Review Article

Limitations and resolutions for dietary assessment of micronutrient intakes

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Micronutrients (vitamins and minerals) are present mostly in small amounts, or concentrated in certain foods. Traditional Asian diets are very diverse and consist largely of foods of plant sources, including several herbs and spices. Challenges in assessing dietary intake include difficulties in collecting information on ingredients in dishes as well as in meals shared by family members, and cooking effects. *Variations in intakes* of micronutrients are determined by frequency of consumption, and how common or concentrated the nutrients are in specific foods. Moreover, assessing only nutrient intake is inadequate, since other food components affect its bioavailability. Non-nutrient food constituents, such as, phytate and polyphenols interfere with the *bioavailability* of iron and zinc. Bioconversion and bioefficacy of precursor nutrients, such as, carotenoids, also affect the estimated intake of vitamin A in its active form. Different strategies are required to deal with these challenges in assessing dietary intakes of micronutrients in order to establish the prevalence of inadequate intake, as well as the association between intake and nutritional status.

Key Words: dietary assessment, micronutrients, Asian diets

INTRODUCTION

Dietary assessments are performed for three main objectives, namely: to assess mean intakes of a group, to determine the prevalence of inadequate intake, and to establish a relationship between dietary intake and laboratory or functional outcomes.[1] Across Asia, traditional diets consists of several dishes with a variety of ingredients. In addition, a typical meal consists of several side dishes which the family members share by scooping the desired amount to their own plates. Asian diets contain a diverse variety of foods from plant sources, including several herbs and spices as condiments or seasoning. In rural areas, diets are more monotonous, but contain localized ingredients that may only be available in those regions. In addition, seasonality that affects food availability (types and amounts) is also common in tropical zones. These features are common across Asia and pose a major challenge in selecting and planning dietary assessment methods. Contributing to the complexity of assessing micronutrients (vitamins and minerals) is that micronutrients are either present in a small amount, or are concentrated in certain foods. This paper attempts to examine the limitations and possible resolutions for dietary assessment of micronutrient intakes in Asian populations.

National nutrition surveys in some Asian countries have included dietary data collection. Dietary intakes were collected by using a tedious method such as weighed records, duplicate meal analysis, 24-hour dietary recalls by interview or, to a limited extent, food records.[2,3] Food frequency questionnaires may also have been included in some of these surveys. Challenges in dietary assessment of micronutrients include: (1) variation in intakes of micronutrients, which relates to the issue of optimal (versus feasible) number of days for dietary data collection, especially in large scale surveys, (2) dietary methods that can capture the diversity of diets, (3) bioavailability of micronutrients, implicating the need for food composition data on nutrients and non-nutrients affecting the bioavailability, and calculation algorithms, (4) seasonal food availability, (5) surrogate interviews and out of home food intakes, and (6) intra-household food distribution and shared plates.

VARIATION IN INTAKES OF MICRONUTRIENTS

Micronutrients are not equally concentrated in all foods. Red meat, poultry, fish, eggs, milk and internal organs, such as liver, may contain several micronutrients (vitamin A, iron and zinc), while vitamin B2 is high in milk. Iron and several B-vitamins are reasonably high in cereals, however, milling of grains result in losses of these micronutrients. Furthermore, each food may not regularly be consumed due to eating habits, seasonality, and limited availability (associated with poverty or poor access). Intra-individual variations in intake of micronutrients have been shown to be much greater than inter-individual variations, affecting the precision of estimates of the prevalence of inadequacies.

Persson *et al* assessed the reliability of dietary intake methods from a longitudinal study during pregnancy in central Java, Indonesia.[4] Six 24-hour recalls were measured for each trimester. The ratio of intra-individual variance to

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inter-variance was <1 for energy and carbohydrates, but >1 for all other nutrients examined (iron, vitamin A and C, calcium and thiamin. While there was good agreement with 3 replicates for macronutrients, at least 6 replicates would be needed for micronutrient assessment. To estimate individual intakes with the precision of 20%, 6 replicates of 24-hour recalls were needed for energy, carbohydrates, vitamin A, iron and vitamin C.

To establish the relationships between diet and biomarkers, several days of both dietary intake and biomarkers may be needed for certain micronutrients. Very often, several 24-hour recalls may be performed, but ethical clearance for a series of phlebotomies is less likely. Booth, *et al*, investigated the relationship between dietary intakes and plasma concentrations of fat-soluble vitamins.[5] Dietary intakes were assessed by 4-day weighed records, and three plasma samples were taken over the period of 20 weeks. Significant correlation was only found for vitamin K, and the correlation improved with more independent records and plasma samples.

Dietary diversity score vs. food variety score

One of the unique characteristic of Asian diets is diversity. However, there has been no established methodology for evaluating this important characteristic. Dietary diversification is one of the main strategies promoted for improving micronutrient deficiencies. An evaluation tool for this purpose is urgently needed, unfortunately, consensus on definition and selection of assessment tools for dietary diversity are still lacking. Ruel made a critical review of dietary diversity, including measurement issues found in developing countries in different parts of the world.[6] Dietary diversity could be measured by summing food items or food groups consumed over a specified period of time (1-7 or even up to 15 days). Dietary diversity was commonly measured qualitatively as a dietary- or food variety score. A serving score was also attempted in some studies.

This review suggests that greater dietary diversity was associated with all macronutrients, and some vitamins and minerals.[6] The nature of these associations vary by context and age groups. What was not examined in these studies was whether increases in dietary diversity also improves the bioavailability of important micronutrients such as vitamin A, iron and zinc. Moreover, there was a strong relationship between dietary diversity and household socioeconomic status. Thus, there is some question on whether socio-economic status confounded the relationship between dietary diversity and growth. Key measurement issues that relate to micronutrients include: (1) the food or food groups in which the micronutrients are found, and the basis for such groupings. In the studies reviewed, it appeared to depend on the objectives for measuring diet diversity and also the local context, (2) bioavailability of vitamins and minerals should be taken into account.

Ogle, *et al* used both single food counts (food variety score, FVS) and food group counts (dietary diversity score, DDS) to assess dietary diversity of adult Vietnamese females, and validated these tools against nutrient intake and nutrient density.[7] The basic tool is a 7-day food frequency questionnaire which included more than 120 food items (for FVS) and 12 food groups (for DDS). Positive associations were found between these scores and energy intake as well as several nutrients. Micronutrient density of diets among the higher diversity group was greater than that of women with lower diversity scores. There were significant associations between both indicators and nutrient adequacy. However, only weak associations were found between dietary diversity scores and nutritional status.

Another study from the Philippines applied dietary diversity in assessing micronutrient intake of 24-71 month old non-breast-feeding children.[8] Mean nutrient intakes were calculated from 24 hour recall data, and used to derive the probability of adequacy of specific micronutrients. There were significant correlations between probability of nutrient adequacy and the dietary diversity score.

BIOAVAILABILITY OF MICRONUTRIENTS

Micronutrients, particularly trace minerals are not fully available for utilization in the body. Only a fraction of iron, zinc and calcium consumed from diets can be utilized because of interference by other food constituents. Consumption of vitamin C rich foods and animal sourced foods with foods containing non-heme iron can enhance the bioavailability of non-heme iron. In contrast, non-nutrient food constituents, such as, phytate and polyphenols present in plants interfere with the bioavailability of non-heme iron and zinc that are present in the diet.[9] Thus, deriving intakes based on the contents of these minerals in foods is inaccurate for establishing the adequacy of these micronutrients. Asian diets may have iron bioavailability range from <5% to as high as >20%, depending on the source of iron (heme/non-heme), presence of absorption inhibitors and enhancers. A few algorithms are now available, but have not been widely applied, especially in assessing adequacy of these micronutrients at population level.[10,11] Bioavailability was also incorporated in deriving dietary diversity in the Philippines.[8]

BIOCONVERSION AND BIOEFFICACY OF PRECURSOR NUTRIENTS

Carotenoids are known precursors of vitamin A, and its equivalence to vitamin A or activities have been debated. It is observed that despite high intakes of provitamin A in Indonesian women, marginal vitamin A deficiency remained.[12] The very important question was raised as to what the bioconversion of provitamin A to active forms of vitamin A is. Reviewing several studies from populations in both developed and developing countries, it was concluded that the recommended ratio of 6 μg β-carotene to 1 μg retinol equivalence may be inappropriate for dietary sources. Studies from both Indonesia and Vietnam showed the bioefficacy of β-carotene in mixed vegetables diets to be 1:21.

SEASONALITY

In the tropical zone of Asia, food availability as well as micronutrient deficiencies vary by season. Therefore, assessing dietary intakes, especially of micronutrients require a method that can capture the seasonal food intakes. Ramakrishnan *et al*. studied vitamin A intakes of children aged 1-3 years, using a quantitative food frequency questionnaire.[13] This questionnaire was developed based on market surveys, and interview with key informants (field workers, mothers). The recall period was the past year. Seasonal foods were captured by asking mothers questions on: number of months of the year when

these foods were available and the frequency of consumption during these periods. Usual portion size was estimated by the mothers and then intakes of the seasonal foods were prorated. The average daily vitamin A intake was calculated separately for β-carotene and retinol. For breast-fed children, breast milk vitamin A from literature was also included in the estimates of daily intakes. The authors pointed out the limitations of the methodology, especially the long recall period and that the diets of children of this age might constantly be changing. Unfortunately, it was not the study's objective to estimate the contribution of seasonal foods to total intake, and thus was not explicitly reported. Nevertheless, this is an example of how seasonality is incorporated in a dietary assessment of micronutrients.

SURROGATE INTERVIEWS AND MEALS EATEN OUTSIDE THE HOME

When assessing intakes of individuals through a surrogate, such as in the case of children, mothers or caretakers may only reported foods eaten at home, while those eaten outside the home may be missed. A study in Kenya demonstrated that vitamins A and C were clearly underestimated if the intakes were based only on the mother's recalls of a child's intakes at home.[14] Children were found to eat several wild fruits, nuts and insects, while they were outside the home, such as being on their way to and from school. This practice was very common especially in the food shortage seasons. Types of foods eaten outside the home may differ by season. During the harvest season, the same food items may be eaten both outside and at home or on the farm. Similar situations may be applicable to Asian communities, especially in rural areas where food production for own consumption and food gathering are still common. Hence, when using surrogate interviews, care must be taken to probe for possible out of home food intakes. If the child is old enough to give information, it would improve the accuracy of the recall by verifying the mother's recall with that of the child.

INTRA-HOUSEHOLD FOOD DISTRIBUTION AND EATING FROM SHARED PLATES

Intra-household distribution of foods has been known to be culturally bound and may relate to gender bias. In some Asian societies, men have the privilege of consuming better foods, such as animal sourced food. A case-control study was conducted to evaluate the relationship between shared plate eating behavior and risk of vitamin A deficiency in young Nepali children (aged 1-6 years).[15] Children who ate with shared plates were more likely to consume or ate a larger portion of several food items, including: grains, vegetables, carotenoid-rich vegetables, pulses, fruits, meats and fish as well as dairy products, when compared to children who ate alone. An interesting finding in this context is that children who shared plate with male adults ate more. However, xerophthalmic children were also found to be more likely to be eating with male adult members, implying that men may be less attentive and encouraging for the child to eat nutritional food than female adults.

In summary, Asian diets are complex and contain several ingredients in a dish or meal. Mostly diets are plant-based, with only a small contribution from animal sources. Dietary diversity methods are promising in capturing the diverse nature of Asian diets. Assessing micronutrients in Asian diets are further complicated by the presence of several food components that may interfere with bioavailability, particularly of trace minerals. Plants also contain precursors of certain nutrients, such as β-carotene, hence there is a need to have consensus on conversion factors to account for bioefficacy of these precursors of vitamin A. Other issues for consideration in assessing micronutrients include seasonality, eating outside the home and shared plates.

AUTHOR DISCLOSURES

Pattanee Winichagoon, no conflicts of interest.

REFERENCES

1. Gibson RS, Sazawal S, Peerson JM. Design and quality control issues related to dietary assessment, randomized clinical trials and meta-analysis of field-based studies in developing countries. J Nutr. 2003;133:1569S-73S.
2. Ministry of Public Health. The fifth national nutrition survey in Thailand, 2003.
3. Barba CVC, Feliciano E. Micronutrient deficiency and its alleviation: The Philippines experience. Asia Pac J Clin Nutr. 2002;121:S371-6.
4. Persson V, Winkvist A, Hartini TNS, Greiner T, Hakimi M, Stenlund H. Variability in nutrient intakes among pregnant women in Indonesia: Implications for the design of epidemiological studies using the 24-h recall method. J Nutr. 2001; 131:325-30.
5. Booth SL, Tucker KL, McKeown NM, Davidson KW, Dallal GE, Sadowski JA. Relationships between dietary intakes and fasting plasma concentrations of fat-soluble vitamins in humans. J Nutr. 1997;127:587-92.
6. Ruel MT. Operationalizing dietary diversity: A review of measurement issues and research priorities. J Nutr. 2003;133: 3911S-26S.
7. Ogle BM, Hung PH, Tuyet HT. Significance of wild vegetables in micronutrient intake of women in Vietnam: an analysis of food variety. Asia Pac J Clin Nutr. 2001;10:21-30.
8. Kennedy GL, Pedro MR, Seghieri C, Nantel G and Brouwer, I. Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. J Nutr. 2007;137:472-7.
9. WHO/FAO. Guidelines on food fortification with micronutrients. Allen L, de Benoist B, Dary O and Hurrell RF (eds). World Health Organization and Food and Agricultural Organization of the United Nations, 2006. Chapter 3.
10. Monsen ER, Balintfy JL. Calculating dietary iron bioavailability: refinement and computerization. J Am Diet Assoc. 1982;80:307-11.
11. Hallberg L, Hulthen L. Prediction of dietary iron absorption: an algorithm for calculating absorption and bioavailability of dietary iron. Am J Clin Nutr. 2000;71: 1147-60.
12. West CE, Eilander A, van Lieshou M. Consequences of revised estimates of carotenoid bioefficacy for dietary control of vitamin A deficiency in developing countries. J Nutr. 2002;132:2920S-6S.
13. Ramakrishnand U, Martorell R, Latha MC, Abel R. Dietary vitamin A intakes of preschools-age children in south India. J Nutr. 1999;129:2021-7.
14. Gewa CA, Murphy SP, Neumann CG. Out-of-home food intake is often omitted from mother's recalls of school children's intake in rural Kenya. J Nutr. 2007;137:2154-9.
15. Shankar AV, Gittelsohn J, West KP, Stallings R, Gnylwali T, Faruque F. Eating from a shared plate affects food consumption in vitamin A-deficient Nepali children. J Nutr. 1998; 128:1127-33.