New Approaches to Establish Mineral Element Requirements and Recommendations: An Introduction

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ABSTRACT Early efforts to establish dietary recommendations were focused on defining minimum intakes of nutrients needed to prevent deficiency diseases. Although these early recommendations have proven to be successful in preventing frank deficiency diseases, new knowledge regarding the functions of nutrients at the biochemical, physiological, and gene levels has shifted the emphasis to defining the kinds and amounts of nutrients needed to optimize physiological and mental functions and to prevent or minimize the development of degenerative diseases that now are dominant public health concerns. Several challenges must be faced in producing recommendations based on this new knowledge. It must be recognized that nutrients are not consumed in isolation from one another, and interactions between a single nutrient and other nutrients and nonnutrients in foods will need to be taken into account when making dietary recommendations for that nutrient. Another factor that will influence dietary recommendations is the genetic variation of humans. New knowledge regarding the effects of genetic variability on human metabolism will ultimately lead to the development of dietary recommendations that address genetic influences on the nutritional needs of specific segments of our population. J. Nutr. 126: 23098-23118, 1996.

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• nutrient interactions • genetic variability
• dietary recommendations • humans

When W. O. Atwater began nutrition research in the U.S. Department of Agriculture (USDA) more than 100 years ago, the Federal government had no nutrition policy and made no recommendations about what people should eat. Atwater, as the first Federal employee to do nutrition research, did have a concern about what constituted the best diets for workingmen and what foods they might consume to have a diet that was both nutritious and economical (Carpenter 1994). However, at that time there were no formal recommendations about nutrition and diet from the government and very little understanding of what nutrients were required for health and in what quantities.

In the second decade of this century, USDA issued the first of many bulletins about nutrition. This first bulletin contained recommendations for feeding infants (Welsh 1994). It was at this time that the essential nutrients were beginning to be discovered. But for a long time, our understanding of nutrient requirements was based in large part upon the effects they had on growth or other rather nonspecific indicators of adequacy.

When the first RDAs were produced during World War II, it was in an atmosphere of food shortages, restrictions and rationing. Although it was clearly recognized that healthy eating was important for both the civilian and military populations, it also was clear that healthy eating was more difficult when food choices were limited. Thus, it was important to define, insofar as possible, the minimum requirements for nutrients to assess the adequacy of diets. Interestingly, describing minimum nutritional requirements was also of importance as we began to have to feed prisoners of war. It

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was recognized that we were morally obligated to feed prisoners enough to meet their needs for health, but there was no desire to feed them any more than that when food supplies for our own military and civilian populations were limited (G. Combs, Sr., personal communication).

Today, food security continues to be recognized as a component of national security, but there is also a greater understanding than there was 50 years ago that it is not enough to have sufficient food with enough calories and protein, but that we need to have good food. That is, food needs to be nutritious. We have also come a long way from the days of being mainly concerned about preventing deficiency diseases. Instead, new knowledge about the functions of nutrients at the biochemical, physiological, and genetic levels has led to ever-heightening interest in defining health, provide for excellent physiological and mental function and to prevent, as much as possible, the development of disease. Although our knowledge about nutrient functions has increased, it is clear to nutritionists that we are not yet where physicists thought they were at the beginning of this century when they thought they had solved all the problems of physics and all the important work had been done.

As we address the problem of how to determine nutrient requirements, we have multiple challenges before us. One is determining the kinds of endpoints that are appropriate to use in making dietary recommendations that will provide diets for optimizing health and function, and insofar as possible, preventing the development of not only the classic nutritional deficiency diseases, but also the chronic diseases that are now major causes of morbidity and mortality in this country.

The second challenge is to somehow integrate these recommendations into a framework that recognizes that we do not consume nutrients in isolation from one another, at least not as long as we are getting them from food. This is a problem that requires new approaches for optimizing multiple variables that can affect nutrient requirements. The current RDAs are mostly recommendations about single nutrients that recognize only in passing that other nutrients might affect the requirement for the one in question. There is an algorithm for estimating iron bioavailability that recognizes that consumption of meat or ascorbic acid can affect iron bioavailability, and hence, dietary requirements. We recognize that calcium and phytate may affect zinc bioavailability. Yet even these algorithms are not 100% reliable in telling us what happens when someone consumes a particular diet. At one time or another, all of us have studied interactions of nutrients, yet our dietary recommendations do not take these interactions into account, for the most part.

I believe we need to take a systems approach to planning our research and to developing recommendations for nutrient intakes. Systems research is an area that is new to most nutritionists. Generally, systems research or systems engineering takes a very broad, holistic and systematic approach to solving problems. An agricultural metaphor can be used to explain what it involves. Traditionally, agricultural researchers have been organized by disciplinary boundaries to solve problems. That means we have had plant breeders developing new varieties of a crop, plant pathologists studying how to control diseases in the crop, entomologists looking for ways to control insect problems, agricultural engineers developing recommendations for irrigation protocols and agronomists working out the optimal fertilizer and tillage practices and making recommendations about crop rotation. The economists who might be able to say if a farmer could make a profit by following the recommendations of these scientists are usually left out entirely. The farmer who is to benefit from the knowledge gained by all this research becomes understandably frustrated. Using a systems approach, we stop looking at narrow problems in entomology or plant genetics and take an integrated approach using all the disciplines and components of the cropping system to solve the problem of developing a profitable approach to growing a crop that will also meet all the regulatory requirements relating to erosion control, pesticide use and the like.

The same approach can be taken to solve nutritional problems. A model needs to be developed for making dietary recommendations or assessing the nutrient adequacy of diets that takes into account that most people get most of their nutrients from food, although some take some kind of supplements. Foods are complex mixtures of nutrients and non-nutrients, many of which have biological activity of one sort or another. Because people do not generally consume single nutrients in isolation from others, we should not be making dietary recommendations for single nutrients that do not take into account intakes of other nutrients and food components. I suspect our current recommendations focused on individual nutrients have fostered the consumption of nutritional supplements. "Designer" foods and increasing fortification and supplementation of foods also complicate the picture. For example, several years ago, orange juice was not a major source of dietary calcium; now for some people, it can be.

We need to include in our model the existence of homeostatic mechanisms that regulate the uptake and loss of many, though not all, nutrients. This is possibly one reason that rules of thumb like the Ca:phytate:Zn ratio do not accurately describe the effects of some diets on those who eat them. If our algorithm cannot take into account the likely effect of phytate on increasing endogenous excretion of zinc (Flanagan 1984), as well as the inhibition of zinc absorption by calcium and or phytate, we are not going to be able to predict if a diet is really adequate in zinc. This situation is further complicated by the fact that absorption and endogenous losses of zinc are both affected by dietary zinc.
intake, but to different degrees (Taylor et al. 1991), and by meal composition (Mataseshe et al. 1980). Furthermore, other nutrients and nonnutrients also affect zinc metabolism, so a model needs to account for all the possible interactions and to assign them appropriate weighting factors. An ideal model will account for all these sorts of factors for each nutrient. As we develop such a model, we will inevitably discover instances where there are gaps in the data, and knowledge of those gaps will be useful in planning research.

Finally, as the U.S. population becomes less homogeneous and as our awareness of genetic variability in the population increases, it seems clear that we need somehow to take into account differences in metabolism that are influenced by race and other genetic factors. It has often been observed that Black Americans have lower hemoglobin values than whites, and a recent article proposed using race-specific criteria to screen for iron deficiency (Johnson-Spear and Yip 1994). We know too, for example, that average bone density varies with race (Consensus Development Panel 1984, Farmer et al. 1984). How much of this variation depends on diet and how much depends on race is not entirely clear. However, as dietary recommendations are made that will provide for the health of our entire population, consideration should be given to major factors, such as race, in addition to sex, age, and reproductive status, that may affect nutritional needs.

All of these challenges will require us to embrace mathematics. Few life scientists are well-trained in mathematics, and many are highly uncomfortable with it. Nevertheless, it seems clear that mathematical tools are available for developing models incorporating the multiple interactions of nutrients, the homeostatic controls on some nutrients, and the population variability in how people utilize the nutrients they consume. Although this will take us beyond the kinetic models that many of us are familiar with, these more advanced mathematical models could lead to decision support systems for evaluating the nutritional adequacy of entire diets. Such systems would allow the public to make knowledgeable decisions regarding their choices for foods capable of providing the nutrients needed to ensure health and optimize performance, which is the goal for establishing nutrient requirements and making dietary recommendations.

**LITERATURE CITED**


