Dietary Reference Intakes: development and uses for assessment of micronutrient status of women—a global perspective

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ABSTRACT
This paper reviews the process of developing the Dietary Reference Intakes (DRIs) and provides a synopsis of the micronutrient status of women worldwide. At a 1993 symposium held by the Food and Nutrition Board (FNB) of the Institute of Medicine (IOM), it was decided that the Recommended Dietary Allowances (RDAs) would be replaced by the DRIs, which would address several issues that the RDAs did not, including chronic disease risk reduction, upper levels for nutrients where toxicity data existed, and the possible health benefits of some food components that did not meet the traditional definition of a nutrient. Another important distinction is that because the DRIs are comprised of 4 reference values—the Estimated Average Requirement (EAR), RDA, Adequate Intake (AI), and a tolerable Upper Level (UL)—and not a single reference value like the previous RDAs, they could be used to differentiate planning from diagnosis or assessment.

The latest DRIs and nutrient intakes are shown for iron, zinc, calcium, Vitamin A and folate status in women in the United States. Data on the micronutrient status of women globally are much more limited. Summary statistics on iron deficiency anemia, night blindness, and risk of zinc deficiency are summarized. Am J Clin Nutr 2005;81(suppl):1194S–7S.

KEY WORDS DRIs, RDAs, EAR, UL, iron, zinc, vitamin A

INTRODUCTION
The RDAs were first published in 1941 and provided the scientific basis of nutrient recommendations for the US population. From 1941 to 1989, the RDAs were updated periodically based on newer scientific information on individual nutrient requirements. The impact of the RDAs were wide-ranging; the RDAs provided the nutritional standard for the US nutrition programs (1) and served as the basis for daily values (DVs) used in nutrition labeling (2). In 1993 a major revision of the RDAs was undertaken by the Institute of Medicine. The RDAs have been replaced by the DRIs, a set of nutrient-based reference values. The DRIs are now used in place of the RDAs in the United States as well as replacing the recommended nutrient intakes (RNIs) for Canada. This paper reviews the process of developing the DRIs, and implications for assessing the micro nutrient status of women worldwide for a range of nutrients.

DIETARY REFERENCE INTAKES
The process of developing the DRIs began in June 1993 with a symposium organized by the FNB of the IOM. The DRI initiative emerged from this meeting. The FNB concluded that there was sufficient new information to support a major reassessment of the RDAs (3). The recommendations emphasized that this reassessment should also address the concepts of diet and the relation to risk reduction for chronic diseases. The DRI initiative, for the first time, would consider the issue of upper levels of intake for some nutrients. In addition, food components that did not meet the criteria of traditional nutrients would be considered in the DRI initiative. The final conclusion from the 1993 symposium was that the FNB needed to devote serious attention to a new format for presenting the DRIs.

The DRI initiative evolved over a 10-year period. The process that followed the 1993 symposium provided a comprehensive, coordinated approach for developing and communicating the DRIs. The framework that emerged for guiding the DRI initiative was posited on 4 basic assumptions (4). First, there was general agreement that functional endpoints had been identified for a number of nutrients and that these endpoints were relevant for establishing nutrient requirements. Second, the advances in defining nutrients requirements provided a clearer delineation of the uses of the DRIs; the application of the DRIs would be able to differentiate planning from diagnosis or assessment. One of the strongest arguments for the DRI initiative was the concern regarding the inappropriate use of the RDAs and RNIs. Unambiguously the FNB noted, “The availability of only a single type of reference value in face of various needs has led to inappropriate applications” (3). Finally, given the global nature of agriculture, food and nutrition issues, harmonization of the nutrient recommendations from the United States and Canada seemed warranted. Thus, it was agreed that the DRIs would be applicable in the US and Canada.

Four reference values now make up the DRIs. The EAR is the daily value that meets the average requirement for healthy individuals in which a functional/clinical indicator of adequacy has been established (4). The EAR is the median of distribution for population requirements; therefore, half the population will fall below and half above this value. The EAR is the basis of deriving the RDA, and is used as the primary reference for assessing the adequacy of groups.

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The RDA is the estimate of the nutrient requirement that meets the needs of 97 to 98% of the healthy individuals. The RDA is intended to be a goal for the daily intake of an individual. The RDA is not an appropriate value for assessing nutrient adequacy of groups because it covers the vast majority of the nutrient requirements of the population. When the requirement for a nutrient is normally distributed, the RDA is 2 standard deviations above the EAR. However, for nutrients that have a non-normal distribution other approaches are used. For example, to set the RDA for iron, a factorial modeling approach is used. This method uses the distribution of the individual requirements for a particular nutrient for age/sex groups. For example, iron requirements for infant, children, and pregnant women include requirements for basal losses as well as the amount needed for maintenance of growth and fetal development.

When insufficient data are available to calculate an EAR, a reference value called the AI is provided instead of the RDA. AIs are based on observed or experimentally determined approximations of nutrient intake by a defined population or subgroup that appear to sustain a defined nutritional status. More judgment is used in the calculation of an AI. In addition, the AI may be based on a single study. Similar to the RDA, the AI can be used as a guide to nutrient intake for an individual. In general, AIs are estimated to be above the RDA for a specific nutrient, although there may be some nutrients where this is not the case.

For the first time the DRI process involves the calculation of a tolerable UL for some nutrients. The UL is the highest level of daily nutrient intake that is likely to pose no risks of adverse health effect to almost all individuals in the general population. The DRIs are clear that the UL is not a recommended level of intake, nor is it a level that is desirable to attain. ULs have been developed through a risk assessment method.

The 4 DRIs, were established for 22 distinct life stages and sex groups. The life stages groups include: infants birth to 6 mo, infants 7 to 12 mo; toddlers, 1 to 3 y of age; early childhood, 4 to 8 y of age; puberty, 9 to 13 y of age; adolescence, 14 to 18 y; young adulthood, 19 to 30 y; middle ages, 31 to 50 y; adulthood, 51 to 70 y; older adults, age 70 and over; and pregnancy and lactation.

In addition to considering life stages and sex groups, the DRIs specified a reference body size to use when more specificity is needed regarding body size and nutrient requirements. For a male 19 to 30 y, a BMI of 24.4 is the reference. For women, in the same age category, a BMI of 22.8 is used. Clearly in the United States, the majority of adults—both men and women—have an average BMI well above the established reference body size.

The new DRIs are more complex than the RDAs and RNIs. In place of a single nutrient value, there are now 4 reference values. The DRIs employ a much broader conceptual approach. Indeed, the UL as a concept of risk had not been used in the RDA process.

The DRIs serve a variety of purposes. One function of the DRIs is to determine adequacy. Each EAR and AI in the DRIs is described in terms of a selected criterion or indicator of adequacy. For example, the AI for calcium is based on balance studies and calcium deposition in the bone. The determination of the EAR or AI for a particular nutrient is sensitive to the indicator chosen.

The DRIs have many uses. The DRIs are the nutritional basis for the Federal nutrition programs. A committee of the FNB recently reviewed the use of the DRIs for nutrition labeling (5).
using the RDA for group estimates of nutrient adequacy. The RDA overestimates the level of deficiency for population comparisons.

Zinc is a nutrient that has garnered increased attention in the past decade. Similar to iron, the EAR for zinc is calculated using the factorial method. The RDA for women for zinc is 8 mg/d. The UL for zinc is 40 mg/d and is based on a reduction in erythrocyte enzyme activity. The EAR for zinc for women 19 to 70 y of age is 6.8 mg/d. Zinc data from the National Health and Nutrition Examination Survey (NHANES) for women 19 to 50 y of age is presented in Table 3. Here again, similar to iron intake data, zinc consumption either from food alone or food and supplements for each age group is above the EAR.

The EAR for vitamin A is based on the assurance of adequate stores. The RDA for women is 700 μg of retinol activity equivalents per day (RAE/d). RAE conversion factors are 1:12 for β-carotene, 1:24 for alpha carotene and 1:24 for beta cryptoxanthin. These conversion factors are much higher than the 1:6 conversion rates that had historically been used. The new conversion factors mean that larger amounts of provitamin A carotenoids are needed to provide the EAR for vitamin A. The EAR for vitamin A is 500 μg RAE/d. The UL for vitamin A for 3000 μg/d preformed vitamin A; worth noting is the fact that many dietary supplements currently have vitamin A levels at or above this amount (9). The EAR for women 18 and older is 500 μg RAE/d.

The mean intakes of vitamin A for women are shown in Table 4. Women from 19 to 50 y of age have usual vitamin A intakes provided from food that is above the EAR of 500 μg RAE/d. In addition, the vitamin A provided by supplements to women in the 50th percentile of intake is an additional 1422 μg RAE/d; this is almost 3 times the EAR.

Calcium is a nutrient that was included in the first edition of the RDAs and low intakes of calcium continue to be a problem for subsets of the US population, in particular, female adolescents (10). The trends in calcium intake for adult women, 20- to 70-y-old, between 1971/74 and 1999/2000 are shown in Table 5. Calcium intakes have increased since the late 1980s in adult women and appear to be due to a combination of factors. Nutrition promotion campaigns targeted to women emphasizing the calcium/osteoporosis prevention theme and the addition of calcium to nontraditional food sources such as orange juice appear to be having some influence on calcium consumption patterns in women (8).

Folate has been identified as a shortfall nutrient in US adult women. In 1998 the Food and Drug Administration (FDA) mandated that all grain products be enriched with folate. This resulted in white bread, for example, increasing its folate content from 34.0 μg/100 g to 95.0 μg/100 g (11). Data on the serum and red blood cell folate before and after the change in bread and flour folate levels are provided in Table 6. For women aged 15 to 44 y of age, there are increases in both serum and red blood cell folate levels (12).

There have been major improvements in the micronutrient status of women postWorld War II in the United States. A variety of policies and programs have contributed to this improvement, including US fortification policy, which has had significant positive impacts on vitamin A, iron, and the B vitamins (13). The increasing incomes of the US population over the past 50 y combined with an agricultural policy that has resulted in lower food prices has narrowed the gap in dietary patterns between low income and other income groups (13). Federal programs such as Women, Infants, and Children (WIC) have also contributed to improved micronutrient status in women (14).

### Micronutrient Status in Women Worldwide

In the early 1990s the problem of “hidden hunger”—micronutrient deficiencies—was given worldwide attention from a series of high level conferences, including the 1992 International Conference on Nutrition (15). It became apparent that large parts of the developing world were plagued by micronutrient malnutrition that could not be seen but that had devastating health and nutritional consequences. The initial focus on hidden hunger emphasized 3 micronutrients—iron, iodine, and vitamin A. The number of individuals worldwide affected by hidden hunger is staggering. Globally, some 250 million children are at risk of vitamin A deficiency, 1.5 billion people live in areas where iodine deficiency disorders are a threat, and 2 billion people suffer from anemia or iron deficiency (16).

Unfortunately, statistics on the micronutrient status of women in developing countries is much less available. Data have concentrated on preschool-aged children and the population as a whole. Information on women is less available and incomplete. In a recent report...
released by United Nations Children’s Fund (UNICEF) and the Micro Nutrient Initiative, there is a sobering wake up call.

“In the several decades since measurement of iron deficiency began, very little headway has been made against this problem... For many decades this has been seen as a “women’s problem”... affecting up to three-quarters of pregnant women. Among policy makers, the unspoken view has seemed to be that women somehow cope and that iron deficiency is not a high enough priority to justify a major nutritional effort to reduce it.” (16).

Data from selected countries on the percent of women, 15- to 49-y-old who suffer from iron deficiency anemia (16) are provided in Table 7. In each of these countries significant factors causing the anemia are low iron intakes and poor bioavailability of dietary iron. Most countries do not have nationally representative surveys of consumption patterns or micronutrient status. A crude estimate is that 500 million women ages 15 to 49 worldwide or 40% of females in the developing world are anemic (17). > 1000 severely anemic young women die every week because they lack sufficient iron to cope with the stress of childbirth (16).

Limited data are available on night blindness in pregnant women; prevalence rates for night blindness range from a low of 3.8% in the United States to 4.4% in Africa and 10.9% in South and Southeast Asia. Here again, the rates of night blindness, particularly in Asia, suggest dietary patterns chronically low in vitamin A.

Zinc is a nutrient that has only recently received increased attention. An international task force on zinc recently concluded that iron deficiency and zinc deficiency often occur in tandem (18). This task force notes that iron and zinc have a similar distribution in the food supply, and some of the same food components affect the absorption of both iron and zinc. The percentage of the populations at risk of zinc deficiency worldwide, and not surprisingly, the problem being more severe in low-income women (17). The poor micronutrient status is part of the larger problem of poor nutritional status, in general, in women.

**REFERENCES**