods

Non-parametric tests were used for food group intakes as these were not normally distributed. Binary logistic regression was used to model intake of individual food groups as predictors of MPA ≥ 0.50. For each food group analyzed, cut-off points based on distribution of grams of intake for each food group were used to form three comparison categories. The first category corresponded to an intake of zero grams, or the lowest tertile of intake when consumption was 100 percent. The second and third categories were either the second and third tertiles of consumption or were determined based upon classifying groups into low and high consumers using median intake. For each food group, energy intake from that group in relation to total energy intake was determined as the residual obtained from regressing energy intake from each food group on total energy intake. All models were adjusted for effect of total energy intake from other food groups and age. Logistic models controlled for age and total energy intake from other food groups; results were not influenced by age for any food group. Analysis was undertaken using STATA IC, version 10 (26). A p value <0.05 was considered significant.

RESULTS

Sample characteristics

Mean age in the sample was 31 years with 16 percent adolescents (15-18yrs) (Table 1). Literacy rate, defined as having attended primary school or Islamic school was 65 percent. In the sub-sample of women with anthropometric measurements, the prevalence of chronic energy deficiency (BMI < 18.5) was 17 percent, while 28 percent of the women were overweight/obese (BMI ≥ 25). Median energy intake was 2,024 kcal (1613 kcal, 25th percentile and 2513 kcal, 75th percentile), with 11 percent of dietary energy from protein, 57 percent from carbohydrate and 32 percent from fat.

Table 1 Descriptive Statistics

Characteristic	n	Mean	SD
Age (y)	102	31.5	10.5
Height (cm)	64	166	5.9
Weight (kg)	64	65.0	14.8
BMI	64	23.6	5.6
Energy (kilocalories)	102	2054.0	716.5
	n	Percent	
BMI ≤18.49	64	17.2	
BMI ≥ 25.0	64	28.1	
Education (% literate)[1]	102	65.1	

[1] Percent of women who reached at least primary school level or went to Islamic school

Dietary patterns and food group intake

The majority of women consumed three meals per day and some also consumed snacks. The most commonly consumed food groups did not differ substantially between recall days. Out of the list of twenty-one possible food groups, the food groups consumed by at least fifty percent of women on each recall day included; Grains and grain products (Grains), Nuts and seeds (Nuts/seeds), Beef, pork, veal, lamb, goat, game meat (Red meat), Large whole fish/dried fish/shellfish and other seafood (Large fish), Vitamin A- rich deep yellow, orange and red vegetables (YORV), vitamin C-rich vegetables and all other vegetables (Other vegetables) (Table 2). For day one, food groups which fell below fifty percent consumption when applying a 15g minimum requirement to count in the score, included Nuts/seeds, Large fish, YORV and Other vegetables. For day two the same food groups were influenced by the 15g restriction, but on day two, consumption of large fish remained above 15g for 55 percent of women.

The diet of this urban sample of women in Mali is based upon consumption of a starchy staple, mainly refined white rice, refined wheat flour or millet accompanied by a sauce typically made from vegetables and beef or fish. Table 3, provides a summary of food group intake based on twenty-one food groups. After grains, vitamin A-rich vegetables were consumed in the largest amounts. The most commonly consumed individual food items in this group were tomato, (eaten by 92% of women) onion (eaten by 90% of women) dried okra (eaten by 62% of women) and cabbage (eaten by 59% of women). Median intakes among consumers were 71g for tomato, or approximately ¼ cup of cooked tomato, 117g of onion, the equivalent of one medium size raw onion, 34g of cabbage and 2.5g of dried okra powder. Forty-one percent consumed some type of dark green leafy vegetable (DGLV). The median DGLV portion size among consumers was 88g, roughly the equivalent of ½ cup of cooked spinach. Some women ate raw green salad, which usually consisted of lettuce, tomato and onion. Nuts and seeds, primarily peanut butter and *soumbala* (African locust bean seed) were consumed by seventy percent of women. As demonstrated in table two, this group was affected by the 15g portion size requirement. Fifty five percent of women consumed African locust bean seed, with a median intake among consumers of 2g. Thirty percent of women consumed peanut butter. The median portion size of peanut butter among consumers was 25g, roughly equivalent to 1½ tablespoons. Fruit was consumed by fourteen percent of women. The most commonly consumed fruits were banana (n=4), orange (n=4) and papaya (n=4). Fruit was sometimes consumed as a snack, or a food item consumed outside what women classified as breakfast, lunch or dinner. Other foods often eaten as snacks were millet donuts, fried cassava and fried potatoes. These foods were typically purchased outside of the home and are commonly sold around urban market areas.

Table 2 Inter-individual variation in consumption of individual food groups

	Percent consuming (≥ 1g)		Percent consuming (≥ 15g)	
Food group	**Day 1 (n=102)**	**Day 2 (n=96)**	**Day 1 (n=102)**	**Day 2 (n=96)**
Grains	100	99	100	99
Other staples	42	41	41	40
Beans/peas	4	2	4	2
Soy products	0	0	0	0
Nuts/seeds	70	72	36	40
Milk/yogurt	48	56	47	56
Cheese	0	0	0	0
Red meat[1]	70	57	70	51
Organ meat	0	0	0	0
Poultry[2]	0	0	0	0
Large fish[3]	56	63	47	55
Small fish[4]	5	8	0	1
Insects/rodents[5]	0	0	0	0
Eggs	8	9	7	9
DGLV[6]	41	50	28	34
YORV[7]	82	72	17	9
Vitamin C-rich vegetables	100	99	100	98
All other vegetables	60	57	45	45
Vitamin A-rich fruits	12	14	9	8
Vitamin C-rich fruits	9	8	7	8
All other fruits	0	0	0	0

1 Beef, pork, veal, lamb, goat, game meat.
2 Chicken, duck, turkey, pigeon, guinea hen, game birds.
3 Large whole fish/driedfish, shellfish and other seafood.
4 Small fish eaten whole with bones.
5 Insects, grubs, snakes, rodents and other small animals.
6 Vitamin A-rich dark green leafy vegetables.
7 Vitamin A-rich deep yellow/orange/red vegetables.

Table 3 Intake[1] (g) of food groups consumed for total sample and among consumers

Food group	All (n=102) Mean amount (g)	Median amount (g)	Range (g)	Among consumers Mean amount (g)	Median amount (g)	Range (g)
Grains	742.7	775.5	119-1619	742.7	775.5	119-1619
Other staples	60.8		0-476	144.2	124.0	5-476
Beans/peas	5.2		0-235	133.5	121.5	56-235
Nuts/seeds	36.7	2.0	0-196	52.7	25.0	1-196
Milk/yogurt	74.5		0-665	155.1	94.0	12-665
Red meat[2]	42.3	41.5	0-147	60.8	52.0	15-147
Large fish[3]	25.0	12.0	0-251	44.7	35.0	5-251
Small fish[4]	0.3		0-11	6.2	5.0	2-11
Eggs	4.1		0-60	52.3	57.5	13-60
DGLV[5]	30.0		0-226	72.8	87.5	1-226
YORV[6]	7.5	5.0	0-37	9.1	5.0	1-37
Vitamin C-rich vegetables	212.2	209.5	17-557	212.2	209.5	17-557
All other vegetables	16.2	11.0	0-116	27.1	24.0	1-116
Vitamin A-rich fruits	3.8		0-80	31.9	20.0	10-80
Vitamin C-rich fruits	14.7		0-371	166.7	42.0	9-371

1 Empty cells are equal to 0 grams.
2 Beef, pork, veal, lamb, goat, game meat.
3 Large whole fish/driedfish, shellfish and other seafood.
4 Small fish eaten whole with bones.
5 Vitamin A-rich dark green leafy vegetables.
6 Vitamin A-rich deep yellow/orange/red vegetables

Figure 1 Percent of women consuming individual food groups on one, both or no recall days (using FGI-21 groups) (n=96)

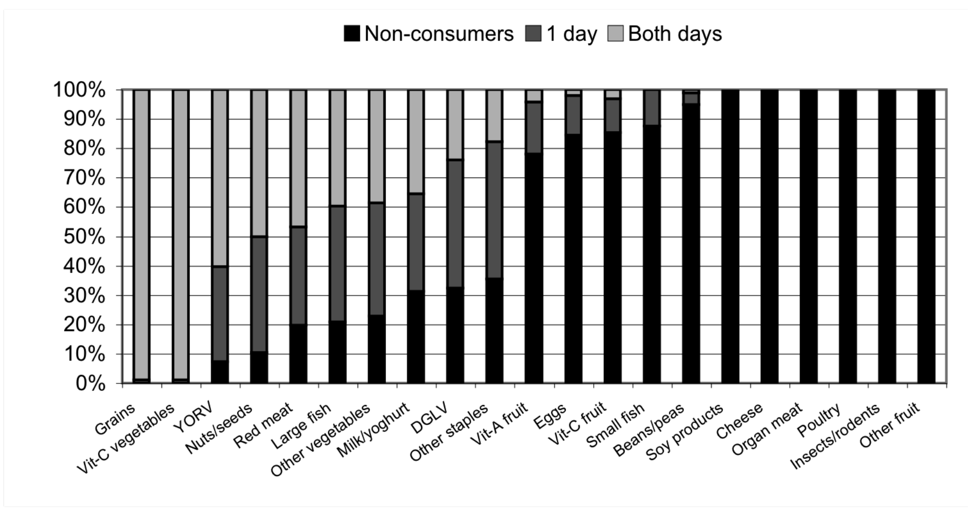

Figure 1, based on the sub-sample of women with two recall days, shows the percent who consumed each food group, both, one or none of the days. Grains, Vitamin C-rich vegetables, YORV and Nuts/seeds were consumed by the majority of women on both recall days. Other starchy staples (Other staples) were consumed by approximately forty percent of women on both recall days, but only by seventeen percent on both days.

Table 4 Mean and median nutrient intake and probability of adequate intake

Nutrient	Mean	SD	Median	EAR	SD[1]	PA (Mean)
Thiamin (mg/d)	1.0	0.50	0.90	0.9[2]	0.09	0.59
Riboflavin (mg/d)	0.8	0.40	0.70	0.9[2, 3]	0.09	0.28
Niacin (mg/d)	10.6	6.50	8.30	11[2, 3]	1.65	0.31
Vitamin B_6 (mg/d)	1.2	0.50	1.20	1.1[2]	0.11	0.67
Folate (g/d)	131.4	82.50	119.10	320[3,4]	32.0	0.00
Vitamin B_{12} (g/d)	1.5	1.00	1.30	2.0[4]	0.2	0.17
Vitamin C (mg/d)	62.6	34.50	58.40	38[2]	3.8	0.88
Vitamin A (RE/d)	358	295.30	244.60	270[4]	54.0	0.50
Calcium (mg/d)	443.9	318.30	374.50	1000[3, 5]		0.27
Iron (mg/d)	16.1	8.80	14.20	[6]		0.54
Zinc (mg/d)	10.2	5.8	8.8	6.0[3, 7]	0.75	0.96
MPA_{pop}	0.47	0.18	0.48			

1 All SD calculated based on EAR and CV, which was assumed to be 10 percent for all micronutrients (FAO/WHO 2002 requirements), except 15 percent for niacin (IOM 2000), 20 percent for vitamin A (IOM 2000) and 12.5 percent for zinc (IZiNCG 2004).

2 EAR back calculated from RNI values of WHO/FAO 2004 requirements.

3 For adolescents group (15-18 years old, n=16), value of 0.8±0.08 was used for riboflavin, 12±1.2 for niacin, 7.0±0.88 for zinc (30 percent bioavailability), 365±73 for vitamin A, 330±33 for folate, 1.0±0.1 for B6, and 1300 AI for calcium.

4 EAR taken from WHO/FAO 2004.

5 Not an EAR, but rather AI from IOM (1997). Following Foote et al. (2004), PA are calculated to be: 0 percent when intake ≤ 1/4 of the AI; 25 percent for intakes > 1/4 and ≤ 1/2 of the AI; 50 percent for intakes > 1/2 and ≤ 3/4 of the AI; 75 percent for intakes > 3/4 and ≤ AI; and 100 percent for intakes above the AI.

6 PA for iron intake are estimated using IOM tables (2000a, page 347), adult women. According to WHO/FAO (2004). Bioavailability of 10 percent was used for our study.

7 This is the estimated median requirement of zinc to be used for diets with higher bioavailability as suggested by IZiNCG (2004).

Micronutrient intakes, PA and MPA

Table 4 shows mean and median micronutrient intakes as compared to the Estimated Average Requirement (EAR) for women of the same age group and physiologic status. The mean probabilities of adequate intake are also provided. Median micronutrient intakes were below the EAR for riboflavin, niacin, vitamin B_{12}, folate, vitamin A and the AI for calcium. Median intakes were above the EAR for vitamin B_6, vitamin C and zinc and equal to the EAR for thiamin. The probability of adequate intake (PA) was <0.20 for B_{12} and folate, ranged between 0.20 and 0.49 for riboflavin, calcium, and niacin, and was 0.50 or above for iron, vitamin A, B_6, thiamin, zinc and vitamin C. MPA_{pop} for the 11 micronutrients was 0.47.

Table 5 Contribution of twenty-one individual food groups to energy and micronutrient intakes[1,2]

Food groups (%)	Energy	Thiamin	Riboflavin	Niacin	Vitamin B_6	Folate	Vitamin B_{12}	Vitamin C	Vitamin A	Calcium	Iron	Zinc
Grains	43.0	53.0	24.8	14.7	35.1	8.8	0.2[3]	0.8	3.3	10.5	40.3	39.4
Other staples	3.1	5.9	2.0	5.9	12.9	6.1		15.0	1.3	1.5	2.2	1.2
Beans/peas	0.2	1.1	0.4	0.2	0.4	8.3				0.3	0.8	0.7
Soy products												
Nuts/seeds	10.3	10.6	6.2	37.5	8.3	13.0			0.1	5.6	17.6	9.0
Milk/yogurt	4.6	5.0	29.4	4.4	3.6	5.0	30.4	0.9	20.2	43.4	0.3	19.5
Cheese												
Red meat	4.8	6.9	8.4	14.4	4.3	1.6	30.6			1.0	9.4	17.0
Organ meat												
Poultry												
Large fish	2.0	1.7	3.7	6.9	5.3	2.3	31.1	0.4	0.4	5.7	4.5	3.8
Small fish				0.2	0.2	0.1	0.5			0.7	0.1	0.1
Insects/rodents												
Eggs	0.3	0.4	1.5	0.1	0.5	0.6	4.1		1.7	0.4	0.5	0.6
DGLV	0.4	2.3	7.3	2.1	3.3	12.2		6.4	35.7	10.6	5.8	1.2
YORV	0.2	1.1	0.8	1.5	2.1	1.8		0.6	11.6	0.5	1.0	0.4
Vitamin C-rich vegetables	3.9	8.8	11.7	8.8	17.0	33.0		66.5	12.3	17.1	14.1	6.2
All other vegetables	0.1	0.9	1.0	0.5	1.3	1.9		1.8	3.5	0.5	0.6	0.4
Vitamin A-rich fruits	0.5	0.1	0.1	0.1	0.1	0.1		2.1	7.5	0.1	0.1	
Vitamin C-rich fruits	0.6	0.5	0.6	0.8	3.9	2.2		2.7	0.6	0.3	0.1	0.3
All other fruits												

1 Percents may not sum to 100 due to nutrient contributions from foods not included in any of the groups comprising the diversity indicators (e.g., fats, sweets, alcohol).
2 Empty cells mean no contribution.
3 This value comes from butter croissant (0.16 mcg/100 g.

Contribution of food groups to nutrient intakes

The contribution of each food group to nutrient intake is dependent upon both the quantity consumed and the nutrient density of the food items in the group. Using the list of twenty one food groups, Table 5 shows the contribution of each group to energy and micronutrient intake. Median intake of Grains was 775 g. This food group contributed 43 percent of energy intake, over fifty percent of thiamin intake and over one third of intakes of vitamin B_6, iron and zinc. Of the food groups included in the score, Nuts/seeds provided the next largest contribution to energy although median intake was only 25 g. Nuts/seeds also supplied over one third of niacin intake and ten percent or more of intakes of thiamine, folate and iron. The median intake of vitamin C-rich vegetables, which included cabbage, tomato and onions, was 209 g. This food group supplied two-thirds of vitamin C intake, one-third of folate intake and over ten percent of intakes of riboflavin, vitamin B_6, vitamin A and iron. Milk and yogurt (Milk/yogurt) supplied only five percent of energy intake, but supplied more than twenty percent of intakes of riboflavin, vitamin B_{12}, vitamin A, and calcium. Eggs did not supply more than five percent of any micronutrient. Flesh foods (beef and large fish) supplied seven percent of total energy intake but nearly two-thirds of vitamin B_{12} and more than 20 percent of intakes of niacin and zinc. DGLV supplied less than one percent of total energy intake, but 36 percent of vitamin A intake and ten percent or more of intakes of folate and calcium.

Table 6 Association between food group intake (g) from twenty-one food groups and mean probability of adequate intake (MPA)

Food group	Median intake[1]	Spearmans coefficient[2]
Grains	776	0.19
Other staples	124	0.14
Beans/peas	122	-0.05
Soy products		
Nuts/seeds	25	0.36*
Milk/yogurt	94	0.25*
Cheese		
Organ meat		
Eggs	58	0.09
Small fish	5	0.08
Large fish	35	0.09
Red meat	52	0.14
Poultry		
Insects/rodents		
DGLV	88	0.27*
YORV	5	0.03
Vitamin A-rich fruits	20	0.04
Vitamin C-rich vegetables	210	0.20*
Vitamin C-rich fruits	42	-0.01
All other fruits		
All other vegetables	24	0.15

[1] Median intake among consumers. [2] * indicates significant correlation.

Correlations between energy intake from individual food groups and MPA

Using grams of intake for the six food group combination all six food groups, were significantly and positively associated with MPA (results not shown). With further disaggregation, some of the associations become more specific to a certain sub-groups (Nuts/seeds for the larger group Legumes/nuts and DGLV for the larger group of Vitamin A-rich fruits and vegetables). In the set of twenty-one food groups, grams of intake from four food groups, Nuts and seeds, Milk/yogurt, DGLV and Vitamin-C rich vegetables were significantly correlated with MPA (Table 6).

Logistic Regression of MPA ≥ 0.50 and grams of intake from significant food groups

Binary logistic regression results for the four food groups, within the set of twenty-one, which were significantly correlated with MPA are presented in Table 7. Results did not differ when controlling for age, but did change slightly when adjusted for energy intake from other food groups. The odds ratio was significant for the medium consumers of the Milk/yogurt group and the highest consumers of the Nuts/seeds and DGLV groups. No amount of intake of vitamin-C rich vegetables group was a significant predictor.

Table 7 Energy adjusted[1] odds ratios for MPA >.5 and those individual food groups, significantly correlated with MPA

Food group intake (g)	Intake in grams[2]	Odds Ratio	CI for OR	p value
Nuts and seeds	0	1.0		
Nuts and seeds	1-25	1.6	0.5-4.6	0.42
Nuts and seeds	>25	5.2	1.7-15.6	0.00
Milk/yogurt	0	1.0		
Milk/yogurt	1-94g	6.5	2.0-21.6	0.00
Milk/yogurt	>94g	1.8	0.6-5.4	0.29
DGLV	0g	1.0		
DGLV	1-88g	1.7	0.6-5.3	0.33
DGLV	>88g	6.0	1.7-21.5	0.00
Vitamin C-rich vegetables	<141g	1.0		
Vitamin C-rich vegetables	141-262g	1.1	0.4-3.3	0.82
Vitamin C-rich vegetables	>262g	2.3	0.8-6.7	0.11

[1] Adjusted for the effect of total energy intake, excluding energy provided from that food group.
[2] Cut-off points to form three comparison categories were based upon intake distributions for each food group.

DISCUSSION

This discussion will review key findings, study limitations and external validity and public health significance of these results in relation to the overall objective of the paper to detect those food groups with the largest contribution to mean probability of adequate intake of micronutrients of urban women living in Mali.

Key findings

Results indicate that macronutrient distributions were within acceptable population intake ranges as defined by WHO/FAO (27). Percent total dietary energy from fat was on the higher end of the acceptable population range. Total dietary energy intakes were also (2054 kcal ± 716). Roughly 50 percent of dietary energy came from starchy staples. This is lower than for most other WDDP sites reported on in this supplement. In the Mali sample, food items not counted in any of the dietary diversity indicators, such as fats and oils, accounted for 20 percent of total dietary energy intake. Twenty-eight percent of the sub-sample of women with BMI measured were classified as overweight or obese.

Grains, nuts/seeds, red meat, YORV, vitamin C-rich vegetables and all other vegetables were the most commonly consumed food groups. Of these, percent of women consuming nuts/seeds, YORV and all other vegetables, were most affected by the 15g minimum requirement. Spearman's correlations for grams of food group intake, based on twenty-one food groups and MPA were significant for Nuts/seeds, Milk/yogurt, DGLV and Vitamin C-rich vegetables. Logistic regression results showed the highest consumers of nuts/seeds were five time more likely to have a probability of adequate intake of micronutrients above 50 percent. Consumers in the highest category of DGLV intake were six times more likely to have a probability of adequate micronutrient intake above 50 percent.

Study Limitations

Both the dietary diversity scores and the micronutrient intakes were calculated from the same 24-hour recall data; this could lead to artificially high correlations because both measures are constructed from the same intake data. Conversely, the random error inherent in all dietary data collection can attenuate correlations (28). Finally, the sample for this study was designed for other purposes, and the relatively small sample size yielded low power for some analyses.

Probabilities of adequacy were low for several micronutrients and MPA_{pop} was only 0.47. Due to the combination of low MPA's and small sample size, only 45 women were above an MPA_{ind} of 0.5, 25 had an MPA_{ind} greater than 0.6 and 11 had MPA_{ind} above 0.7 for these reasons, MPA >50% was used throughout the analysis. There are no clear guidelines on how to define an acceptable level of mean probability of adequacy. Ideally, the bench-mark chosen to define adequate intake would be set higher, for example 0.80 or 0.90. In order to use a higher and more desirable probability, the sample population studied would need to have micronutrient intakes higher than those observed in this population.

Which individual food groups have the most importance in terms of inclusion in diversity scores?

When foods were aggregated into six groups, all six were significantly correlated with MPA. Legumes/nuts, ASF, Vitamin A-rich F/V and Other F/V increased the odds of having $MPA_{ind} \geq 0.50$ (results not shown). Analysis of the more disaggregated groups helped to define some of the specific relationships. For example, the relationship between intake of legumes and nuts and MPA was driven by the sub-group Nuts/seeds, rather than beans/peas or soy products, which were very rarely consumed. The food group red meat, rather than large fish, small fish or poultry, was responsible for the correlation between ASF and MPA; small fish and poultry were rarely consumed, but large fish were consumed by a substantial proportion of women, yet did not contribute strongly to higher MPA. Among vitamin A-rich fruits and vegetables, only vitamin A-rich dark green leafy vegetables were significantly correlated with MPA.

In a similar study of women in Bangladesh, dark green leafy vegetables, fish, nuts/seeds, and dairy were the food groups of most nutritional importance in terms of providing micronutrients (12). In analysis of diets of rural school children in Kenya, vegetables, fruits and dairy were the food groups with the strongest correlation to a diet most likely to be adequate in micronutrients (29). A study of the adequacy of micronutrient density of complementary foods from nine countries tested how well selected nutrient dense food groups predicted dietary quality (8). Seven food groups (grains; legumes and nuts; dairy; flesh foods; eggs; vitamin A rich fruits and vegetables and other fruits and vegetables) and an additional combination of animal source foods (dairy or eggs or meat/fish/poultry) were tested. The most consistent result across all countries was for the combination of "animal source foods" which included dairy and/or eggs and/or meat/fish/poultry. Additionally in some countries dairy, vitamin-A rich fruits and vegetables and other fruits and vegetables were good indicators of better dietary quality of complementary foods.

Based on the convergence of evidence from these studies, dairy, eggs, fruits and vegetables, particularly dark green leafy vegetables, fish, red meat and legumes and nuts, or their sub-groups are key food groups for use in developing proxy indicators of micronutrient adequacy based on dietary diversity scores. However, for operational purposes, it is important to note that the food groups contributing most to micronutrient adequacy varied by study site. This conclusion supports dietary diversity as a universal indicator, since no single (or even combination) of "sentinel" groups performed as well across diverse contexts.

Many probabilities of adequate micronutrient intake were low as was overall MPA, despite one-third of the population being overweight or obese according to BMI cut-offs.

This finding places emphasis on the role of micronutrient adequacy of the diet and illustrates that adequate intake of dietary energy does not ensure adequate intakes of a range of micronutrients. In this population the nutrients with the lowest estimated prevalence of adequacy were folate, vitamin B_{12}, riboflavin and niacin. Increasing intakes of Red meat, DGLV and Nuts/seeds could increase intakes of some of these key nutrients. Each of these food groups was consumed at least one of the recall days by a majority of women, indicating that there are no cultural barriers to consumption of foods within these groups. Qualitative research methods could be used to explore constraints and opportunities related to increasing consumption frequency and quantity of foods within these food groups. These food groups could form the basis of focus for both programmatic efforts and individual dietary choices where the desired goal is to promote micronutrient adequacy through food-based approaches.

The role of the food group fats and oils was not explored in this analysis. Research undertaken previously on micronutrient density of complementary food, found that including a food group of fats and oils weakened the performance of an indicator as a proxy of micronutrient density of complementary foods (8). In general, fats and oils are not rich in micronutrients. Notable exceptions to this are red palm oil which is rich in vitamin A and for the purposes of this study was included in the vitamin A-rich fruits group. Butter also contains vitamin A, but was not counted in any food group in this study. With the goal of achieving the strongest proxy indicator for micronutrient adequacy, the fats and oils food group, should be omitted from the score. However, with a broader goal of monitoring changes in dietary patterns and associations between dietary diversity and other aspects of nutritional status including body mass index, it is advisable to collect information on consumption of fats and oils.

Implications for development of proxy indicators of micronutrient adequacy

Part of the overall goal of the Women's Dietary Diversity Project described in detail in the methods and summary papers of this supplement, was to analyze the relationship between simple indicators of dietary diversity and diet quality for women. The analysis in this paper, which had a more in-depth focus on performance of individual food groups helped to draw attention to the performance and role of certain food groups in achieving nutrient adequacy in this particular population from urban Mali. In our study, the food groups most affected by the 15g limit were Nuts/seeds and YORV. The food groups large fish, small fish eaten whole with bones (Small fish) and DGLV were also influenced by the 15 g minimum intake. The difference in the Nuts/seeds group was almost entirely due to the frequent consumption of fermented African locust bean seed, which is often added to sauce for flavouring and used in very small amounts. In the vitamin A rich deep yellow, orange and red vegetable group tomato paste was a common ingredient in sauce accompanying the staple food, but the amount consumed rarely exceeded 15 grams. This type of consideration and reflection on dietary patterns within the local context will be needed in order to identify those foods likely to be consumed in small quantities. Further research is needed on the best way to adapt survey tools to exclude these items from scores.

The lack of consumption of six out of the twenty-one food groups in the most disaggregated measure indicates that the full potential of this level of disaggregation cannot be assessed in the sample from Mali. This is likely to be true in many resource-poor areas. It is possible that if tested in an environment where diets are more diversified, more of these food groups would be significantly associated with higher MPA. In terms of selecting food groups to include in a score, there are considerations in terms of data collection with the more disaggregated sets of food groups. The larger the number of food groups in the score, the more time will be required for field adaptation to identify examples of locally available foods to be included in each food group. This is particularly true when trying to identify local fruits and vegetable as vitamin-A or vitamin-C rich, especially in the absence of food composition data for some of these foods. While in theory this is not a problem, in practice it could create confusion both during survey training and also when reporting results if based on only a sub-set of food groups available in the local context.

CONCLUSION

This analysis showed a strong and positive association between the food groups, nut/seeds and DGLV and probability of adequate intake of micronutrients. The food groups milk/yogurt and vitamin C-rich vegetables were also notably, but less strongly associated with overall probability of adequate micronutrient intake. These results suggest that dietary diversification is a valid strategy to improve micronutrient intake of women of reproductive age. In Mali, a particular focus on increasing intake of nuts and seeds and DGLV could be used in vulnerable populations.

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ANNEX 1 Food groups used in diversity indicators and food group abbreviations[1]

6-group indicators	Abbr	9-group indicators	Abbr	13-group indicators	Abbr	21-group indicators	Abbr
All starchy staples	Staples	All starchy staples	Staples	All starchy staples	Staples	Grains and grain products	Grains
						All other starchy staples	Other staples
All legumes and nuts	Legumes /nuts	All legumes and nuts	Legumes/ nuts	All legumes and nuts	Legumes/ nuts	Cooked dry beans and peas	Beans/ peas
						Soybeans and soy products	Soy products
						Nuts and seeds	Nuts/ seeds
All dairy	Dairy	All dairy	Dairy	All dairy	Dairy	Milk/yoghurt	Milk/ yoghurt
						Cheese	Cheese
Other animal source foods	ASF	Organ meat	Organ meat	Organ meat	Organ meat	Organ meat	Organ meat
		Eggs	Eggs	Eggs	Eggs	Eggs	Eggs
		Flesh foods and other miscellaneous small animal protein	Fish, meat, poultry	Small fish eaten whole with bones	Small fish	Small fish eaten whole with bones	Small fish
				All other flesh foods and miscellaneous small animal protein	Other animal protein	Large whole fish/dried fish/shellfish and other seafood	Large fish
						Beef, pork, veal, lamb, goat, game meat	Red meat
						Chicken, duck, turkey, pigeon, guinea hen, game birds	Poultry
						Insects, grubs, snakes, rodents and other small animals	Insects/ Rodents

Vitamin A-rich fruits and vegetables[a]	Vitamin A-rich F/V	Vitamin A-rich dark green leafy vegetables	DGLV	Vitamin A-rich dark green leafy vegetables	DGLV	Vitamin A-rich dark green leafy vegetables	DGLV
		Other vitamin A-rich vegetables and fruits[c]	Other vitamin A-rich F/V	Vitamin A-rich deep yellow/ orange/red vegetables	YORV	Vitamin A-rich deep yellow/ orange/red vegetables	YORV
				Vitamin A-rich fruits	Vitamin A-rich fruits	Vitamin A-rich fruits	Vitamin A-rich fruits
Other fruits and vegetables	Other F/V	Other fruits and vegetables	Other F/V	Vitamin C-rich vegetables	Vitamin C-rich vegetables	Vitamin C-rich vegetables	Vitamin C-rich vegetables
				Vitamin C-rich fruits	Vitamin C-rich fruits	Vitamin C-rich fruits	Vitamin C-rich fruits
				All other fruits and vegetables	Other fruits and vegetables	All other vegetables	Other vegetables
						All other fruits	Other fruit

[1] Abbr indicates abbreviation food group name.

REFERENCES

1. ACC/SCN. Fourth Report on the World Nutrition Situation. Geneva: ACC/SCN in collaboration with IFPRI; 2000.
2. Cellule de Planification et de Statistique du Ministère de la Santé (CPS/MS), Direction Nationale de la Statistique et de l'Informatique du Ministère de l'Économie, de l'Industrie et du Commerce (DNSI/MEIC) et Macro International Inc. *Enquête Démographique et de Santé du Mali 2006* Calverton, Maryland: CPS/DNSI et Macro International Inc; 2007.
3. UNICEF and the Micronutrient Initiative. Vitamin and Mineral Deficiency. A global damage assessment report. [Internet]. [Cited 13 January, 2009]. Available from: http://www.micronutrient. org/CMFiles/PubLib/Report-67-VMD-A-Global-Damage-Assessment-Report1KSB-3242008-9634.pdf
4. Savy M, Martin-Prével Y, Sawadogo P, Kameli Y, Delpeuch F. Use of variety/ diversity scores for diet quality measurement: relation with nutritional status of women in a rural area in Burkina Faso. *Eur J Clin Nutr* 2005;59:703-716.
5. Gibson R, Ferguson E. An interactive 24-hour Recall for Assessing the Adequacy of Iron and Zinc Intakes of Developing Countries. Washington, DC: Harvest Plus; 2008. Technical Monograph 8.
6. Ogle B, HuangHung P, Thi Tuyet H. Significance of wild vegetables in micronutrient intakes of women in Vietnam: an analysis of food variety *Asia Pac J Clin Nutr* 2001;10(1):21-30.
7. Hatloy A, Torheim L, Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr* 1998;52(12):891-8.
8. Working Group on Infant and Young Child Feeding Indicators. Developing and validating simple indicators of dietary quality and energy intake of infants and young children in Developing Countries: Summary of findings from analysis of 10 data sets. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2006.
9. Steyn NP, Nel JH, Nantel G, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutr* 2006;9(5):644-650.
10. Kennedy G, Pedro MR, Seghieri C, Nantel G, Brouwer I. Dietary diversity is a useful indicator of micronutrient intake in nonbreast-feeding Filipino children. *J Nutr* 2007;137:1-6.
11. Daniels M, Adair L, Popkin B, Truong Y. Dietary diversity scores can be improved through the use of portion requirements: an analysis in young Filipino children. *Eur J Clin Nutr* 2009;63:199-208.
12. Arimond M, Torheim LE, Wiesmann D, Joseph M, Carriquiry A. Dietary Diversity as a Measure of Women's Diet Quality in Resource-Poor Areas: Results from rural Bangladesh site. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project/Academy for Educational Development (AED); March, 2008.
13. Ahn BC, Engelhardt K, Joung H. Diet variety is associated with socio-economic factors. *Ecol Food Nutr* 2006;45:417-430.
14. Torheim LE, Ouattara F, Diarra M, Thiam F, Barikmo I, Hatloy A, Oshaug, A. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. *Eur J Clin Nutr* 2004;58: 594-604.
15. Ruel MT. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr* 2003;133:3922S-3926S.
16. WHO. Indicators for assessing infant and young child feeding practices: conclusions of a consensus meeting held 6–8 November 2007 in Washington, DC, USA. Geneva: WHO; 2008.
17. Arimond, M., Wiesmann D, Torheim LE, Joseph M. Carriquiry A. Validation of Dietary diversity as a measure of the micronutrient adequacy of Women's Diets. Background and Research Protocol. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2008.
18. UNICEF. Monitoring the Situation of Children and Women: Multiple indicator cluster survey manual. New York: Division of policy and planning, UNICEF; 2006.
19. WHO. Physical status: the use and interpretation of anthropometry. Geneva: WHO; 1995. WHO Technical Report Series 854.
20. Koreissi Y, Fanou N, Brouwer I. *Development of the fonio food composition table*. INCO FONIO Project; 2007.
21. Barikmo I, Ouattara F, Oshaug A. *Table de composition des aliments du Mali*. Oslo: Akershus Universiy College; 2004.
22. U.S. Department of Agriculture, Agricultural Research Service. *USDA Table of Nutrient Retention Factors, Release 6*. [Internet]. Available from: Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl.
23. U.S. Department of Agriculture, Agricultural Research Service. *USDA National Nutrient Database for Standard Reference, Release 20*. [Internet]. Available from Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl.
24. World Food Dietary Assessment System (no date). Users Guide to the World Food Dietary Assessment System, version 2.0. [Internet]. [cited 6 August, 2008]. Available from: http://www.fao.org/infoods/software/wfood2.doc
25. FAO/WHO. Human vitamin and mineral requirements. Rome: FAO; 2007. Report of a joint FAO/WHO Expert consultation.

26. StataCorp. Stata Statistical Software: Release 10-IC. College Station, Texas: StataCorp LP; 2007.
27. WHO/FAO Diet, Nutrition and the prevention of chronic diseases. Geneva: WHO; 2003. Report of a Joint WHO/FAO expert consultation.
28. Block G, Hartman M. Issues in reproducibility and validity of dietary studies. *Am J Clin Nutr* 1989;50:1133-8.
29. Ruel M, Graham J, Murphy S, Allen L. Validating simple indicators of dietary diversity and animal source food intake that accurately reflect nutrient adequacy in developing countries. Report submitted to GL-CRSP; July, 2004.

CHAPTER 6

ANALYSIS OF DIETARY DIVERSITY SCORES CONSTRUCTED FROM A REFERENCE PERIOD OF ONE OR SEVEN DAYS IN AN AREA OF ACUTE FOOD INSECURITY IN SOMALIA

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Submitted for publication

ABSTRACT

Background/Objectives Information on dietary diversity is increasingly used in food security and nutrition assessments, however, there are many different methods used to construct diversity scores. This paper compares household level diversity scores and dietary profiles constructed from a one or seven day recall period.

Subjects/Methods Four hundred and thirty households in El Barde, Somalia. Information on dietary diversity of the household was obtained using a list based questionnaire. Household-level dietary diversity scores were constructed by summing the number of food groups, out of twelve, consumed over the two recall periods.

Results Median household dietary diversity score was 4 (3,5 – 25th and 75 percentile) for both recall periods. Distributions between 1d and 7d DDS were significantly different ($p < 0.05$). Food group consumption in the lowest and highest tertiles exhibited the same pattern for both recall periods. In the lowest tertiles the majority of households consumed cereal, milk and sugar. In the highest tertiles oil, meat and pulses were also consumed. Theoretical probabilities of consumption of individual food groups were lower than reported one day consumption, particularly for oil and fats, meat and poultry and pulses. Significant relationships between main source of income ($p < 0.05$), and main source of food production ($p < 0.05$) were found for both scores.

Conclusion The results indicate that a one day recall period can be relied upon to provide an appropriate and quick assessment of household dietary diversity and may be preferable in emergency contexts.

INTRODUCTION

Measurement of dietary diversity is increasingly used in household food security and nutrition assessments for chronically food insecure populations (1,2) and emergency settings (3,4). Household dietary diversity scores have been correlated with household per capita energy intake in diverse settings (5,6). Information on household dietary diversity can be used to assess household food access (7) and household level dietary patterns (1).

Recently there has been a concerted effort to standardize the measurement of dietary diversity as an indicator of household food security status (8). Despite growing recognition of the value of dietary diversity as part of a suite of indicators to monitor and evaluate food security, there are several aspects which could be harmonized, such as the length of recall period and composition of food groups used to construct the scores (9).

Considerations include the time and cost needed for data collection and analysis, burden on the respondent and overall accuracy of the indicator. In an emergency setting, indicators should be as practical as possible (5) while providing accurate input for allocation decisions (10). Therefore what is needed is the most expedient method to identify populations which do not have access to adequate food. This paper compares the performance of two dietary diversity scores constructed from one and seven day reference periods in a highly food insecure area of Somalia.

SUBJECTS AND METHODS

The survey was conducted in December, 2006 in the El Barde district of Somalia. The primary livelihood in the area is pastoralist. The district has historically been highly food insecure and was in acute food and livelihood crisis during 2006 (11). The main objective of the survey was to estimate the prevalence of acute malnutrition among children aged 6-59 months, and secondarily to identify underlying causes of malnutrition. The questionnaire was divided into three sections, (i) household characteristics, (ii) child feeding, immunization and health and (iii) household food consumption. This analysis is based on the household characteristics and household food consumption sections.

Data were collected in 430 households selected by two-stage cluster sampling. A list of the population in all settlements within the district was constructed with the aid of WHO polio population figures and additional input from key informants. Thirty clusters were randomly selected using population proportional to size. In each cluster, households were selected using random walk procedure sampling (12).

The survey collected information on the consumption of foods from twelve food groups recommended by FANTA (13): Cereals and cereal products; Meat/ poultry/offal; Eggs;

Roots/tubers; Vegetables; Fruits; Pulses/ legumes/nuts; Dairy; Oils/fats; Sugar/honey; Fish/seafood and Miscellaneous (including spices, sweets). For the food consumption module, the respondent was the mother of the child living in the household, who is generally the meal preparer (personal communication Ahono Busili 18 March, 2009). Respondents were first asked if a member of the household consumed any food prepared in the house from each of the twelve food groups in the last seven days, and if yes, the number of days the food was consumed over the past week. The respondent was then asked if any member of the household consumed any food item from the same twelve food groups in the last twenty-four hours, including any snacks. Respondents did not provide a free recall of foods consumed, but were prompted to respond "yes" or "no" to each food group with examples of commonly consumed foods for each group. For each of the food groups, respondents were also asked to identify the main source of the food.

A one day household dietary diversity score (1d-HDDS) and the seven day household dietary diversity score (7d-HDDS) were the two primary indicators tested. These scores were constructed by summing the number of the twelve food groups consumed by any member of the household over two respective reference periods. An indicator of habitual food group consumption was constructed based on the percent of households consuming the food group three or more times per week. This definition of habitual consumption is based upon earlier work of a similar nature (14). Theoretical probabilities of consumption on one out of seven days were calculated for comparison with reported consumption over the one day period, using the following formula: [∑probability of one day consumption of any food group = (% hh consuming every day of the week *7/7) + (% hh consuming six days of the week *6/7) + (% hh consuming five days of the week *5/7) + (% hh consuming four days of the week *4/7) + (% hh consuming three days of the week *3/7) + (% hh consuming two days of the week *2/7) + (% hh consuming one days of the week *1/7) + (% hh consuming no days of the week *0/7)]. For example, if ten percent of households reported consuming pulses five, six and seven times per week, the calculation of the theoretical probability of the food group being consumed during the one day recall would be [∑probability = (.10 *7/7) + (.10 *6/7) + (.10 *5/7) = 0.26. Based on this theoretical probability, one would expect 26 percent of households to report consuming pulses the previous day.

A variable was created to identify households as urban or rural based on population size. Fifty-five percent of households were in rural areas and forty-five percent in urban areas. Households were asked the number of persons living together and eating from the same pot during the time of the assessment. The mean household size was 6.3 (2.2). Household sizes were regrouped into small (≤ 5 members), medium (6-7 members) and large (≥ 8 members).

The Bland and Altman method (15) was used to assess level of agreement between the 1d and 7d HDDS. There is no test for the statistical significance of the agreement; however, the direction and amount of bias can be visually assessed. Limits of agreement were calculated using the formula $mean_d \pm 2s_d$, where $mean_d$ is the mean difference of 7d-HDDS – 1d-HDDS and s_d is the standard deviation of the differences.

Kappa coefficient was used to assess the proportion of agreement between the percent of food groups consumed based on the recall periods and the percent 'habitual' consumption. The Kappa coefficient is influenced by prevalence and becomes lower when frequency of the desired outcome is low or high (16). To account for this both unadjusted and adjusted kappa coefficients were calculated.

Statistical analyses were carried out in SPSS v. 13.0 (17) and STATA IC10 (18). Neither the 1d-HDDS nor 7d-HDDS passed recommended tests for normality (19). Nonparametric statistical tests were used, means and standard deviations presented in table one for informational purposes. A median test was used for 1d and 7d score distributions. The two sample test of proportions was used for proportion of households consuming different food groups over the two recall periods. The Kruskal-Wallis test was used to examine the relationship between socio-economic factors and the dietary diversity scores. Statistical significance was at the level of $p < 0.05$ for all analyses.

Table 1 Descriptive statistics of household dietary diversity scores based on one and seven day recall periods

	1d-HDDS	**7d-HDDS**
N	430	430
Mean (sd)	4.1 (1.4)	4.4 (1.5)
Median [1] (25th and 75th percentile)	4 (3,5)	4 (3,5)
Mode	4	4
Minimum	0	1
Max	9	9
Households below median (%)	65	55

[1] Significant difference of distributions using median test ($p < 0.05$).

RESULTS

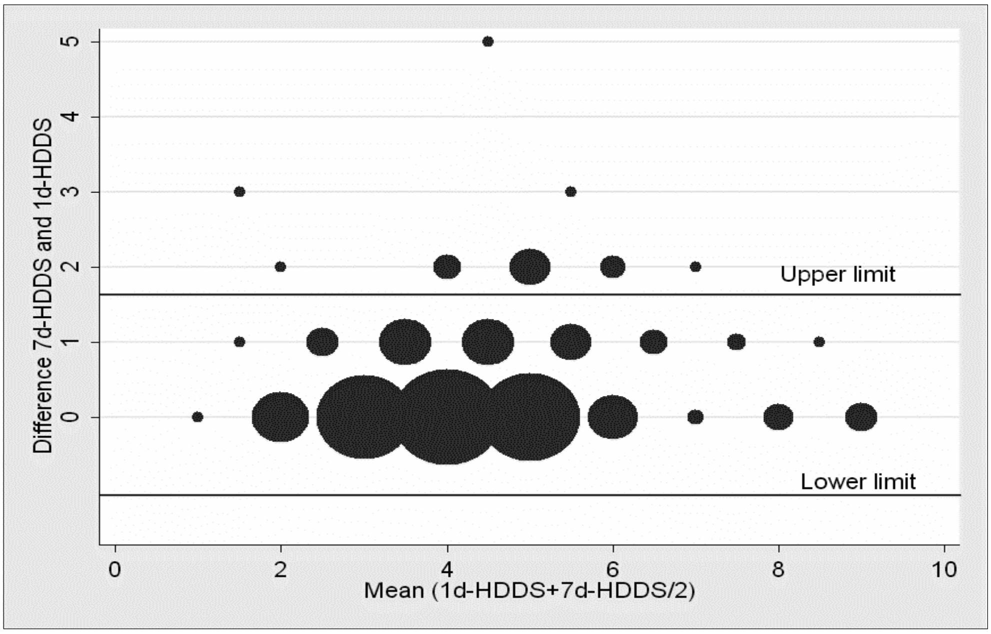
Comparison of 1d-HDDS and 7d-HDDS

Table 1 shows the descriptive statistics related to both scores. There were significantly different distributions of 1d-HDDS and 7d-HDDS using the median test ($p < 0.05$).

For 75 percent of the households, the same number of food groups was consumed over one and seven days. For 18 percent there was a difference of one food group. The remaining seven percent differed by two or more food groups. If a difference of one food group or less is accepted to reflect good agreement between the measures, there was good agreement for 93 percent of households.

The Bland and Altman diagram (Figure 1) shows no evident bias in difference of the scores at either higher or lower dietary diversity. 1d-HDDS is always ≤ 7d-HDDS, with a range between 0-5, $mean_d$ 0.33 and s_d 0.65. Limits of agreement fell between -1.03 and 1.63.

Figure 1 Bland Altman Diagram with reference lines indicating upper and lower limits of agreement[1]

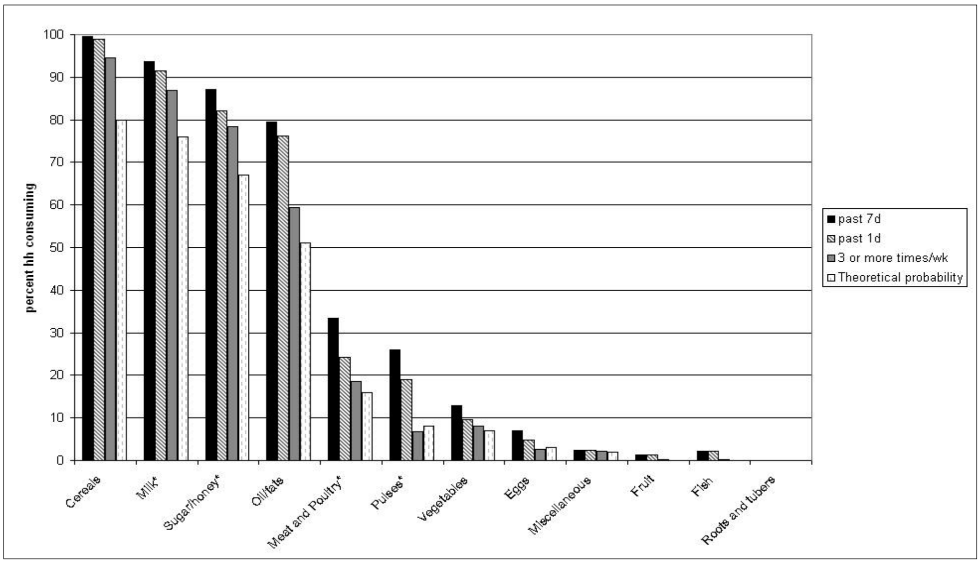


1 Size of the circle represents number of households.

Analysis of dietary patterns

The diet for most households consists of cereals, milk, sugar and oil (Figure 2). This pattern holds across four different measures; (i) once in the past week, (ii) once over the past day, (iii) three or more times per week and (iv) calculated theoretical probability described in the methods section. For the seven day recall period, a third of households reported consuming meat or poultry. One quarter consumed pulses at least once per week. There were statistically significant differences in the proportion of households consuming sugar/honey, meat/poultry and pulses once in the past seven days as compared to the past one day.

Figure 2 Percent of households consuming each food group by 1d-HDDS, 7d-HDDS, habitual consumption and theoretical one day consumption[1]



[1] * indicates that the proportion of households consuming the food group once during the past 7d is significantly greater than those consuming the past 1d.

The theoretical probability can be compared to the number of households reporting consuming the food group the previous day. The percent of households reporting consumption the previous day is higher for all food groups than the theoretical probability.

The same overall dietary pattern is obtained from both recall periods when using tertiles to describe food group intake (Table 2). In the lowest tertile, cereals, milk and sugar are the main food groups consumed. As dietary diversity scores increase, oil is added to the diet. In the highest tertile meat and pulses are added. Fruits and vegetables are rarely consumed in any tertile. Roots and tubers were not consumed.

Results comparing the one day and seven day recall periods with the measure of usual consumption were similar (Table 3). There was a high level of agreement in adjusted kappa coefficients comparing usual consumption with percent of households consuming the food group using either recall period. The lowest adjusted coefficients were for the food groups oils/fats, meat/poultry and pulses. Overall percent of agreement for these three food groups was 79, 89 and 84 respectively for comparison of one day and usual consumption and 79, 85 and 80 respectively when comparing seven day and usual consumption.

Table 2 Foods consumed by more than 50% of HH by dietary diversity tertile

Lowest tertile		Medium tertile		Highest tertile	
1d (n = 145)	**7d (n = 115)**	**1d (n = 136)**	**7d (n = 123)**	**1d (n = 149)**	**7d (n = 192)**
Cereal	Cereal	Cereal	Cereal	Cereal	Cereal
Milk	Milk	Milk	Milk	Milk	Milk
Sugar	Sugar	Sugar	Sugar	Sugar	Sugar
		Oil	Oil	Oil	Oil
				Meat	Meat
				Pulses	Pulses

Table 3 Prevalence adjusted and unadjusted Kappa coefficients and percent agreement for households consuming each food group once the past day, once over seven days or three or more days in seven days

	Prevalence adjusted (unadjusted)			Percent agreement		
	1d:7d[1]	≥3:1d[2]	≥3:7d[3]	1d:7d	≥3:1d	≥3:7d
Cereals	0.98 (0.57)	0.90 (0.19)	0.90 (0.15)	99	94	95
Milk	0.95 (0.83)	0.84 (0.58)	0.87 (0.62)	97	91	93
Sugar/honey	0.90 (0.80)	0.75 (0.61)	0.82 (0.69)	94	87	90
Oil/fats	0.93 (0.91)	0.61 (0.55)	0.61 (0.55)	96	79	79
Meat and Poultry	0.82 (0.78)	0.79 (0.68)	0.71 (0.62)	90	89	85
Pulses	0.87 (0.81)	0.70 (0.35)	0.63 (0.34)	93	84	80
Vegetables	0.93 (0.84)	0.94 (0.83)	0.91 (0.75)	96	97	95
Eggs	0.96 (0.81)	0.93 (0.48)	0.91 (0.52)	97	96	95
Miscellaneous	1.0 (1.0)	0.99 (0.95)	0.99 (0.95)	100	99	99
Fruit	1.0 (1.0)	0.98 (0.28)	0.98 (0.28)	100	98	98
Fish	1.0 (1.0)	0.96 (0.20)	0.96 (0.20)	100	98	98
Roots and tubers	1.0 (1.0)	1.0 (1.0)	1.0 (1.0)	100	100	100

1 Agreement between households consuming once over past day or once over past seven days.
2 Agreement between households consuming three or more days over past seven days or over past day.
3 Agreement between households consuming three or more days over past seven days or once over past seven days.

Associations between dietary diversity scores and socio-economic characteristics

The relationship between each score and other socio-economic characteristics is presented in Table 4 Results by main income source were significantly different for both 1d and 7d-HDDS ($p < 0.05$). Within income source, traders have the highest median scores. The mean DDS was higher in urban than rural areas, but the medians were the same. For both 1d and 7d scores, there were significant differences by main source of food ($p < 0.05$). Those households that purchased their food had significantly higher HDDS than other households.

Table 4 Relationship between 1d and 7d-HDDS and selected socio-economic indicators

SES indicator	n	1d-HDDS[1]	p value	7d-HDDS[1]	p value
Main source of income					
Livestock	209	4 (3,5)	0.00	4 (3,5)	0.00
Crops	39	4 (3,5)		5 (4,5)	
Casual labor	134	4 (3,5)		4 (3,5.25)	
Trade	42	5 (4.75,6.25)		5.5 (4.75,7)	
Salary or remittance	6	4 (4)		4.5 (4,5.25)	
HH size					
1-5 members	169	4 (3,5)	0.10	4 (4,5)	0.43
6-7 members	151	4 (3,5)		4 (3,5)	
8 or more members	110	4 (3,5)		4 (3,5)	
Residence					
Urban	192	4 (3,5)	0.27	4 (3,5)	0.51
Rural	238	4 (3,5)		4 (3,6)	
Received formal or informal support					
Yes	92	4 (2,5.75)	0.88	5 (3,6)	0.70
No	338	4 (3,5)		4 (4,5)	
Main source of food for the household					
Own production	64	3 (2,4)	0.00	3.5 (2,5)	0.00
Purchase	310	4 (3,5)		5 (4,5)	
Other (food aid, gift, borrow)	55	4 (3,4)		4 (3,5)	

[1] Values are median (interquartile range).

DISCUSSION

These results from El Barde district indicated a very monotonous diet, with the same pattern of consumption whether analyzed over one or seven days. Since at present there are no standardized cut-points for the number of food groups which need to be consumed to achieve adequate dietary diversity nor a threshold level of prevalence to define severity of the problem, this type of comparative analysis of tertiles or quartiles is recommended (1,13). Distributions of the scores using the median test were significantly different, however in practical terms the medians and interquartile ranges were the same for both scores. Bland Altman analysis did not reveal any consistent bias, but levels of agreement could be considered wide. Differences in prevalence of consumption were greatest for the food groups meat/poultry, pulses and sugar/honey. Meat/poultry and pulses were consumed an average of one or fewer days per week. The nutritional contribution of these food groups in the diet is important, however, use of this information to help in differential classification of household food security status requires further research. The same two socio-economic characteristics, main source of income and main source of food procurement were significant characteristics for both indicators.

There were limitations to the study. The question sequence was the same for all households, beginning with questioning about the previous week, followed by questioning of consumption of any of the twelve food groups during the previous 24 hours. It is possible that responses to the 24 hour consumption were influenced by the preceding set of questions on consumption over the past week. The study excluded feast days or special occasions (weddings, funerals) where the previous day's consumption would have been unusual. However, there was no proportional representation of market days or other days during the seven day period in which one day consumption may alter from that of other days. Savy (2007) found that in areas where there is not daily access to a market, one day dietary diversity scores are influenced by the pattern of market days (20). In many parts of the world, there are one or two days during the week where diets may contain more variety, more calories and also more 'luxury' foods. The seven day time period will capture these days. When using the one day reference period, this should be accounted for during data collection by including a proportional number of 'special' days in the sample. Failure to do so could lead to underestimation of the number of food groups consumed.

The overall dietary pattern in each score tertile illustrates the monotony of the diet. The survey period reflects poor food availability. Reasons for this include poor rainfall in 2005 and the major rainy season in 2006 which stressed the livelihoods of the population (12). Civil insecurity during this period also contributed to the burden of food insecurity. In the highest tertile meat and pulses were added to the diet, but there was very low consumption of other perishable food items including fruits, vegetables, fish and eggs. This could be due to poor availability of these foods as well as the inability of households to access through purchase, own production or non-cultivated harvest.

The most appropriate length of reference period depends on whether information will be used for individual or population level. Longer recall periods are needed in order to measure habitual intake of individuals (21,22). When the objective of the score is to provide a picture of the dietary pattern for a community our results indicate a twenty-four hour reference period is adequate. A similar study concluded that for the purposes of gathering information on population level diet patterns of young children, the 7-day food group recall did not provide substantial advantage over the simpler 24-hour reference period (14).

An advantage of a shorter recall period is reduced potential for recall error. It is likely that memory error will lead to underreporting of food items consumed (23). Research by Savy *et al,* found that there was greater recall error with two and three day recall as compared to one day recall (20). Our data comparing the theoretical probability of percent of households consuming a food group (based on the average number of days the food group was consumed over the seven days) and the percent of households reporting consumption of the food group over the past 24 hours showed a tendency for higher reported consumption over the 24 hour recall. It is not possible with this dataset to test the direction of the error. It could be due to over reporting for the 24 hour period or under reporting over the seven day period. Based on previous research it is more likely that the seven day recall is an underestimation of the number of food groups consumed. In this case, the 1d-HDDS is a better reflection of the true intake for one day, while the 7d-HDDS is a less accurate reflection of the seven day period due to recall error.

The relationships found between the dietary diversity scores and household socio-economic factors indicate that dietary diversity is a sensitive indicator to household food access and an appropriate monitoring tool for assessing household food security. Primary source of livelihood has been identified as a particularly useful determinant of food security status (24). In the present study dietary diversity was influenced by main source of income, and main type of household food procurement. The relationships were the same for one and seven day diversity scores. Other studies have shown similar relationships between dietary diversity and these types of household characteristics. In Mali, Hatloy and colleagues (2000) found that household socio-economic status was correlated with household-level DDS in both urban and rural areas, with higher DDS in urban areas (25). Another study in Mali found DDS was not related to aid from family members or the number of crops cultivated, but was influenced by gender, education, geographic area of residence and socio-economic score (26). In Korea, participants with higher household income, higher education and living in urban areas had greater dietary diversity (27). Our results did not show a difference between diversity scores and residence. This could be due to the high level of food insecurity present in the area and general lack of diverse foods available in the market.

For use as a tool to detect nutritional vulnerability at household level, this analysis indicates that there does not seem to be added value of a 7 day over 1 day recall period. The median and modal scores were the same and there were no differences dietary patterns based on score tertiles. Further research is needed to determine the population level significance of percentage consumption of individual food groups over seven as compared to one day of recall. The simplicity of administration and analysis of the one day recall period is an advantage when working in emergency settings where information is needed quickly. In addition the one day recall period is less prone to memory failure on the part of the respondent. This study contributes to the body of evidence leading to harmonization of the recall period used when assessing household-level dietary diversity. However, there is a need for further studies on the utility of longer reference periods in food insecure and emergency settings where the diet is less monotonous.

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REFERENCES

1. FAO. Guidelines for measuring household and individual dietary diversity (version 4) [Internet]. Rome: FAO; 2008. [cited 12 January 2009]. Available from: http://www.foodsec.org/ tr/nut/guidelines.pdf
2. Hammink W. Food for Peace Information Bulletin 07-02 [Internet]. [cited 16 July, 2009] Available from: http://www.usaid.gov/our_work/humanitarian_assistance/ffp/fy08_ffpib_new_reporting.pdf
3. WFP-VAM. Technical Guidance Sheet. Food Consumption Analysis. Calculation and use of the Food Consumption Score in Food Consumption and Food Security Analysis. Rome: WFP; 2007.
4. IPC Global Partners. Integrated Food Security Phase Classification Technical Manual. Version 1.1. Rome: FAO; 2008
5. Wiesmann D, Bassett L, Benson T, Hoddinott J. Validation of the World Food Programme's Food Consumption Score and Alternative Indicators of Household Food Security. Washington, DC: International Food Policy Research Institute; 2009. Discussion paper 00870.
6. Hoddinott J, Yohannes Y. Dietary diversity as a food security indicator. Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2002.
7. Hoddinott J. Choosing outcome indicators of Household Food Security. Technical Guide #7. Washington, DC: International Food Policy Research Institute; 1999.
8. WFP-VAM/FAO. Interagency workshop report. Measures of food consumption – harmonizing methodologies. [Internet]. Rome: WFP; 2008. [cited 3 June, 2009]. Available from: http://documents.wfp.org/stellent/groups/public/documents/ena/wfp196629.pdf
9. Ruel MT. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr* 2003 ;133:S3922-S3926.
10. WFP. Emergency Food Security Assessment Handbook. 1st Edition. Rome: WFP; 2005.
11. Food Security Analysis Unit – Somalia (FSAU), FSAU Technical Report Series No.V.9. *2006 Post Gu Analysis*. [Internet]. [cited 18 March, 2009]. Available from: http://www.fsausomali.org/
12. Food Security Analysis Unit-Somalia, International Medical Corps (IMC), UNICEF and WFP. Nutrition Assessment Report. El Barde Districts Bakool Region Somalia. Nairobi: FSAU; 2006.
13. Swindale A, Bilinsky P. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (v.2). Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2006.
14. Arimond M, Ruel M. Dietary diversity, dietary quality and child nutritional status: Evidence from Eleven Demographic and Health Surveys. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2004.
15. Bland J, Altman D. Statistical Methods for Assessing Agreement Between Two Methods of Clinical Measurement. *Lancet* 1986;February 8, 307-310.
16. Sim J, Wright C. The Kappa statistic in reliability studies: use, interpretation and sample size requirements. *Physical Therapy* 2005;85(3):257-268.
17. SPSS for Windows Release 13.0 Chicago, IL: SPSS Inc; 2004.
18. STATACorp. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP; 2007.
19. Field A. Discovering statistics using SPSS for Windows. London: Sage publications; 2000.
20. Savy M, Martin-Prével Y, Traissac P, Delpeuch F. Measuring dietary diversity in rural Burkina Faso: comparison of a 1 day and a 3-day dietary recall. *Public Health Nutr* 2007; (10)1:71-78.
21. Drewnoski A, Ahlstrom Henderson S, Driscoll A, Rolls B. The Dietary Variety Score: Assessing diet quality in healthy young and older adults *J Am Diet Assoc* 1997; 97:266-271.
22. Nyambose J, Koski K, Tucker K. High Intra/Inter-individual variance ratios for energy and nutrient intakes of pregnant women in rural Malawi show that many days are required to estimate usual intake. *J Nutr* 2002;132:1313-1318.
23. Jelliffe DB, Jelliffe EFP. Community Nutritional Assessment. Oxford University Press, New York. 1989.
24. FAO. The state of food insecurity in the world. Rome: FAO; 2000.
25. Hatloy A, Hallund J, Diarra M, Oshaug A. Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). *Public Health Nutr* 2000;3(1):57-65.
26. Torheim LE. Methods for assessing dietary intake in rural Mali, West Africa [dissertation]. Oslo, Norway: Akershus University College;2003.
27. Ahn BC, Engelhardt K, Joung H. Diet variety is associated with socio-economic factors. *Ecol Food Nutr* 2006;45:417-430.

CHAPTER 7

PROXY MEASURES OF HOUSEHOLD FOOD CONSUMPTION FOR FOOD SECURITY ASSESSMENT AND SURVEILLANCE: COMPARISON OF THE HOUSEHOLD DIETARY DIVERSITY AND FOOD CONSUMPTION SCORES

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ABSTRACT

Objective This paper provides an overview of the Household Dietary Diversity score and the Food Consumption Score, two indicators used for food security assessment and surveillance and compares their performance in food security assessments in three countries.

Design Cross sectional cluster sampling design using an interview administered structured questionnaire on household food security including household level food group consumption measured over one and seven days.

Setting Survey data are from Burkina Faso, Lao PDR and Northern Uganda

Subjects 3640 households in Burkina Faso, 3913 households in Lao PDR and 1956 households in Northern Uganda.

Results Spearman's correlation coefficients between the scores were 0.73 in Burkina Faso, 0.65 in Lao PDR and 0.53 in Northern Uganda. Prevalence adjusted kappa coefficients showed substantial strength of agreement in two countries. The proportion of agreement between the two scores ranged from 85% in Lao PDR to 65% in Northern Uganda. Dietary profiles based on food group consumption using score tertiles were comparable. Rankings of the most food insecure areas within a country corresponded well in Northern Uganda and Burkina Faso but not in Lao PDR. Both indicators showed moderate correlations with other proxy measures of food security.

Conclusion Despite methodological differences used to create the scores, similar classification of the most food insecure areas at national and sub-national levels was obtained. For the purpose of classifying the level of food insecurity in sub-national areas it is preferable to compare rankings rather than percent of households below a score cut-point.

INTRODUCTION

Many organizations involved in food security assessments use qualitative measures of household dietary diversity as proxy measures of quantity and quality of household food consumption. Quantitative dietary assessment techniques use data collected primarily at individual level and allow for calculation of dietary energy and nutrient intakes which can then be compared to nutrient requirements. While individual dietary survey methods have a high degree of accuracy, they are difficult to implement, particularly in developing countries due to cost, logistics and other considerations such as respondent burden (1). Qualitative measures of household food consumption are attractive as the information required for their construction is less time consuming and less costly to collect than quantitative dietary intake methods.

Both the Food and Agriculture Organization of the United Nations (FAO) and the World Food Programme (WFP) use information on dietary diversity and food consumption as one element to inform food security analysis, however the organizations use different data collection methods and analytic strategies (2,3,4). FAO uses a one-day household dietary diversity (HDD) score based on guidelines produced by FANTA(5) and WFP uses a food consumption score (FCS) which combines dietary diversity and frequency of consumption over seven days. Both the HDD score and FCS have been validated in different countries as proxy measures of household per capita energy intake (6-9). The tools are both used for monitoring and surveillance of household economic access to food (4) and in both methods data collected can also be used to consider dietary patterns and consumption of specific foods.

Guidelines prepared by FAO (2) describe tools adapted for a decentralized[1] level utilizing simple data collection and analytical techniques and requiring no external software or other technical assistance. In addition to creation of a dietary diversity score for measuring population level dietary diversity, the guidelines recommend creating dietary profiles and using the data to identify the proportion of households consuming a food groups of special interest, such as dark green leafy vegetables or organ meat.

The WFP guidelines on food consumption analysis describe a method which captures information on both dietary diversity and food frequency, or number of days of consumption of the food item or group (3). Generally assessments are undertaken with national or regional WFP staff and analysis is performed by a trained staff member. The WFP guidelines also describe analytic methods for exploring food consumption profiles using principle components and cluster analysis. WFP and FAO have been called on to work together to

[1] Tailored for use at various administrative levels, including, district, regional level, but also appropriate for use at national level.

support coherent action to address food insecurity (10) and often work in the same countries and undertake joint food security assessments. There are also situations where FCS and HDDS could both be incorporated into decision making on food security. For example both indicators could be available for use within the Integrated Food Security Phase Classification (11). FAO and WFP have recognized the need to provide guidance on comparing results obtained from the two indicators and to work together to identify similarities and differences in the food consumption indicators currently in use by each organization (12). The objective of this study is to evaluate the similarities and differences between dietary patterns and food security rankings obtained from each tool.

METHODS

Data sets from Burkina Faso, Lao People's Democratic Republic (Lao PDR) and North Uganda (N. Uganda) were used in a comparative analysis of the HDD tool and FCS. In all three sites, the surveys included questions about household dietary diversity during the previous 24 hours and 7 days. Tables one and two summarize the main methodological differences in data collection, indicator construction and analytical approach between the indicators. Table two looks more specifically at the food groups and weighting used to construct each score.

Table 1 Main features of each method

Characteristic	FCS	HDD score
Recall method and time period	List based recall of household consumption and frequency of consumption over the past 7 days	Qualitative 'free' recall of all food/drink consumed by any household member[1] during the past 24 hours
Number of food groups used to create the score	8	12
Number of food groups in the questionnaire	Varies by country context	16
Weighting of food groups	Each food group consumed receives a weight from 0.5-4	Each food group consumed has a value (weight) of 1
Typical cut-points	≤ 21.0 = poor 21.5-35.0 = borderline >35.0 = acceptable	Population distribution of scores used to form tertiles (or quartiles) for analysis of groups
Out of home food consumption	Not counted in the FCS	Not counted in the HDD score

[1] In this method food consumed by only one member of the household and not the others is still recorded. For example if a child was given a piece of fruit to eat as a snack this is recorded as 'yes' for fruit even if no other members of the household ate fruit.

Table 2: Food groups used to construct the FCS and HDD score

FCS		HDD score		
Food group	**Weight**	**Food group in questionnaire**	**Food group used to calculate HDD score**	**Weight**
Cereals, tubers and root crops	2	Cereals	Cereals	1
		White roots and tubers	White roots and tubers	1
Meat and Fish	4	Organ Meat Flesh Meat	Meat	1
		Fish	Fish	1
		Eggs	Eggs	1
Milk	4	Milk and dairy	Milk and dairy	1
Oil/fats	0.5	Oils and fat	Oils and fat	1
Fruit	1	Vit. A rich Fruits Other Fruits	Fruits	1
Vegetables	1	Vit. A rich Vegetables and Tubers Dark Green Leafy Vegetables Other Vegetables	Vegetables	1
Pulses	3	Pulses, legumes and nuts	Pulses, legumes and nuts	1
Sugar	0.5	Sweets	Sweets	1
Condiments (not counted in FCS)	0	Spices, condiments and beverages	Spices, condiments and beverages	1

Description of HDDS methodology

The dietary diversity questionnaire in the HDD method elicits information on consumption of 16 food groups over the reference period of the past 24 hours. The list of 16 food groups is standard and therefore remains the same for any country/context. In areas where red palm oil is consumed, the list of food groups is expanded to 17. The person primarily responsible for meal preparation for the household is asked to recall all meals, snacks and beverages consumed inside the home by any household member. When the recall is completed, the enumerator ticks the appropriate food group on the questionnaire. The enumerator then checks with the respondent for any food groups not mentioned in the recall.

To create the HDD score, the sixteen food groups in the questionnaire are aggregated into twelve food groups. The rationale for collecting information on all sixteen food groups, rather than just the twelve used to construct the score is to allow for additional analysis of food groups of particular interest, such as dark green leafy vegetables or vitamin A-rich fruit. The HDD score is the sum of the number of the twelve food groups consumed (range 0-12).

Description of FCS methodology

To construct the FCS, information on household-level food consumption is gathered from a country specific list of food items and food groups. The respondent is asked about the households' frequency of consumption in number of days over the past week of each food group/item. Food items are then grouped into eight specific food groups. The consumption frequencies (number of days of consumption over the previous seven days) of the eight groups are summed. Any frequency values over seven are capped at seven. This value obtained for each food group is multiplied by a food group weight, which is based on the nutrient profile of each food group. The sum of the weighed food group scores is the food consumption score (FCS). WFP has defined thresholds for categorizing households into food consumption groups (FCGs).

Description of the data sets

In Lao PDR WFP conducted a Comprehensive Food Security and Vulnerability Analysis. The sampling frame was based on data from the 2005 census. The sample included rural households from 25 villages in 16 provinces. A two-stage cluster sample procedure was applied. The total household sample size was 4000, out of these, 3926 households participated in the survey and 3913 households have complete data for both HDDS and FCS. Respondents were asked questions related to income, total expenditure, expenditure on food and asset ownership.

To collect information on dietary diversity a 23 item list was used. Respondents were asked whether anyone in the household had consumed the food item/food group in the past seven days and if yes, the number of days the item/group was consumed. They were then asked whether anyone in the household had consumed the item/group in the previous 24 hours. The HDDS for Lao PDR is based on a sum of 11 instead of 12 food groups. The food group spices, condiments and beverages was not included in the questionnaire.

In North Uganda WFP conducted an Emergency Food Security Assessment in 2007. The sample universe consisted of all villages in the resettled areas in Lira and all IDP camps in Gulu, Pader, Kitgum, Apac & Oyamin, and Amuria & Katakwithe districts. Population figures in the camps were based on the WFP distribution figures and population figures for the resettlement area came from Government of Uganda. In the resettlement areas, peri-urban zones with a population greater than 5000 people were removed as the focus of the survey was rural population centres. A two-stage cluster sample procedure was applied. Camps or villages were selected with probability proportional to size (PPS) while households were randomly selected from a camp/village list. The total household sample size was 1980, out of these, 1958 households participated in the survey and 1956 households have complete data for both HDDS and FCS. Food consumption information was collected using a list of 19 items. Respondents were asked the number of days the item/group was consumed inside the house during the past seven days. They were also asked the number of times anyone in the household had consumed the item/group in the previous 24 hours. The HDDS was based on a sum of 11 instead of 12 food groups. The food group Spices, condiments and beverages was not included in the questionnaire.

In Burkina Faso WFP conducted a Nutritional Survey in 2007 in collaboration with UNICEF and with the technical support of the *Institut de Recherche pour le Développement* (IRD). The survey was designed to be representative of five rural regions, Sahel, North, Central North, East and South West. Villages were selected by probability proportional to size and households within each village were selected using the random walk method. The sample reached a total of 3640 households all with complete data for both HDDS and FCS. The HDDS is constructed using all 12 recommended food groups.

Analytical methods

Data analysis was carried out in SPSS version 13 (13). Statistical significance was assessed at $p < 0.05$. Descriptive statistics are reported taking into account survey design. Spearman's correlation was used to test correlation between the two scores and between each score and other food security indicators. The kappa coefficient and prevalence adjusted kappa coefficient were used to assess the level of agreement beyond that expected by chance (14) when classifying households falling below the above defined cut-offs. The Landis and Koch definitions of fair, moderate and substantial strength of agreement were used (15).

Theoretical probabilities of consumption on one out of seven days of selected food groups were calculated in order to compare these with reported consumption over the one day period. The theoretical probability of one day consumption of a food group was calculated as [∑probability of one day consumption of any food group = (% hh consuming every day of the week *7/7) + (% hh consuming six days of the week *6/7) + (% hh consuming five days of the week *5/7) + (% hh consuming four days of the week *4/7) + (% hh consuming three days of the week *3/7) + (% hh consuming two days of the week *2/7) + (% hh consuming one days of the week *1/7) + (% hh consuming no days of the week *0/7)]. The probability of the food group being consumed in the past 24 hours is 7/7 or 100% if the food was consumed every day of the week. If the consumption is six out of seven days, there is 6/7 or 86% probability that the food group was consumed the previous day, if the consumption is five days out of seven, the probability would be 5/7 (or 71% chance of being consumed the previous day) and so on. Each of these probabilities were then multiplied by the percent of households reporting x number of days of consumption. Z test for proportions was used to compare percent of households consuming the food groups over the one day recall as compared to the theoretical probability of consumption.

Cut points[1] based on each score were used to compare classification of food insecure areas at national and sub-national levels. WFP has established cut-points of ≤ 21.0 FCS to indicate poor food consumption and between 21.5 - 35.0 FCS to indicate borderline food consumption (3). The FAO guidelines (2) do not provide a standardized cut-off point for defining food insecure households. In this analysis a cut-point of ≤3 food groups for HDD score was compared with ≤ 35.0 FCS (poor and borderline food consumption). Chi squared test was used to detect differences in percent of the populations falling below the HDD score and FCS cut-points.

RESULTS

Descriptive statistics and correlation between FCS and HDD score

The mean FCS and HDD score for each country are presented in Table 3. The highest mean scores for both HDD score and FCS are in Lao PDR, followed by Burkina Faso and N. Uganda. Spearman's correlations between FCS and HDD score were significant in all three countries.

Table 3 Descriptive Statistics for FCS and HDD score

Indicator	Burkina Faso (n 3640)	Lao PDR (n 3913)	N. Uganda (n1956)
FCS mean (sd)	45.0 (16.4)	51.1 (13.9)	36.1(12.2)
FCS range	5.5-112	8-112	5-100
HDD score mean (sd)	4.6 (1.3)	5.2 (2.1)	3.3 (1.4)
HDD score range	0-11	1-11	0-11
Spearman correlation FCS and HDD score	0.73*	0.65*	0.53*

1 * indicates significant correlation, at ($p < 0.05$).

Unadjusted Kappa coefficients had a moderate strength of agreement in Burkina Faso and fair strength of agreement in Lao PDR and N. Uganda (Table 4). Over 80% of households are classified the same in Burkina Faso and Lao PDR. There are fewer similar classifications in N. Uganda. Prevalence adjusted kappa coefficients improve the strength of agreement in Burkina and Lao PDR, but not in Northern Uganda.

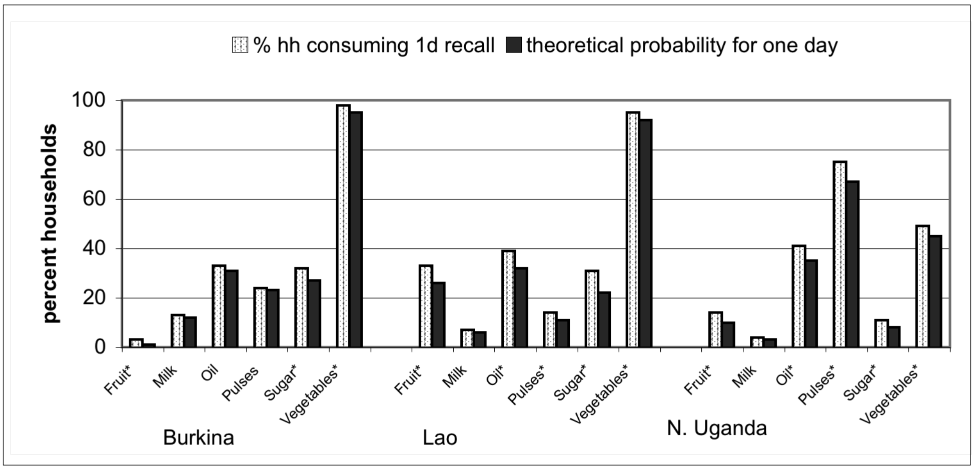
1 The FAO guidelines (FAO, 2007) do not provide a standardized cut-off point for defining food insecurity households. For the purposes of comparative analysis with the FCS cut-points, a threshold of ≤ 3 food groups was chosen.

Table 4 Kappa coefficients for HDD scores and FCS

		Kappa (prevalence adjusted)	Proportion of agreement (%)	Strength of agreement unadjusted score (adjusted. score)	
Burkina	HDDS≤3:FCS≤ 35	0.57 (0.65)	82	Moderate	(Substantial)
Lao PDR	HDDS≤2:FCS≤ 35	0.34 (0.72)	85	Fair	(Substantial)
	HDDS≤3: FCS≤35	0.40 (0.61)	80	Fair	(Substantial)
N. Uganda	HDDS≤2:FCS≤ 35	0.31 (0.33)	65	Fair	(Fair)
	HDDS≤3: FCS≤35	0.33 (0.35)	66	Fair	(Fair)

Figure 1 illustrates a comparison between percentage of positive response over 1-day and probability of obtaining the same percentages over 7-day period using the theoretical probabilities described in the methods section. Comparisons are made for those food groups which have the same definition for both indicators (milk and dairy; oils and fats; fruit; vegetables; pulses and sugar (FCS) sweets (HDD). There was a consistent tendency across all countries for a slightly higher percentage of households to report consuming the food groups over the past 24-hours as compared to theoretical probability of one out of seven days. These differences were significant for all food groups except for dairy in Lao PDR and N. Uganda and dairy, oil and pulses in Burkina Faso.

Figure 1 Comparison of one day recall and theoretical probability of consuming the food group one out of seven days[1]

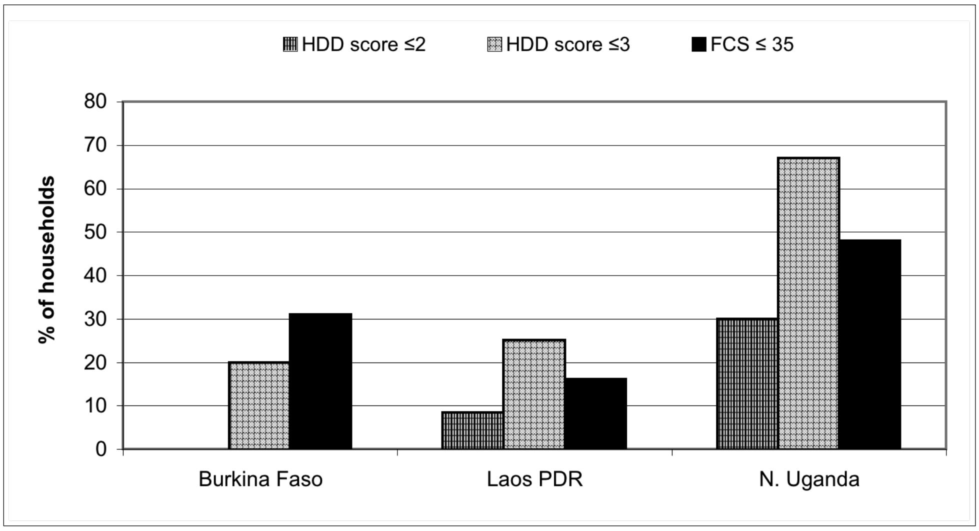


1 * indicates significant difference between percentages at $p < 0.05$.

Comparing cut-points and prevalence of food insecurity at national and sub-national level

The best correspondence of HDD score to FCS ≤ 21.0 was between 2 and 3, while FCS ≤ 35.0 corresponds to a score slightly higher than 3 food groups (results not shown). Figure 2 shows the percent of households with HDD score ≤ 2 and ≤ 3 as compared to the percent of households with FCS ≤ 35.0. Chi square was significant ($p < 0.05$) for all HDD score and FCS comparisons. Using either an HDD score of two or three, the prevalence of households below the cut-point is highest in N. Uganda, followed by Lao PDR and lowest in Burkina Faso. While for the FCS, the highest prevalence is found in N. Uganda, but then is followed by Burkina Faso and lastly Lao PDR.

Figure 2 Percentage of households in Burkina Faso, Lao PDR and N. Uganda below selected cut-points



In addition to looking at national level estimates, it is often desirable for programmatic purposes to identify the most disadvantaged areas within a country. Ideally the performance of each indicator would be tested against a gold standard measure, such as per capita dietary energy intake, however, this information is not available for these datasets. The cut-points of FCS ≤ 35.0 and HDD score ≤ 3 were applied to sub-national strata.

For illustration purposes, the percent of households with low FCS and low HDD score is shown along with the respective rank by each score. Applying a "prevalence threshold" for example 30 percent or more of households below the chosen cut-point for each indicator led to larger discrepancies in classification between the two scores than does comparing ranks based on prevalence within each score (Table 5).

Table 5 Ranking of FCS and HDD score by geographical strata in Burkina Faso, Lao PDR and N. Uganda

Geographical strata	Ranking[1] of % hh below cut-point		Percent of hh below cut-point	
	using FCS	using DDS	FCS ≤ 35	HHDS ≤ 3
Burkina Faso				
Region				
Center North	2	2	38	26
East	5	4	22	14
North	3	3	30	19
Sahel	4	5	25	15
South West	1	1	51	34
Lao PDR				
Provinces				
Attapeu	12	4	9	34
Bokeo	1	1	42	61
Bolikhamxay	13	14	4	9
Champassak	16	16	2	3
Huapanh	5	8	21	25
Khammouane	10	2	10	49
Luang Namtha	9	11	16	14
Luang Prabang	8	5	17	32
Oudomxay	6	3	19	41
Phongsali	7	10	19	19
Saravane	2	13	30	13
Savannakhet	14	12	4	14
Sekong	4	6	25	31
Vientiane	15	15	4	9
Xayaboury	11	7	10	28
Xieng Khoang	3	9	26	21
N. Uganda				
Strata				
Gulu Mother Camp	5	3	45	81
Gulu Transit Camp	3	6	51	63
Kitgum Mother Camp	4	4	50	71
Kitgum Transit Camp	7	5	43	68
Pader Mother Camp	8	7	38	61
Pader Transit Camp	2	2	76	82
Apac & Oyam Mother Camps	1	1	82	84
Amuria, Katakwi Mother Camps	9	9	28	40
Lira Resettlement	6	8	46	49

[1] Rank of 1 is most food insecure.

The trend in most areas, was for a lower percent of households to fall below the FCS cut-point, with a higher percent below ≤3 HDD score. In Burkina Faso, there was correspondence of rank for three out of five sub-national strata. The rankings were the same for the three most food insecure regions. In N. Uganda, there was correspondence of rank in four out of nine strata. Both scores ranked Apac & Oyam and Pader transit camps as the first and second most food insecure areas. In Lao PDR, rankings for HDD score and FCS corresponded only in Bokeo, which was ranked most food insecure according to both measures.

Table 6 Correlation of FCS and HDDS with other indicators of food security in Burkina Faso, Lao PDR and N. Uganda

Country	Food Security indicator	Correlation with FCS[1]	Correlation with HDDS[1]
Burkina Faso	Number of meals the day before:		
	Children 0-5 year old	0.27 *	0.22 *
	Children 6-14 year old	0.30 *	0.28 *
	Females 15 year old or older	0.32 *	0.33 *
	Male 15 year old or older	0.29 *	0.30 *
Lao PDR			
	HH total expenditure	0.30*	0.30*
	Total food expenditure	0.23*	0.24*
	Per capita food expenditure	0.22*	0.22*
	Per capita non food expenditure	0.31*	0.28*
	Percentage food expenditure	-0.04*	-0.01
	Asset index	0.32*	0.33*
N. Uganda			
	HH total expenditure	0.27 *	0.17 *
	Total food expenditure	0.17 *	0.08 *
	Total non-food expenditure	0.30 *	0.22 *
	Per capita total expenditure	0.24 *	0.16 *
	Per capita food expenditure	0.14 *	0.06 *
	Per capita non-food expenditure	0.29 *	0.22 *
	Percentage food expenditure	-0.05 *	-0.11 *
	Number of meals the day before:		
	Adult (above 13 years) meals	0.32 *	0.22 *
	Children (<=6 years) meals	0.23 *	0.11 *
	Children (7-12 years) meals	0.24 *	0.16 *

[1] * indicates significant correlation, at ($p < 0.05$).

Correlation of HDD score, FCS and other indicators of food security

The FCS and HDD score demonstrated similar strength of correlation with other food security indicators (Table 6). In Burkina Faso and Lao PDR there are no striking differences in the magnitude or significance of the correlation coefficients. In N. Uganda, the FCS presents higher correlation coefficients with every tested indicator, with the exception of percentage of expenditure on food.

Analysis of Dietary Patterns

The FAO guidelines promote analysis of dietary profiles based on comparing the food groups consumed by households in higher and lower score distributions. The dietary profiles of the lowest and highest tertiles for HDD score and FCS are compared in Table 7. The food groups listed for the HDD score column represent those food groups consumed by 50% or more of the households in the given tertile. The food groups listed for FCS represent food groups consumed three or more and four or more of the previous seven days by 50% or more of the households in the given tertile.

Table 7 Dietary profiles using HDD score and FCS tertiles

Country	Lowest tertile			Highest tertile		
	HDD score	**FCS ≥3d**	**FCS ≥4d**	**HDD score**	**FCS ≥3d**	**FCS ≥4d**
Burkina Faso	Cereals Vegetables Condiments (not a group in FCS)	Cereals[1] Vegetable Fruit	Cereals[1] Vegetable	Cereals Vegetables Fish Sugar Oil Condiments (not a group in FCS)	Cereals[1] Vegetable Meat/fish/eggs Fruit Sugar Oil	Cereals[1] Vegetable Meat/ fish/eggs Fruit
Lao PDR	Cereals Vegetables	Cereals[1] Vegetable Meat	Cereals[1] Vegetable	Cereals Tubers Vegetables Meat Fish Eggs Fruit Oil Sugar	Cereals[1] Vegetable Meat/fish/eggs Fruit Oil Sugar	Cereals[1] Vegetable Meat/fish/eggs
N. Uganda	Cereals Pulses (49%)	Cereals[1] Vegetables	Cereals[1]	Cereals Pulses Tubers Vegetables Oil	Cereals[1] Pulses Vegetables Oil	Cereals[1] Pulses

[1] This food group includes cereals, tubers and root crops.

The dietary profile for the lowest tertile of HDD score and FCS provides nearly the same picture for each of the three countries. When looking at food groups consumed by the highest tertiles, the HDD method appears to capture more detail, but this is mainly due to the use of eight as compared to twelve food groups. For example in Lao PDR, consumption of meat, fish and eggs is observed in the highest tertile for HDD score, but this detail is not obtained for FCS, since all of these foods are aggregated into one food group. Comparing food groups consumed three or more rather than four or more times per week corresponded better with HDD profiles.

DISCUSSION

Correlation coefficients of the two scores were significant in all countries. Adjusted kappa coefficients showed substantial agreement in overall classification for two out of three sites. There were statistically significant differences comparing percent of household's falling below the HDD score as compared to FCS cut-points. Assigning ranks to the three countries based on highest prevalence within the selected cut-point and indicator resulted in N. Uganda being ranked most food insecure by both HDD score and FCS, Lao PDR is ranked second and Burkina Faso third by HDD cut-points and Burkina Faso ranked second and Lao PDR ranked third by FCS. When looking at sub-national rankings, there was agreement by rank of the most food insecure area in all three countries. Rankings of the more food secure areas were more discrepant, particularly in Lao PDR. Dietary profiles for the lowest score tertiles were nearly identical, with greater differences in food group consumption when comparing four or more days of consumption to HDD profiles for the highest score tertile. Both scores performed similarly when correlated with other indicators of food security available in each dataset.

The aim of remainder of the discussion is to provide a description of how the main differences between the two methods affect the comparability of the two scores. The main methodological differences include (i) number and definitions of food groups used to construct the score (ii) length of reference period used in the recall (iii) application of weights to food groups and (iv) construction of a score combining frequency and dietary diversity.

Number and definition of food groups

When comparing results of dietary patterns by tertiles, the HDD method captured more detail in the highest tertile, while the lowest tertile for both methods reflected the same diet. The number and definition of food groups is mainly responsible for the variation in detail seen at the higher levels of each score. The rationale in the HDD method for including a more disaggregated list of food groups is to allow more versatility with analysis. For example, disaggregation of animal source foods into four groups (meat, fish, eggs, and dairy) allows for detection of differences in consumption across groups with different characteristics or over time.

The difference in number and definition of food groups had an effect on detection of food insecure households. The province of Saravane in Lao PDR provides a good example. The percent of households falling below the defined cut point was 30 percent for FCS and 13 percent for HDD score. Saravane was ranked as the second most food insecure area by FCS, but was ranked as one of the most food secure areas (13^{th} out of 16) by HDD. Eighty-nine, 63 and 41 percent of households reported consuming meat, fish and eggs over the past 24-hours. For calculation of FCS, these food groups are aggregated into one group. Fifty-two percent of households consumed meat/fish/eggs all seven days, the equivalent of 28 points for FCS, consumption of the meat/fish/egg food group for the remaining 48 percent of the households was spread evenly across zero to six days. There was also a tendency in this province for foods reported consumed only two to three times per week, to have been reported consumed in the previous 24 hours.

Length of reference period

These datasets indicate that 24 hour household recall of individual food groups is always slightly higher than what would be hypothetically captured for any one day, when the recall period is measured over seven days. For example in the twenty four hour recall oil was reported as being consumed by 33%, 39% and 41% of households in Burkina Faso, Lao PDR. and N. Uganda, while the theoretical probability of oil being consumed on any given day was 31%, 32% and 35% respectively. Although most of the differences were small, many of them were statistically significant. These differences are explained either by a level of over reporting for one day, under reporting over seven days or some combination of both errors.

Previous research would suggest the most likely explanation is underreporting during the longer recall period, rather than over reporting during the one day recall. Recall error increases the longer back into the past respondents are asked to remember and this memory error leads to underreporting of food items consumed (16). Research by Savy *et al,* found that there was a greater recall error with two and three day recall as compared to one day recall (17).

Weighting of food groups

This comparative review found that weighting had an impact on the comparability of the two scores. Provincial level data from Lao PDR was analyzed in more depth due to the greater divergence seen at provincial level analysis when ranking provinces using FCS and HDD score cut-points. The diet in Lao PDR is dominated by cereals, vegetables and fish. The FCS assigns cereals a weight of two, vegetables a weight of one and fish a weight of four, while in the HDD score, each food group has an equal weight of one. If these three food groups were consumed by the household over the previous day, the HDD score would be three, while the FCS would be seven. The magnitude of the difference between the two scores is compounded by the number of days in the week that the higher weighted food groups were consumed.

Currently the HDD score treats all food groups equally, which could be considered as assigning an equal weight to each group. The FCS applies a weighting system, but the current weights were found to not improve the accuracy of score over an unweighted score in terms of correlation with energy intake (8). Rose and colleagues found that when comparing various types of food consumption scores, using food group weights based on formulas derived in a locally specific context provided the strongest correlation with a proxy measure of household dietary energy availability (9). While locally designed weighting systems may produce the strongest correlations, the data needed to construct them are often not available and this would also produce a country specific indicator which could not be used as a standardized international indicator. Rose concludes that differences in performance of weighted as compared to unweighted scores did not merit replacing an existing data collection system, but this aspect should be taken into account if considering a new system. If performance of the indicator is improved, then weights may be warranted in both the FCS and HDD score. Further validation of the appropriate weights to use is needed, while keeping in mind the objective of maintaining a standardized indicator for multi-country use.

Combining dietary diversity with frequency of consumption

Traditional food frequency methodology uses a combination of diversity and frequency, but generally to assess dietary patterns over a much longer time frame of months to one year. IFPRI concluded that indicators based on a recall period of seven days combining frequency (number of times consumed per week) and diversity were preferable to scores using only diversity (8). In two out of three countries used to validate proxy indicators of household food security, the FCS, which takes the frequency of consumption into account, correlated better with household energy intake than simpler measures using only dietary diversity. The merit of a score based on a one day recall period combining frequency (number of times per day) of consumption with diversity has not been the subject of much research in developing countries. The added accuracy achieved with scores that combine frequency and diversity should be weighed against the additional time and effort required for survey training, data collection, respondent fatigue and data analysis. Issues related to underreporting of frequency could also be an area for further research.

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REFERENCES

1. Food and Agriculture Organization of the United Nations (FAO). Measurement and Assessment of Food Deprivation and Undernutrition. Proceedings from the International Scientific Symposium on Measurement and Assessment of Food Deprivation and Undernutrition; 26-28 June, 2002; Rome, Italy. Rome: FAO; 2003.
2. FAO. Guidelines for measuring household and individual dietary diversity (version 4) [Internet]. Rome: 2008. (cited 12 January 2009) Available from: http://www.foodsec.org/tr/nut/guidelines.pdf
3. World Food Programme (WFP)-Vulnerability Analysis and Mapping (VAM). Technical Guidance Sheet. Food Consumption Analysis. Calculation and use of the Food Consumption Score in Food Consumption and Food Security Analysis. Rome: WFP; 2007.
4. WFP. Comprehensive Food Security and Vulnerability Analysis Guidelines. [Internet] Rome: WFP; 2009. (cited 18 June, 2009). Available from: http://documents.wfp.org/stellent/groups/public/documents/ manual_guide_proced/wfp203199.pdf
5. Swindale A, Bilinsky P. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (v.2). Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2006.
6. Hoddinott J, Yohannes Y. Dietary diversity as a food security indicator. Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development; 2002.
7. International Food Policy Research Institute. Review and validation of dietary diversity, food frequency and other proxy indicators of household food security. Rome: WFP-VAM; 2006. Paper prepared for WFP/VAM as part of Strengthening Emergency Needs Assessment Capacity (SENAC).
8. Wiesmann D, Bassett L, Benson T, Hoddinott J. Validation of the World Food Programme's Food Consumption Score and Alternative Indicators of Household Food Security. Washington, DC: International Food Policy Research Institute (IFPRI); 2009. IFPRI Discussion paper 00870.
9. Rose D, Chotard S, Oliveira L, Mock N, Libombo M. Comparative Evaluation of Dietary Indicators used in Food Consumption Assessments of at-risk populations *Food Nutr Bull* 2008;29(2):113-122.
10. WFP. Progress report on the Implementation of the World Food Summit Plan of Action. [Internet]. Rome: WFP; 2008. [cited 11 June 2009] Available from: ftp://ftp.fao.org/docrep/fao/meeting/ 013/ai753e.pdf.
11. IPC Global Partners. IPC Technical Manual version 1.1. [Internet]. Rome: FAO; 2008. [cited 19 June 2009]. Available from: http://www.ipcinfo.org/tech.php
12. World Food Programme –Vulnerability Analysis and Mapping Branch & Food and Agriculture Organization of the United Nations (2008). Interagency workshop report. Measures of food consumption – harmonizing methodologies. [Internet] Rome: WFP; 2008. [cited 3 June 2009] Available from: http://documents.wfp.org/stellent/groups/ public/documents/ena/wfp196629.pdf
13. SPSS for Windows Release 13.0. Chicago: SPSS Inc; 2004.
14. Sim J, Wright C. The Kappa Statistic in Reliability Studies: Use, Interpretation and Sample Size Requirements *Phys Ther* 2005;85:257-268.
15. Landis RJ, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33: 159-174.
16. Jelliffe DB, Jelliffe EFP. Community Nutritional Assessment. New York: Oxford University Press; 1989.
17. Savy M, Martin-Prével Y, Traissac P, Delpeuch F. Measuring dietary diversity in rural Burkina Faso: comparison of a 1 day and a 3-day dietary recall. *Pub Health Nutr* 2007; (10)1:71-78.

CHAPTER 8

GENERAL DISCUSSION

Household food security and malnutrition, micronutrient malnutrition in particular, are public health concerns in developing countries. Dietary diversification is a recommended approach to alleviate nutritional problems resulting from food insecurity and inadequate intake of micronutrients. Many organizations promote the collection of information on dietary diversity to inform food security and nutritional assessments, but there is no agreed upon set of indicators used for this purpose. Certain outstanding methodological questions are impeding development of standardized indicators. This thesis has a two-fold aim i) to examine relationships between dietary diversity and adequate intake of micronutrients and ii) to consider outstanding methodological questions. These include, determining an appropriate cut-point for (in)adequate intake of micronutrients from the diet and the effect of length of recall period on characterizing dietary patterns. This chapter will review the main findings, discuss limitations of the methods used, propose areas for further research and finally put the findings into the larger context of relevance to public health.

MAIN FINDINGS

The main findings of this thesis are summarized in Table 1. At individual level, dietary diversity scores showed a consistent, positive association with probability of adequate micronutrient intake. Studies in Filipino children and Malian women showed that use of a minimum quantity of consumption of 10g or more for children and 15g or more for women of reproductive age in order for the food group to count in the score, improved the correlation between the score and probability of adequate nutrient intake. These same two studies also demonstrated that the relationship between dietary diversity and nutrient adequacy was due in part to increasing energy intake, but remained in correlations and linear models where dietary energy intake was controlled, indicating a role independent of energy intake. The best cut-off point for use as a dichotomous indicator to define inadequate intake was between four and six food groups in the two studies on children. In women of reproductive age in Mali, five or more food groups for restricted scores based on six and nine food groups was the best cut-off across a mean probability of adequate (MPA) range of 0.50 to 0.70 percent.

The primary question related to household-level scores was the performance of the scores based on either a one or seven day recall period. The recall period of one day provided a similar mean and the same modal number of food groups as did the score based on seven days in Somalia. Dietary patterns based on score tertiles were the same or similar in all four countries analyzed.

METHODOLOGICAL ISSUES

This section will discuss potential sources of error in the data sets used to draw the conclusions presented in this thesis. Potential sources of error are classified into selection bias, information bias and confounding.

Table 1 Summary of main findings

Study population and design	Main findings
Research question What is the relationship between micronutrient intake and individual dietary diversity scores (DDS), including the effect of eliminating foods consumed in small quantities?	
Population non-breastfeeding Filipino children (n=2805 2-5.9y) Outcome mean probability of adequacy (MPA) for 11 micronutrients Determinants DDS-9 and DDS-9R (chapter 2)	Philippines: The unrestricted and restricted scores were both significantly correlated with MPA (r=0.36 and 0.44 respectively). The use of a 10 g minimum to count in the score improved the score performance.
Population South African children (n=2200 1-8y) Outcome Mean adequacy ratio of 11 micronutrients, energy and protein (MAR) Determinants DDS9 and Food variety score (FVS) (chapter 3)	South Africa: Both DDS and FVS were significantly correlated with MAR (r=0.63 and 0.67) respectively.
Population urban Malian women (n=102 15-49y) Outcome MPA for 11 micronutrients Determinants DDS 6,9,13 and 21 and DDS-6R,9R, 13R and 21R (chapter 4)	Bamako, Mali: All eight indicators tested were positively and significantly correlated with MPA. The strongest correlations were for six food groups and nine food groups (r=0.48) with the 15 gram restriction applied.
Research question Which food groups are the most strongly correlated to MPA?	
Population Bamako, Mali. Outcome MPA for 11 micronutrients Determinants Food groups based on those defined for DDS 6 and DDS 21 (chapter 5)	Nuts/seeds and vitamin A rich dark green leafy vegetables were the food groups with the highest odds ratio for MPA <0.5
Research question What is the most appropriate cut-off point to create a dichotomous indicator of inadequate or adequate micronutrient intake?	
Populations Philippines, South Africa and Mali (see above) (chapters 2,3 and 4)	Philippines: A cut-point of ≤ 6 food groups had the best indicator performance for MPA of 0.5. South Africa: A cut-point of ≤ 4 was the best predictor of MAR <50% Mali: A cut-point of ≥ 5 had the best indicator performance for MPA >50-70% using the six and nine restricted food group indicators
Research question What difference does a one or seven day recall period make in characterizing household level dietary patterns?	
Population El Barde, Somalia (n=430 hh) Dependent variable Household Dietary Diversity Score (HDDS12 1d) Independent variable HDDS12 7d (chapter 6)	In Somalia, the median and modal number of food groups consumed did not differ whether based on one or seven days of recall. The dietary patterns of each score tertile were the same whether measured over one or seven days.
Population Burkina Faso (n=3640 hh), Lao PDR (n=3913 hh), Northern Uganda (n=1956 hh) Dependent variable HDDS11 1d Independent variable Food Consumption Score (FCS) (chapter 7)	In all locations, the dietary profiles constructed from one (HDDS) or seven (FCS) days of recall were similar.

Selection bias

Selection bias can be present in studies when persons 'self' select such as volunteer for studies or if data are collected from a predefined area such as a health care clinic (1). Selection bias could also occur as a result of refusal to participate associated with a particular characteristic, such as embarrassment over a state of household food insecurity. None of the studies in this thesis were based on a self selection method, therefore potential for this type of bias is limited. The individual level studies used two and three stage random sampling procedures, while the household level studies were mainly two-stage sampling, with the first stage selected based on probability proportional to size and the second stage using a type of random walk procedure (2,3). In Mali, there was the potential for selection bias to be introduced at the third stage of sampling when selecting one woman out of the household. For example, in polygamous households, selection bias could have been introduced if the first wife was systematically chosen. Instead to reduce the potential for this type of bias, one woman from all eligible women in the household was randomly selected. High levels of refusal to participate could also introduce selection bias. Refusal to participate is generally low in developing countries. Information on participation rates available from our studies were 93 percent in South Africa and 95 percent in Mali.

Information bias

There are many potential sources of information bias present in these data sets including, correlated measurement error and errors related to the use of 24-hour recall data, food composition data, use of a dietary diversity questionnaire and failure to proportionally represent market days.

Correlated measurement error

Correlated measurement error is of concern in the four papers (chapters 2-5) aimed at defining the relationship between individual dietary diversity scores and micronutrient intake and also to a lesser extent in the comparison papers of household dietary diversity scores. In order to validate one measurement instrument against another, measures should be independent, with information collected from two different points in time (4). In our studies looking at individual dietary diversity and micronutrient intake the same data collection tool (24 hr recall) was used to assess nutrient intake and to create the dietary diversity scores. Measurement errors in the dependent and independent variables will be correlated, which could lead to falsely high correlations. Our results showed correlation between dietary diversity score (DDS) and mean adequacy ratio (MAR) of 0.63 in South Africa and DDS and MPA of 0.44 and 0.48 in the Philippines and Mali using restricted scores. Correlation coefficients between DDS and nutrient adequacy (assessed as MAR) using independent measures, were slightly lower (r=0.35 and r=0.29), but still significant (5). Our correlations could be inflated due to correlated measurement error, with the true value closer to a correlation between 0.3-0.4.

Errors associated with dietary recall data

Chapters 2-5 are based upon data collected using the 24-hour recall method for assessing dietary intake. There are several types of errors related to use of retrospective dietary recall methods. These can be categorized into two types; random and systematic errors.

One of the largest sources of random error with 24-hour dietary data is day to day variation in intakes. Random errors generally weaken estimates of association (4,6). The presence of random error in these data sets could effect the strength of association between dietary diversity scores, energy intake, intake of individual micronutrients and the composite probability of adequate micronutrient intake. The effect of random error is reduced through sample size and/or increasing the number of recall days (7). The results from the Philippines and South Africa are based on sample sizes of 2805 and 2200 respectively which should reduce the influence of random error in these results. The data from Mali are based on a relatively small sample size (n=102), but represent two days of recall data for a large sub-set of the original sample (n=96). Additionally the Mali data used statistical methods to account for intra and inter individual variation in nutrient intakes. For these reasons, random error should have been minimized, increasing confidence in the strength of associations found in these studies.

Systematic error is a greater cause for concern. Systematic under and over reporting of intake is common with the 24-hour recall methodology in Western societies (8,9) and also likely but less well documented in developing countries. It is hypothesized that errors related to under or over reporting could be both quantitative and qualitative in nature, meaning not only is total intake over or under reported, but may disproportionately effect food groups culturally considered to be unhealthy or desirable (10). Accurately identifying the existence of a qualitative reporting bias has not been the subject of much research to date. The risk from quantitative errors of over or under reporting was reduced in our data sets by careful review of dietary records in the case of Mali and cleaning of outliers based on energy intake in relation to requirements for the Philippines and South Africa. The existence of under or over reporting should not effect the relationship between dietary diversity scores and probability of micronutrient adequacy in our results since both the dietary diversity score and nutrient intakes were computed from the same data. Under or over reporting errors would be more influential when trying to associate dietary diversity scores and nutritional outcomes based on biochemical or anthropometric assessment.

Food composition tables represent another potential source of systematic error when translating estimated intake of foods into nutrients (11). Imprecise food composition data could lead to over or under estimation of nutrient intakes. Errors in nutrient composition could be associated with only one or two foods or with individual nutrients due to the analytical methods used. This could lead to incorrect assumptions about the strength of association between dietary diversity scores and intake of individual food groups or individual micronutrients. Each of the three sites used for assessing the performance of the individual dietary diversity score as a predictor of nutrient adequacy used a systematic approach to food composition information. The first source of food composition information was the national food composition table, based upon the rationale that use of a national food composition table should provide the most accurate data on the nutrient content of locally available foods and provide the most complete reference for foods indigenous to that country. When a national food composition table was missing needed nutrient values, these were substituted using a systematic method for each study. Nutrient retention factors were used in the Philippines and Mali to account for nutrient losses during the cooking process. A sub-sample of the nutrient values used in the Mali site underwent a quality control evaluation, increasing the validity of the nutrient intake values assigned to these foods. While use of food composition data remains challenging, particularly in developing country settings such as those in this thesis, efforts were made to minimize the potential for erroneous conclusions based on incorrect food composition data.

Effect of seasonality and market days

Seasonality and market days have both been shown to effect dietary diversity scores. In a study in rural Burkina Faso dietary diversity was measured in April, (beginning of cereal-shortage) and September (end of cereal shortage season), there was a significant increase in individual-level dietary diversity scores, from 3.4 in April to 3.8 in September, with 32 as compared 8 percent of women with a diversity score of less than three food groups (12). In Mozambique, there was a seasonal effect on consumption of certain food groups, particularly for the food group vitamin A-rich fruits, which included mango. (13). Market day effected dietary diversity scores and food group consumption in Burkina Faso. Dietary diversity scores were measured on three days, the mean was higher for women when there was a market day in the village as compared to when there was none (statistically significant difference in DDS for only one out of three days measured). There were also significant differences in consumption of the food groups vegetables and meat/fish (12). This could be a factor in our studies for both the individual and household-level scores. In the individual-level studies, the effect of a market day and seasonality variations could have resulted in either higher or lower scores than the yearly average. However these studies were aimed at defining the relationships at the point in time measured and therefore this effect should not change the interpretation of our results. There could be an influence of market days in the two household-level studies comparing the 24-hour recall period with that of seven days. One-day household-level scores could have been higher if the day of recall was a market day. Information on market days was not collected in our studies, so the impact of this variable can not be assessed. It is not likely that this effect influenced our results since dietary patterns were the same for one and seven days in Somalia, and similar in the other three locations.

Errors in collecting information through the use of a dietary diversity questionnaire

Chapters 6 and 7 are based upon household level information gathered through means of a dietary diversity questionnaire. This survey instrument has several potential sources of error and interpretation of results based upon dietary diversity scores should also take into consideration fluctuations due to seasonality and market access.

Within the questionnaire format, sources of error include misclassification of food items into food groups and the questioning style. To reduce classification errors, the foods which go into each food group should be exclusively defined and enumerators should be adequately trained. There are two types of questioning styles, an open recall followed up with list-based questions or only list-based questions. With the open recall approach, subjects are asked to recall all foods consumed in the past 24-hrs, the diet is recorded in spaces provided in the questionnaire. Food items mentioned are then put into the appropriate food groups and followed up with list-based questioning. In the list based approach respondents are prompted to answer 'yes' or 'no' to consumption of any food item from a food group category. There is unpublished evidence, to suggest that more accurate information is obtained when respondents are first asked to provide a free recall of all food and drinks consumed rather than when respondents are prompted to answer 'yes' or 'no' to consumption of any item from a food group category. The reason for this is most likely that memory errors of the respondent are reduced when recalling in a linear fashion from morning until night foods consumed throughout the day. This approach also allows for errors to be corrected after the data collection period, since information on the free recall is written on the questionnaire form. The free recall approach would probably be practical only for the reference period of the previous 24 hours up to perhaps three days, but would be an impractical approach if recall for the previous week is desired. For the household level dietary diversity scores in this thesis only the list-based approach was used, this could have resulted in greater misreporting, which could result in either higher or lower scores.

There is also the possibility of misreporting on the part of the respondent. Errors on the part of the respondent could be based on memory failure or be driven by an individual motivation to appear better or worse off. For example, the respondent could underreport food groups consumed if there was motivation to receive assistance. Chapters 6 and 7 in this thesis based on the household-level scores were undertaken by or with the co-operation of WFP and so there could have been reporting error on the part of the respondent due to expectation of assistance.

Two of the main limitations of household-level tools are that they do not include foods consumed outside of the home and for foods consumed within the home, they do not distinguish whether consumption occurred for one, several or all members of the household. These limitations are recognized in this work and inferences from household to individual level intakes are not made. In our data sets, from rural and emergency settings, out of home food consumption is thought to be rare. In the sub-sample of urban areas, out of home food consumption could lead to artificially low household level scores as out of home food consumption is common in urban areas (14).

Confounding

Total dietary energy is one of the most important confounders for chapters 2-4. Dietary diversity and micronutrient intake both increase with increasing total energy intake, therefore it is important to assess if the relationship between dietary diversity scores and micronutrient intake is due only to increasing energy intake. Total energy intake was controlled for in the Philippines and Mali. In South Africa energy was incorporated in the MAR. After controlling for energy in the Philippines and Mali, a significant and positive effect remained for dietary diversity, as a determinant of MPA, although results were attenuated. This means that probability of micronutrient adequacy is related in part to increasing total dietary energy, but there is also a separate, independent effect on probability of adequacy by increasing the number of food groups consumed. In South Africa, the correlation coefficients for individual micronutrients and DDS were significant for all 13 nutrients tested ($r=0.38$ for energy and r between 0.12 to 0.49 for micronutrients). Including energy in the MAR for South Africa could have lead to an overall higher correlation coefficient between DDS and MAR, but due to the strength of individual correlations with other micronutrients, a significant relationship independent of energy intake is also expected.

Socio-economic status (SES) is another potential confounder but was not controlled for in our studies as the information was not available. Some studies have found that dietary diversity score increases with SES (15,16), while others have not (17). There is also an influence of SES on intake of micronutrient-dense food groups (18,19). However in one study looking at the influence of SES on both DDS and micronutrient intake, results were significant only for DDS and SES and not for SES and micronutrient intake (15). Due to the inconsistency of results between the relationships found in other studies, it is not likely that this potential confounder would alter the direction or significance of correlations our change our conclusions about the relationship.

Age, gender, height and weight could be potential confounders. In the Philippines regression models controlled for age, gender, height and weight. Only child age was found to be a significant determinant of MPA in the model controlling for energy. In South Africa results were stratified by age group, correlations for MAR and DDS were significant for all age groups. In Mali, age and height were investigated in regression models, but were not significant determinants of MPA.

EXTERNAL VALIDITY

Relationship between micronutrient intake and DDS, including the effect of eliminating small quantities

A recent review on the use of dietary patterns as predictors of nutrient intake adequacy found a range of association between DDS and nutrient adequacy from 0.29 to 0.66, the study concluded that diet indices were tools with fair to moderate validity to assess adequacy of micronutrient intakes (20). Several studies cited in chapter one have confirmed our findings of a positive and significant relationship between dietary diversity scores and intake of micronutrients within the range of 0.3 to 0.7 which can be considered as small to moderate strength of correlation. Many of these studies have the same correlated measurement error limitations presented in the previous section. Only the study by Torheim (5) used independent measures and correlations were on the lower end of the range generally found (0.29 to 0.35). Correlations within this range can be considered as small to moderate, and are of typical strength in dietary assessment data.

Chapters 2 and 4 look into the issue of not counting small portion sizes in the diversity score. In both studies, the scores requiring a minimum level of intake (10g for children and 15g for adult women) performed better than those based on a minimum intake of only one gram. Other studies have shown that applying a portion size cut-off improved the correlation between dietary diversity scores and probability of nutrient adequacy in adults (21) and in children (22).

Most appropriate cut-off point for use as a dichotomous indicator

Chapters 2-4 define the most appropriate cut-off in each setting, for use of dietary diversity scores as a dichotomous indicator. Dichotomous indicators are useful tools for screening for vulnerability within populations and to determine prevalence of a problem at population level. First, an acceptable (or unacceptable) level for the predicted outcome variable (nutrient adequacy), has to be chosen, this can then be compared to various levels of the dietary diversity score.

Our study from South Africa and two studies in children in the Philippines are based on diversity scores using nine food groups, but slightly different analytical methods to define nutrient adequacy. Our results in South Africa, showed a DDS of four provided the highest balance of sensitivity and specificity for predicting inadequate intake, defined as MAR below 50 percent. Our results from the Philippines showed the best cut-point was six food groups or fewer for MPA of 50 percent. Daniel's study from the Philippines, also based on nine food groups, found a cut-off of ≤ 4 food groups maximized sensitivity and specificity for MPA < 50% (22). This study also tried to optimize the indicator at MPA >75% and showed ≥ five food groups maximized the balance between sensitivity and specificity in the 10g restricted indicator. Among school-age children in Kenya, the best food group cut-off was five food groups, using an indicator based on seven food groups, and a mean probability of inadequacy (MPI) of 50% (23). Results from children 13-58 months in Mali found the best cut-off to be six food groups out of a possible score of eight, at a MAR of 75 % (24). These results point to a cut-off range of four to six or fewer food groups to define inadequate intakes. Comparisons across different study sites should bear in mind differences including, differing ages of the children, number of food groups used in the scores, definition of outcome variable (MAR, MPA or MPI).

There is also the question of whether the cut-off point should have the objective of defining a level of inadequacy or of adequacy. In some research circles defining inadequacy is treated with caution as there is tendency to interpret those falling above the threshold of inadequate intake as adequate. For example, if the probability of inadequate intake were defined as three or fewer food groups, there is a tendency to define four or more food groups as nutritionally adequate, when in fact this may not be true, in the same population, the cut-off for maximizing adequate intake may be six or seven food groups, not four.

The Women's Dietary Diversity Project[1], used standardized definitions for MPA and the number and types of food groups in the scores, with the purpose of predicting adequate micronutrient intake. Results for the best cut-off for the portion size restricted indicators based on nine, thirteen and twenty-one food groups ranged between four to five food groups, four to six food groups and five to seven food groups respectively. The summary report concludes that no single indicator or cut-off point yielded an acceptable balance of sensitivity, specificity, and misclassification across all sites (21). Evidence from theses sites is however pointing to a range between four to six food groups. A main disadvantage in these studies was overall low levels of micronutrient intake resulting in very few women above higher MPA cut-offs. For this reason, conclusions on the most appropriate cut-off are based upon using MPA of 50-70 percent. Ideally results to define a cut-off point for an indicator of adequate intake would be based on a higher MPA. Currently, there are no guidelines on the best MPA cut-off to use in indicator development, however, MPA cut-offs between 75 to 90 percent would seem more desirable for this purpose.

[1] The Women's Dietary Diversity Project is a collaborative research initiative lead by and funded through FANTA, to assess the potential of simple indicators of dietary diversity to function as proxy indicators of diet quality for women of reproductive age in resource-poor settings. Collaborator sites included Mali (this thesis), Bangladesh, Burkina Faso, Mozambique and the Philippines.

Choosing a dichotomous cut-off is also subjective, as different levels of sensitivity and specificity may be appropriate in different situations. Considerations related to choosing between different cut-offs include cost and undesirability of false results (25, 26). When the indicator is designed to predict inadequate intake, false negatives, or persons with low MPA misclassified as not at risk, are more of a concern than false positives, persons with a higher MPA misclassified by the cut-point. Decision making on the most appropriate cut-off point should favor sensitivity over specificity and within this balance, select the cut-off with the lowest percentage of false negatives. If false positives are high, the cost of programs targeted toward only individuals or households below the cut-off will be increased. Risk in terms of social undesirability of misclassification is rather low in the case of predicting micronutrient intake as compared to for example misclassification of HIV status.

Relationships between individual food groups and micronutrient intake

Some of the previous research at food group level was motivated by trying to define 'sentinal' food groups, or food groups which dominated the relationship between diversity and micronutrient intake and could be used as an even simpler means of predicting dietary adequacy. For example could asking a question (yes/no) about consumption of an animal source food group replace questioning about a longer list of food groups. In chapter five, the contribution of individual food groups to mean probability of adequacy was assessed. Two food groups, nuts/seeds and dark green leafy vegetables increase the odds of achieving an MPA above 50%. In a similar study of women in Bangladesh, dark green leafy vegetables, fish, nuts/seeds, and dairy were the food groups of most nutritional importance in terms of providing micronutrients (13). Analysis undertaken by the Working Group on Infant and Young Child Feeding Indicators in nine countries found that consumption of animal source foods (red meat, poultry, dairy product, egg or seafood) predicted micronutrient density of complementary foods reasonably well (27). In location specific sites in their study, the food groups dairy, vitamin A-rich fruits and vegetables and other fruits and vegetables were good markers of dietary quality. In analysis of diets of rural school children in Kenya, vegetables, fruits and dairy were the food groups with the strongest correlation to a diet most likely to be adequate in micronutrients (23). The overall conclusion seems to be significant food groups are site specific, but in general, animal source foods and fruits and vegetables play key roles in the relationship between dietary diversity and micronutrient intakes. More useful than trying to identify global-level sentinel food groups may be to identify locally specific micronutrient dense fruits, vegetables and animal source foods which are locally available and affordable. When year-round availability is a problem, preservation techniques such as drying and canning can be used to provide seasonal sustainability of micronutrient rich foods.

Effect of recall period on associations of household food security and other indicators

Chapter six and less directly, chapter seven assess the performance of dietary diversity scores based on a recall period of one or seven days. A seven day reference period should capture more information on overall dietary patterns and therefore provide more information to inform decision making. The disadvantage of a longer recall period includes more time required for data collection and analysis and greater potential for recall error (28). In Somalia, there was a statistically significant difference in score distributions, but dietary profiles and relationships with other socio-economic variables were the same, whether the score was based on a one or seven day recall period. Both of the studies in this thesis demonstrated a tendency for consumption of food groups from a one day recall period to be higher than the theoretical probability of consumption on one out of seven days. This is most likely due to under reporting over the seven day period. In rural Burkina Faso individual-level one day DDS was 3.5 while DDS measured over 3 days was significantly different at 4.4 but similar to our findings, both scores were related to other socio-economic indicators and the authors conclude that a one day recall period was adequate (29). This study also found memory bias associated with the three-day recall period. In eleven data sets measuring dietary diversity in young children, there was strong agreement between a one day indicator and an indicator based on consumption of the food group three or more of the past seven days (30). Similar to our conclusions, the authors state that there was little added value to the seven day recall for characterizing population level dietary patterns reflecting frequently eaten foods.

CONCLUSIONS

Dietary diversity scores are useful predictors of probability of adequate dietary intake of micronutrients in young children in the Philippines and South Africa and in women of reproductive age in Mali. Requiring a minimum quantity of consumption for a food group to count in the score improves score performance.

Results related to defining a cut-off point to create a dichotomous indicator were inconsistent across our studies, but fell within the range of four to six food groups for predicting poor intake of micronutrients in children and five or more food groups to predict better intake of micronutrients in women of reproductive age.

For the purposes of characterizing dietary patterns of households at population level a one day recall period is sufficient.

OUTSTANDING QUESTIONS AND CONSIDERATIONS FOR FUTURE RESEARCH

This thesis work is focused on simple indicators suitable for use in developing countries where food security and undernutrition are of primary concern. The motivation was to contribute to the development of indicators appropriate for use in resource constrained environments, but with a meaningful interpretation for dietary intake and household food security status. There are some outstanding questions related to score construction, such as the value-added of promoting more complex scores which may be more accurate. There is also the broader issue of the need to transition to the use of more complex indices, which can measure additional dietary components such as sodium, saturated fat and cholesterol.

Number of food groups to include in the scores and creating a dichotomous indicator

There is no clear answer on the best number of food groups to use when constructing scores for the purpose of using the score as a proxy of micronutrient intake. Our studies and those of other researchers have found positive and significant relationships between food group diversity indicators constructed from various combinations of food groups, yet no recommendations for standardization have been formalized. The Women's Dietary Diversity Project tested the performance of indicators using six, nine, thirteen and twenty-one food groups, but was not able to identify a set of food groups which consistently performed the best across multiple study sites. Inability to determine the best set of food groups to use to construct a dietary diversity score for use as a proxy of micronutrient intake, hampers the development of a standardized indicator for international use.

Similarly, neither studies at individual-level or household-level have arrived at consensus on a cut-point to create a dichotomous indicators. Results from studies at individual-level point to a range between four and six food groups. Research at household-level has been scarce, even though, a dichotomous indicator for detecting household level food security would also be useful.

Weighted scores and consumption frequencies

This thesis has provided answers to outstanding questions related to score construction, such as the advantage of not including foods consumed in small quantities in the score. Additional outstanding issues include, the increased accuracy of assigning weights to food groups based on a desired nutritional property and taking into account consumption frequency. Weighting systems will differ if the desired outcome is energy or micronutrient intake. Weighting systems for use as household-level food security indicators in one study were found to better predict availability of dietary energy at household level (31) while in another study the weighting system used did not improve correlations with calorie consumption per capita (32). Choosing weights to assign to individual food groups to help predict multiple micronutrient adequacy is much more difficult and has not been the subject of much research. This is because a wide range of micronutrients are present to different degrees in most food groups included in the score. Another outstanding question is the value added of incorporating frequency of consumption into dietary diversity scores. Including either of these aspects into score construction will detract from the goal of simplicity. The added burden of applying a weighting system would be present only at the stage of data analysis and not during data collection, while applying a minimum portion size restriction would add further burden to both enumerator and respondent during data collection. A scoring system which also includes frequencies of consumption adds to the burden of both data collection and analysis.

Dietary quality

The scores described in this thesis reflect only one aspect of dietary quality, energy intake for household-level and adequate dietary intake of micronutrients for individuals. There are many additional aspects of dietary quality which can be measured. Both unwanted and desirable dietary components, such as consumption of sodium, cholesterol and saturated fat on the one hand and intake of fruits and vegetables on the other are incorporated into scores such as the Healthy Eating Index (33) and the Diet Quality Index (34). The drawback of these types of scores in the settings studied in this thesis is that they are constructed from quantitative dietary intake data, which is expensive to collect and time consuming to analyze. Many developing countries are facing a double nutritional burden, characterized by continuing high prevalence of poor child growth and micronutrient deficiencies, but coupled with increasing adult overweight and obesity and diet related chronic disease (35,36). There may be a point where diet quality aspects other than those directly related to food security become more important than simplicity of the scores analyzed in this thesis.

PUBLIC HEALTH AND POLICY SIGNIFICANCE

In order to better support national nutrition actions in developing countries, rapid feedback provided through valid indicators is needed (37). Cost and complexity of data collection and analysis are key considerations for widespread and repeated use of an indicator in resource-poor settings. Dietary diversity measures fit these criterion due to their simplicity. No special equipment is needed for data collection, which allows costs to be kept down and data analysis can be carried out with a simple statistical or spreadsheet package. The data collection tool is also flexible and can be tailored to suit program specific goals. For example, information on specific foods or food groups can easily be added into the questionnaire format to allow for monitoring and evaluation of changes in prevalence of consumption of key food groups.

Collection of information on dietary diversity is supported by numerous organizations including, the Food and Nutrition Technical Assistance Project (FANTA), the Food and Agriculture Organization (FAO), the World Food Programme (WFP) and the World Health Organization (WHO). There is one internationally endorsed indicator of "Minimum Dietary Diversity" for young children 6-23 months of age. This indicator has been accepted for inclusion in Demographic and Health Surveys.

There are two main indicators used to measure household-level dietary diversity, the Household Dietary Diversity Score (HDDS) and the Food Consumption Score (FCS). HDDS has been accepted as an impact indicator to be used in United States Agency for International Development Multi-year Assistance Programs which implement activities to improve household access to food (38) and is also part of FAO guidelines on measurement of dietary diversity (39). The FCS is used by WFP in Food Security and Vulnerability Assessments (2).

The results from our study support the use of simple dietary diversity scores as they showed to be acceptable indicators for use at individual and household level. The disadvantages of these simple measures of dietary diversity are that exact quantities of intake are not measured, so statements about levels of nutrient intake are not possible. At household level, the measure does not capture foods consumed outside of the home and also does not provide information on food groups consumed by individual household members.

Our findings highlight the following public health considerations when using dietary diversity scores:

- Scores constructed from six and nine food groups were better than those constructed from thirteen and twenty-one food groups. Scores based on fewer food groups reduce time needed for questionnaire adaptation to locally specific contexts and reduce the burden on the respondent and enumerator. However, if choosing between using six or nine food groups, a score based on nine food groups could be favored as more information on specific food groups of public health interest is provided.

- Excluding small quantities from counting in the score is recommended, but increases complexity during data collection and could lead to more error in the score. Errors can be limited to an extent by use of the free recall method of data collection, a high level of field supervision and early detection and resolution of problems during data collection. Adhering to this recommendation will increase time needed to adapt the questionnaire to the specific context and increase the burden on the enumerator and respondent during data collection.

- Results related to choosing a cut-point for creation of a dichotomous indicator were inconsistent. In terms of public health policy, dichotomous indicators are useful for advocacy and communication purposes because statements of prevalence can be made. These may be considered more meaningful to policy makers and the general public than for example comparing mean or median scores by tertiles. For the purposes of an indicator of improved micronutrient adequacy of the diet five or more food groups out of a possible nine could be recommended for women in Mali. Further studies, particularly including populations with higher overall levels of micronutrient intake are needed to reach agreement for an internationally acceptable cut-off.

- For the purposes of characterizing dietary patterns of households at population level a one day recall period is sufficient. A shorter recall period is advantageous in that less time is required for data collection and there is less potential for recall error.

Dietary diversity scores are simple and convenient tools and should be incorporated as monitoring and evaluation tools in food security and nutrition assessments at national level and below. Greater harmonization of certain aspects of score construction, such as the number of food groups used in the score and the length of reference period would be beneficial for improving understanding and interpretation. Balance between simplicity and improved accuracy should be weighed when moving toward agreement on harmonization of methodological aspects. International agreement on a cut-point to create dichotomous indicators for an individual-level score for older children and adults and a household-level score is a priority area for further work.

REFERENCES

1. Ahlbom A, Norell S. Introduction to Modern Epidemiology. Chestnut Hill, USA: Epidemiology Resources Inc; 1990.
2. World Food Programme. Comprehensive Food Security and Vulnerability Analysis Guidelines. Rome: WFP; 2009. pp.356.
3. Gibson R, Ferguson E. An interactive 24-hour Recall for Assessing the Adequacy of Iron and Zinc Intakes of Developing Countries. Washington, DC: Harvest Plus; 2008. Technical Monograph 8.
4. Kaaks R, Riboli E, Esteve J, van Kapppel AL, van Staveren WA. Estimating the accuracy of dietary questionnaire assessments: Validation in terms of structural equation models. *Statistics in Medicine* 1994;12:127-42.
5. Torheim LE, Barikmo I, Parr C, Hatloy A, Ouattara F, Oshaug A. Validation of food variety as an indicator of diet quality with a food frequency questionnaire for Western Mali. *Eur J Clin Nutr* 2003;57:1283-1291.
6. Beaton G, Milner J, Corey P, McGuire V, Cousins M, Stewart E, de Ramos M, Hewitt D, Grambsch PV, Kassim N, Little JA. Sources of variance in 24-hour dietary recall data: implications for nutrition study design and interpretation. *Am J Clin Nutr* 1979;32:2456-2559.
7. Nelson M, Black A, Morris J, Cole T. Between and within-subject variation in nutrient intake from infancy to old age: estimating the number of days required to rank dietary intakes with desired precision. *Am J Clin Nutr* 1989;50:155-67.
8. Beaton G, Burema J, Ritenbaugh C. Errors in the interpretation of dietary assessments. *Am J Clin Nutr* 1997;65:1100S-1107S.
9. Willett W. Nutritional Epidemiology, second edition. New York: Oxford University Press; 1998.
10. Ferro Luzzi A. Individual food intake survey methods. In: Measurement and Assessment of Food Deprivation and Undernutrition. Proceedings from the International Scientific Symposium on Measurement and Assessment of Food Deprivation and Undernutrition. Rome: FAO; 2003.
11. Rand W, Windham C, Wyse B, Young V. editors. Food Composition Data: A user's perspective. Proceedings from the conference. 26-29 March, 1985, Logan, Utah. Avon, UK: Bath Press; 1987.
12. Savy M, Martin-Prével Y, Traissac P, Emyard-Duvernay S, Delpeuch F. Dietary diversity scores and nutritional status of women change during the seasonal food shortage in rural Burkina Faso. *J Nutr* 2006;136:2625-2632.
13. Arimond M, Torheim LE, Wiesmann D, Joseph M, Carriquiry A. Dietary Diversity as a Measure of Women's Diet Quality in Resource- Poor Areas: Results from Rural Bangladesh Site. Washington, DC: Food and Nutrition Technical Assistance II Project, Academy for Educational Development; 2008.
14. van't Riet H, den Hartog AP, van Staveren W. Non-home prepared foods: contribution to energy and nutrient intake of consumers living in two low-income areas in Nairobi. *Public Health Nutr* 2002 Aug;5(4):515-522.
15. Ponce X, Ramirez E, Delisle H. A more diversified diet among Mexican men may also be more atherogenic. *J Nutr* 2006;136:2921-2927.
16. Hatloy A, Hallund J, Diarra M, and Oshaug A. Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). *Public Health Nutr* 2000;3(1):57-65.
17. Savy M, Martin-Prével Y, Danel P, Traissac P, Dabiré Hb, Delpeuch F. Are dietary diversity scores related to the socio-economic and anthropometric status of women living in an urban area in Burkina Faso? *Public Health Nutr* 2008;11(2):132-141.
18. Gikes K, Turrell G, Patterson C, Newman B. Socio-economic differences in fruit and vegetable consumption among Australian adolescents and adults. *Public Health Nutr* 2002;5(5):663-669.
19. Gikes K, Turrell G, van Lenthe F, Brug J. A multi-level study of socio-economic inequalities in food choice behaviour and dietary intake among the Dutch population: the GLOBE study. *Public Health Nutr* 2006;9(1):75-83.
20. Roman-Vinas B, Ribas Barba L, Ngo J, Martinez-Gonzalez MA, Wijnhoven T, Serra-Majen L. Validity of dietary patterns to assess nutrient intake adequacy. *Br J Nutr* 2009;101(S2):S12-S20
21. Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels M, Deitchler M, Fanou N, Ferguson E, Joseph M, Kennedy G, Martin-Prével Y, Torheim LE. Dietary diversity as a measure of the micronutrient adequacy of women's diets in resource-poor areas: Summary of results from five sites. Washington, DC: Food and Nutrition Technical Assistance II Project, Academy for Educational Development; 2009.
22. Daniels M, Adair L, Popkin B, Truong Y. Dietary diversity scores can be improved through the use of portion requirements: an analysis in young Filipino children. *Eur J Clin Nutr* 2009;63:199-208.
23. Ruel M, Graham J, Murphy S, Allen L. Validating simple indicators of dietary diversity and animal source food intake that accurately reflect nutrient adequacy in developing countries. Report submitted to GL-CRSP; 2004.
24. Hatloy A, Torheim L, Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *Eur J Clin Nutr* 1998;52(12):891-8.

25. Habicht JP. Some characteristics of indicators of nutritional status for use in screening and surveillance. *Am J Clin Nutr* 1980 Mar;33:531-535.
26. Zweig M. Campbell G. Reciever-operating characteristic (ROC) plots: a fundamental evaluation tool in Clinical Medicine. *Clin Chem* 1993;39(4):561-577.
27. Working Group on Infant and Young Child Feeding Indicators. Developing and validating simple indicators of dietary quality and energy intake of infants and young children in Developing Countries: Summary of findings from analysis of 10 data sets. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2006.
28. Jelliffe DB, Jelliffe EFP. Community Nutrition Assessment.. Oxford University Press, New York, New York. 1989.
29. Savy M, Martin-Prével Y, Traissac P, Delpeuch F. Measuring dietary diversity in rural Burkina Faso: comparison of a 1 day and a 3-day dietary recall. *Public Health Nutr* 2007; (10)1:71-78.
30. Arimond M, Ruel M. Dietary diversity, dietary quality and child nutritional status: Evidence from Eleven Demographic and Health Surveys. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, Academy for Educational Development (AED); 2004.
31. Rose D, Chotard S, Oliveira L, Mock N, Libombo M. Comparative Evaluation of Dietary Indicators used in Food Consumption Assessments of at-risk populations *Food Nutr Bull* 2008;29(2):113-122.
32. Wiesmann D, Bassett L, Benson T, Hoddinott J. Validation of the World Food Programme's Food Consumption Score and Alternative Indicators of Household Food Security. Washington, DC: International Food Policy Research Institute (IFPRI); 2009. IFPRI Discussion paper 00870.
33. Basiotis P, Carlson A, Gerrior S, Juan W, Lino M. The Healthy Eating Index: 1999-2000. Washington, DC: United States Department of Agriculture, Center for Nutrition Policy and Promotion; 2002.
34. Drewnowski A, Renderson S, Driscoll A, Rolls B. The Dietary Variety Score: Assessing diet quality in healthy young and older adults. *J Am Diet Assoc.* 1997; 97(3):266-271.
35. Popkin B. The Nutrition Transition and Obesity in the Developing World. *J Nutr* 2001;131:871S-873S.
36. Tanumihardjo S, Anderson C, Kaufer-Horwitz M, Bode L, Emenaker N, Haqq A, Satia J, Silver H, Stadler D. Poverty, obesity, and malnutrition: An international perspective recognizing the paradox. *J Am Diet Assoc* 2007;107:1966-1972.
37. Bryce J, Coitinho D, Darton-Hill I, Pinstrup-Anderson P. Maternal and child undernutrition: effective action at national level. *Lancet* 2008 February; 371:510-526.
38. Hammink W. Food for Peace Information Bulletin 07-02 [Internet]. (cited 16 July, 2009). Available from: http://www.usaid.gov/our_work/humanitarian_assistance/ffp/fy08_ffpib_new_reporting.pdf
39. FAO. Guidelines for measuring household and individual dietary diversity (version 4) [Internet]. Rome: FAO; 2008. (cited 12 January 2009) Available from: http://www.foodsec.org/ tr/nut/guidelines.pdf.

SUMMARY

Household food insecurity and malnutrition, micronutrient malnutrition in particular, are public health concerns in developing countries. Dietary diversification is a recommended approach to alleviate nutritional problems resulting from food insecurity and inadequate intake of micronutrients. Many organizations promote the collection of information on dietary diversity to inform food security and nutritional assessments, but there is not an agreed upon set of indicators used for this purpose. The research described in this thesis investigated the strength of the relationship between dietary diversity scores and intake of micronutrients through foods and also explored some outstanding methodological questions related to score construction. This thesis has a two-fold aim i) to examine relationships between dietary diversity and adequate intake of micronutrients and ii) to consider outstanding methodological questions. These include, determining an appropriate cut-point for (in)adequate intake of micronutrients from the diet and the effect of length of recall period on characterizing dietary patterns.

RELATIONSHIP BETWEEN DIETARY DIVERSITY SCORES AND MICRONUTRIENT INTAKE FROM FOODS

Previous research has found a consistent and positive relationship between dietary diversity scores and nutrient intake. Sub-optimal nutritional status, including micronutrient deficiencies is associated with poverty and household food insecurity. A monotonous diet, defined as regular consumption of a limited number of food groups is also associated with poverty and food insecurity. In the context of this thesis, dietary diversity scores are constructed by summing the number of different food groups consumed over a defined reference period. Chapters two and three test the relationship between dietary diversity scores and micronutrient intake from foods in populations of children in South Africa and the Philippines. Chapter four tests the same relationship in women of reproductive age in an urban area of Mali. Correlations between dietary diversity scores and micronutrient intake ranged between 0.36 in the Philippines to 0.63 in South Africa. Using a portion size limit, 10g for children in the Philippines and 15g for adult women in Mali improved the correlations, from 0.36 to 0.44 in the Philippines and from 0.33 to 0.48 for nine food groups in Mali. These results further confirm the positive and significant relationship between dietary diversity and micronutrient intake from food in diverse populations and across diverse age groups.

IMPORTANCE OF INDIVIDUAL FOOD GROUPS

A few previous studies have tried to identify 'sentinel' food groups which could be useful as stand-alone predictors of individual-level intake of micronutrients from foods. Some, but not all studies found that consumption of an 'animal source food' (red meat, poultry, dairy product, egg or seafood) was an adequate predictor of micronutrient intake. In these studies fruit and vegetable food groups or sub-groups were also often highlighted. In chapter five the strength of individual food groups and probability of adequate micronutrient intake was assessed. In our study population of women in Mali, the animal source food group was significantly correlated to mean probability of adequacy (MPA) and this relationship was further refined in the more disaggregated groupings to dairy intake, rather than intake of red meat, poultry, eggs or seafood. Energy adjusted odds ratios for MPA >.5 and those significant individual food groups out of twenty-one, found the most consistent relationships and largest odds ratios were for the highest consumers of dark green leafy vegetables and nuts and seeds, results for dairy and MPA > 0.5 were less consistent. Important conclusions are that our results do not support animal source foods as a sentinel food group, but rather in this population in Mali, nuts/seeds and dark green leafy vegetables were the most significant food groups. Inconsistent results across study sites when trying to identify sentinel food groups is likely to be due to regional specific dietary patterns. More useful than trying to identify global-level sentinel food groups may be to identify locally specific micronutrient dense food groups. From a practical standpoint, this does require more effort and is not as easy as advocating across the board increased consumption of certain sentinel food groups.

DICHOTOMOUS INDICATORS

Several studies have had the objective of defining a cut-point to create a dichotomous indicator out of the continuous dietary diversity score. In terms of standardizing interpretation and comparing prevalence, this is a suitable goal. However, comparisons across studies with this objective are difficult due to different number of food groups used to create the scores as well as different definitions of outcome. There is also the question of whether the cut-off point had the objective of defining a level of inadequacy or of adequacy. Chapters two, three and four in this thesis investigate a dichotomous cut-off, however the same limitations described above are applicable in interpretation of our results. Chapters two and three are based upon the same number and definition of food groups and both studies are in populations of children, however, chapter two attempts to define the cut-off point for inadequate intake of micronutrients from foods using a micronutrient adequacy ratio and chapter three used the probability approach to define micronutrient adequacy. Chapter four is based on results from women in Mali where the performance of several food group combinations was tested, with the aim of defining a cut-point for adequacy. In South Africa, four or fewer food groups was the best cut-point for inadequate intakes. While in the Philippines six or fewer food groups was the best cut-off for MPA < 0.5. In Mali five or more food groups was the best cut-off for an MPA > 50 percent. Findings from these three studies alone provide insufficient evidence for defining a cut-point for creation of a dichotomous indicator, however, our results point to a cut-point of five or more food groups to promote adequacy when using scores based on six to nine food groups.

REFERENCE PERIOD

One outstanding methodological issue addressed in chapters six and seven was the reference period. The reference period used to construct dietary diversity scores generally ranges from one to seven days, with one or seven days being the most commonly used reference periods. Chapter six compares dietary diversity scores over reference periods of one and seven days in a food insecure setting in Somalia. Both scores were constructed by summing the number of food groups out of a possible twelve consumed by any member of the household within the defined reference period. Median household dietary diversity score was 4 for both recall periods, but the distributions of the two scores were significantly different. Patterns of food group consumption in the lowest and highest tertiles were the same. In the lowest tertiles the majority of households consumed only cereal, milk and sugar over both reference periods. Chapter seven compares two different scores, the Food Consumption Score (FCS) and the Household Dietary Diversity Score (HDDS). Both scores are advocated for use in food security assessments. There are many methodological differences between the two scores, including length of reference period, number of food groups used to construct the score and assigning weights to food groups when constructing the FCS. Results from both chapter six and seven showed probable indication of underreporting for scores based on the seven day recall period. Additionally, population level assessment, based on comparing median number of food groups consumed (chapter six) and dietary profiles constructed from food groups eaten by the majority of the population over each reference period (chapter six and seven) did not show substantial advantage to collecting information over a reference period of seven rather than one day. With the aim of using the least complex method to inform decision making about population level diet patterns and not usual intakes our results indicated a one day recall period is sufficient.

Conclusions drawn from these studies are not without limitations. Results in chapters two to four used the same quantitative dietary intake survey to construct dietary diversity scores and micronutrient intakes. This could lead to artificially high correlations, but significant correlations are still expected. Future studies should look at the association when the measures are independent. Dietary diversity scores should be constructed through use of a qualitative dietary diversity questionnaire and micronutrient intake from food, based on a quantitative methodology such as those used in chapters two through four. Several important potential confounders were controlled in most of our studies, including total dietary energy intake, age, height and weight. None of our studies controlled for socio-economic status, as this information was not available. We would not expect a change in the direction or significance of the association found due to socio-economic status.

Dietary diversity scores are a promising tool for food security and nutrition assessment. Our results support the use of individual-level dietary diversity scores as indicators of micronutrient intake from foods and household-level score for characterizing dietary patterns. In resource constrained environments, simple, quick and reasonably accurate indicators to evaluate the dietary intake of vulnerable populations are needed since it is not feasible to use lengthy dietary intake methods to establish whether the diet is adequate in terms of micronutrient quality. Some of the most pressing current research questions include greater clarity on a score cut-point for creation of a dichotomous indicator and the added value of including weights for specific nutrient dense food groups. As populations around the world become more food secure and the burden of micronutrient deficiency lessens, research on indicators for developing countries which delve further into dietary quality will be needed.

SAMENVATTING

(SUMMARY IN DUTCH)

In ontwikkelingslanden vormen voedselonzekerheid op huishoudniveau en ondervoeding, vooral door gebrek aan micronutriënten, een gevaar voor de volksgezondheid). Om problemen veroorzaakt door deze voedselonzekerheid en onvoldoende micronutriënteninname te voorkomen, wordt algemeen aanbevolen om gevarieerd te eten. Veel organisaties raden aan de diversiteit van het voedingspatroon te meten om de voedsel- en voedingssituatie te beoordelen maar er zijn geen algemeen geaccepteerde indicatoren om dit te doen. Het onderzoek beschreven in dit proefschrift heeft twee doelstellingen: i) het onderzoeken van de relatie tussen diversiteit van het voedingspatroon (uitgedrukt in een diversiteitsscore) en de inname van micronutriënten via voedsel, en ii) het beantwoorden van een aantal nog openstaande methodologische vragen ten aanzien van de constructie van de score. Deze vragen omvatten onder andere het bepalen van een grenswaarde van de diversiteitsscore voor (on)voldoende inname van micronutriënten, en het effect van de lengte van de referentieperiode op het karakteriseren van voedingspatronen.

RELATIE TUSSEN DIVERSITEITSSCORES EN MICRONUTRIËNT-INNAME VIA VOEDSEL

Eerder onderzoek heeft een consistente en positieve relatie tussen voedingsdiversiteitsscores en voedingsinname gevonden. Suboptimale voedingsstatus, inclusief micronutriënt-tekorten, is gekoppeld aan armoede en voedselonzekerheid op huishoudniveau. Een monotoon voedingspatroon, dat is gedefinieerd als een regelmatige consumptie van een beperkt aantal voedselgroepen, is ook gekoppeld aan armoede en voedselonzekerheid. In deze thesis zijn de diversiteitsscores berekend door optelling van het aantal verschillende voedselgroepen, geconsumeerd tijdens een vooraf gedefinieerde referentieperiode. In hoofdstuk twee en drie wordt de relatie tussen diversiteitsscore en micronutriëntinname uit voedsel onderzocht bij kinderen in Zuid-Afrika en de Filippijnen. In hoofdstuk vier wordt dezelfde relatie onderzocht bij vrouwen van reproductieve leeftijd uit een stedelijk gebied in Mali. De correlatie coëfficiënten tussen diversiteitsscore en diversiteitsscore varieerden van 0,36 in de Filippijnen tot 0,63 in Zuid-Afrika. Bij gebruik van een portie grootte van ten minste 10 g voor kinderen in de Filippijnen en ten minste 15 g voor vrouwen in Mali, verbeterden de correlaties van 0,36 tot 0,44 in de Filippijnen en van 0,32 naar 0,50 voor zes voedselgroepen in Mali. Deze resultaten bevestigen de positieve- en significante relatie tussen diversiteit van voedingspatronen en micronutriëntinname via voedsel in verschillende bevolkingsgroepen en in verschillende leeftijdsgroepen.

HET BELANG VAN AFZONDERLIJKE VOEDSELGROEPEN

Een klein aantal eerdere studies heeft geprobeerd om zogenaamde 'sentinel' voedselgroepen te identificeren, die gebruikt zouden kunnen worden als op zichzelf staande voorspellers van individuele micronutriëntinname via voedsel. Sommige, maar niet alle studies, vonden dat het gebruik van dierlijke voedselproducten (rood vlees, vlees van pluimvee, melkproducten, eieren of vis) een toereikende indicator van micronutriëntinname was. In deze studies werden groenten- en fruitvoedselgroepen of subgroepen ook vaak benadrukt. In hoofdstuk vijf wordt de relatie tussen afzonderlijke voedselgroepen en de kans op een adequate micronutriëntinname beoordeeld. In onze studiepopulatie Malinese vrouwen, was de voedselgroep van dierlijke oorsprong significant gecorreleerd met de kans op adequate inname (MPA) en bij verdere verfijning van de voedselgroep bleek deze relatie voornamelijk door inname van melkproducten te worden veroorzaakt en niet door inname van rood vlees, vlees van pluimvee, eieren of vis. De meest consistente relaties en de hoogste odds ratio voor een MPA> 0, 5, gecorrigeerd voor energie-inname, werden gevonden bij de hoogste consumptie van donkergroene bladgroentes en noten/zaden, de resultaten voor melkproducten waren minder consistent. Belangrijke conclusies zijn dat onze resultaten het gebruik van de voedselgroep van dierlijke oorsprong als 'sentinel' voedselgroep niet ondersteunen, maar dat in de Malinese onderzoekspopulatie juist de donkergroene bladgroentes en noten/zaden belangrijke voedselgroepen zijn. Inconsistente resultaten, gevonden voor de verschillende onderzoeksgebieden, worden waarschijnlijk veroorzaakt door regiospecifieke voedingspatronen. Het is waarschijnlijk waardevoller om lokale voedselgroepen met een hoge nutriëntdichtheid te identificeren dan te proberen om sentinel voedselgroepen te onderscheiden voor algemeen gebruik. Vanuit praktisch oogpunt vereist dit een grotere inspanning en is minder eenvoudig dan het in het algemeen stimuleren van consumptie van bepaalde sentinel voedselgroepen.

DICHOTOME INDICATOREN

Verschillende eerdere studies hadden tot doel een grenswaarde te definiëren om te komen tot een dichotome indicator van voedseldiversiteit. Dit zou een gestandaardiseerde interpretatie en het vergelijken van prevalenties vergemakkelijken. Helaas wordt het vergelijken van dergelijke studies bemoeilijkt door het gebruik van verschillende voedselgroepen bij de bepaling van de diversiteitsscores en door verschillen in definitie van de uitkomst. Daarnaast is het van belang of de grenswaarde bedoeld was als indicatie van adequate- dan wel inadequate inname. Hoofdstukken twee, drie en vier in dit proefschrift onderzoeken of een dergelijke dichotome grenswaarde gevonden kan worden. Helaas zijn bovengenoemde problemen bij vergelijking van studies ook van toepassing op de interpretatie van onze resultaten. De studies beschreven in hoofdstuk twee en drie zijn gebaseerd op hetzelfde aantal en dezelfde definitie van voedselgroepen. Beide studies zijn uitgevoerd bij kinderen. Hoofdstuk twee tracht echter een grenswaarde voor inadequate inname van micronutriënten uit voedsel te bepalen, op basis van een ratio van eigenlijke inname in relatie tot aanbevolen inname, terwijl hoofdstuk drie een grenswaarde voor adequate inname probeert te bepalen via het berekenen van de kans op adequate inname op basis van het gemiddelde en distributie van aanbevolen hoeveelheden. Hoofdstuk vier is gebaseerd op resultaten van vrouwen in Mali, waarbij de prestaties van verschillende voedselgroep-combinaties zijn getest met als doel een grenswaarde voor adequate inname te definiëren. De beste grenswaarde voor inadequate inname in Zuid-Afrika was vier of minder voedselgroepen, terwijl in de Filippijnen zes of minder voedselgroepen de beste grenswaarde was voor een MPA<0,5. In Mali was vijf of meer voedselgroepen de beste grenswaarde voor een MPA > 50 procent. Bevindingen van deze drie studies alleen vormen niet voldoende bewijs voor het definiëren van een grenswaarde om te komen tot een dichotome indicator, maar onze resultaten wijzen echter op een grenswaarde van vijf of meer voedselgroepen voor adequate inname bij gebruik van diversiteitsscores gebaseerd op totaal zes tot negen voedselgroepen.

REFERENTIEPERIODE

Hoofdstukken zes en zeven richten zich op het effect van verschillende referentieperiodes. In het algemeen variëren de referentieperiodes, gebruikt voor het vaststellen van diversiteitsscores van één tot en met zeven dagen, met één of zeven dagen als meest gebruikte referentieperioden. **Hoofdstuk zes** vergelijkt diversiteitsscores gebaseerd op referentieperiodes van één en zeven dagen in een situatie gekenmerkt door voedselonzekerheid in Somalië. Beide scores werden gevormd door optelling van het aantal voedselgroepen geconsumeerd in het huishouden uit een totaal van twaalf voedselgroepen binnen de gedefinieerde referentieperiodes. De mediane diversiteitsscore op huishoudniveau was 4 voor beide periodes, maar de verdelingen van de twee scores weken significant af. Voedselpatronen in de laagste en hoogste tertielen van diversiteitsscores waren hetzelfde voor beide referentieperiodes. In het laagste tertiel consumeerde de meerderheid van de huishoudens alleen graan, melk en suiker in beide referentieperioden. **Hoofdstuk zeven** vergelijkt twee verschillende scores, de voedselconsumptiescore (FCS) en de diversiteitsscore op huishoudniveau (HDDS). Gebruik van beide scores wordt bepleit in het vaststellen van voedselonzekerheid. Er zijn veel methodologische verschillen tussen de twee scores, zoals de lengte van de referentieperiode, het aantal voedselgroepen gebruikt om de score te maken en het gebruik van wegingsfactoren voor voedselgroepen bij de vorming van FCS. Resultaten van zowel **hoofdstuk zes als zeven** wijzen op mogelijke onderrapportage voor scores gebaseerd op een zevendaagse referentieperiode. Op populatieniveau, gebaseerd op vergelijking van het mediane aantal voedselgroepen geconsumeerd (**hoofdstuk zes**) en van voedselgroepen geconsumeerd door de meerderheid van de populatie gedurende elke referentieperiode (**hoofdstuk zes en zeven**), blijkt er geen substantieel voordeel te zijn voor gebruik van een zevendaagse referentieperiode boven een ééndaagse periode. Aangezien het doel is te komen tot een eenvoudige methode ten behoeve van besluitvorming over voedselpatronen op populatieniveau en niet over gebruikelijke inname, geven onze resultaten aan dat een ééndaagse periode voldoende is.

Conclusies uit deze studies zijn niet zonder beperkingen. Analyses in **hoofdstuk twee tot vier** maakten gebruik van hetzelfde kwantitatieve voedselconsumptieonderzoek om diversiteitsscores én micronutriënteninname te berekenen. Dit kan leiden tot kunstmatig hoge correlaties, maar verwacht wordt dat de correlaties ook bij gebruik van onafhankelijke methodes nog steeds significant zullen zijn. Toekomstige studies moeten de relatie tussen diversiteitsscores en micronutriëntinname, vastgesteld met onafhankelijke methodes, verder onderzoeken. Diversiteitsscores moeten dan vastgesteld worden met een kwalitatieve diversiteits-vragenlijst en micronutriënteninname via voedsel moet worden vastgesteld met behulp van een kwantitatieve methodologie zoals gebruikt in hoofdstukken twee tot en met vier. In het merendeel van onze studies werd gecontroleerd voor verschillende belangrijke potentiële verstorende factoren, zoals voedings-energie inname, leeftijd, lengte en gewicht. Geen van onze studies controleerde voor sociaaleconomische status, omdat informatie hierover niet beschikbaar was. We verwachten echter niet dat de richting of significantie van de gevonden associaties zal veranderen door correctie voor sociaaleconomische situatie.

Diversiteitsscores bieden een veelbelovend instrument voor de vaststelling van voedselonzekerheid en voeding. Onze resultaten ondersteunen het gebruik van diversiteitsscores als indicatoren voor micronutriëntinname via voedsel op individueel niveau, alsmede voor het karakteriseren van voedselpatronen op huishoudniveau. In situaties gekenmerkt door armoede, zijn simpele, snelle en accurate indicatoren nodig om de voedselinname van kwetsbare populaties te kunnen evalueren. Onder dergelijke omstandigheden is het niet mogelijk om uitgebreid voedselconsumptie-onderzoek te doen als middel om na te gaan of het voedselpatroon voorziet in een adequate inname van micronutriënten. Toekomstig onderzoek moet verder duidelijkheid verschaffen over een grenswaarde voor een dichotome indicator en over de toegevoegde waarde van het gebruik van wegingsfactoren voor specifieke nutriëntdichte voedingsmiddelen voor de constructie van een diversiteitsscore. Aangezien wereldwijd de voedselzekerheid van populaties meer en meer verbetert en de last van micronutriëntentekorten vermindert, is in de toekomst onderzoek nodig naar indicatoren voor ontwikkelingslanden die de kwaliteit van het voedingspatroon verder uitdiepen.

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BRIEF BIOGRAPHY

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PUBLICATIONS

Kennedy G, Fanou N, Seghieri C, Brouwer ID. Dietary Diversity as a Measure of the Micronutrient Adequacy of Women's Diets: Results from Bamako, Mali Site. Washington, DC: Food and Nutrition Technical Assistance II Project, Academy for Educational Development; 2009.

Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels M, Deitchler M, Fanou N, Ferguson E, Joseph M, Kennedy G, Martin-Prével Y, Torheim LE. Dietary diversity as a measure of the micronutrient adequacy of women's diets in resource-poor areas: Summary of results from five sites. Washington, DC: Food and Nutrition Technical Assistance II Project, Academy for Educational Development; 2009.

Kennedy G, Pedro M, Seghieri C, Nantel G, Brouwer ID. Dietary Diversity Score is a useful indicator of micronutrient intake in non breast-feeding Filipino children. *J Nutr* 2007;137:472-477.

Kennedy G, Nantel G, Brouwer ID. Kok FJ. Does living in an urban environment confer advantages for childhood nutritional status? Analysis of disparities in nutritional status by wealth and residence in Angola, Central African Republic and Senegal. *Public Health Nutr* 2006;9(2)187-93.

Kennedy G, Nantel G. Shetty P. Assessment of the double burden of malnutrition in six case study countries *in The Double Burden of Malnutrition Case studies from six developing countries.* Rome, Italy: FAO; 2006.

Steyn NP, Nel JH, Nantel G, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutr.* 2006;9(5):644–650

Kennedy G, Islam O, Eyzaguirre P and Kennedy S. Field testing of plant genetic diversity indicators for nutrition surveys: rice-based diet of rural Bangladesh as a model. *Journal of Food Composition and Analysis* 2004;18:255-268.

Kennedy G, Nantel G, Shetty P. Globalization of food systems in developing countries: a synthesis of case studies *in Globalization of food systems in developing countries: impact on food security and nutrition* Rome, Italy: FAO; 2004.

Kennedy G, Nantel G, Shetty P. The scourge of hidden hunger: global dimensions of micronutrient malnutrition. *Food, Nutrition and Agriculture* 2003;32:8-16.

Kennedy G. Discussion Group Report – anthropometric survey methods. *In Proceedings of Measurement and assessment of food deprivation and undernutrition.* FAO, Rome: FAO;2003.

Kennedy G, Burlingame B. Analysis of food composition data on rice from a plant genetic perspective. *Food Chemistry* 2003;80:589-596.

Kennedy G, Burlingame B, Nguyen N. Nutrient Impact Assessment of rice in major rice consuming countries. *International Rice Commission Newsletter* 2002;51:33-40.

Kennedy, G. Global trends in dietary energy supply from 1961-1999. *Food, Nutrition and Agriculture* 2002;30:53-61.

OVERVIEW OF COMPLETED TRAINING ACTIVITIES

Discipline specific activities

Courses

Regression Analysis, Erasumus University, 2004
Komeet Software Training , 2006

Meetings

5th International Conference on Dietary Assessment Methods, Chang Rai, Thailand, 2003
International conference on Poverty, Food and Health, Lisbon, Portugal, 2003
Globalization, urbanization and the food systems of developing countries
Rome, Italy 2003
Urban Research Symposium, New York, USA 2003
International Meeting on World Alliance of Cities against poverty, Rome, Italy 2004
International meeting on Human Rights and Social policies to achieve the MDG's,
New York, USA 2004
Workshop on Dietary diversity, dietary quality and child growth, Rome, Italy, 2004
Workshop on Assessment of dietary changes and their health implications in countries facing the double burden of malnutrition, Rome, Italy, 2004
International stakeholders meeting on Biodiversity, dietary diversity, nutrition and health
International Technical Meeting Moving towards a common approach for food security analysis and response: the contribution of the IPC, Rome, Italy 2007
Human Nutrition Indicators for Biodiversity, side event at the 13th meeting of the Subsidiary body on Scientific and Technical Advice, Rome, Italy 2008
Women's Dietary Diversity Project collaborators meeting, Washington, DC, 2008
Measuring Food Consumption, Harmonizing methodologies, Interagency Workshop
Rome, Italy 2008
19th International Congress of Nutrition, Bangkok, Thailand 2009

General courses

SPSS Tutorial 2004-2009
Group Facilitation 2005

Optionals

Preparation PhD research proposal
Literature study, 2004-2009

Design and Layout
Xilef Welner Rome, Italy

Printing
GVO