Bioavailability Algorithms in Setting Recommended Dietary Allowances: Lessons from Iron, Applications to Zinc

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ABSTRACT In addition to determining the amounts of isolated nutrients required for physiological function and homeostatic control, setting Recommended Dietary Allowances requires a consideration of nutrient bioavailability from foods in common diets. Bioavailability algorithms, or mathematical models to estimate nutrient bioavailability from different diets, have great appeal to help establish recommended intakes and identify beneficial dietary modifications. Accurate algorithms are difficult to develop because of the chemical complexity of the food supply and the numerous interactions that affect the bioavailability of mineral elements. A combination of reductionist and holistic approaches is necessary to identify the effects of isolated dietary components, and then to evaluate these effects in the complicated matrix of a whole diet. The most extensive development of bioavailability algorithms for mineral nutrients has been for iron, and understanding the strengths and weaknesses of the iron algorithms may help in development of algorithms for other inorganic nutrients such as zinc. Examples are provided to indicate the possible revision of iron bioavailability algorithms, the difficulty of verifying the iron bioavailability algorithms with iron status indices, and the possible development of zinc bioavailability algorithms. Bioavailability must be considered in the context of the biological control of mineral absorption, utilization and excretion, which may outweigh the importance of mineral bioavailability from diets in affluent countries with a varied and abundant food supply. While bioavailability algorithms may be helpful in estimating the effects of dietary changes or recommendations, and in improving diets of populations with a high incidence of deficiency of the mineral, they are not as yet sufficiently developed and validated for setting quantitative recommendations for "bioavailable" mineral intake. J. Nutr. 126: 2345S-2353S, 1996.

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• bioavailability algorithms

Bioavailability is the proportion of a nutrient in food which is absorbed and utilized [O'Dell 1984]. Recommended Dietary Allowances (RDAs) require consideration of nutrient bioavailability from foods in common diets, in addition to determining physiological requirements for isolated nutrients. Two key questions [Food and Nutrition Board; Institute of Medicine 1994] concerning revision of the Recommended Dietary Allowances for minerals are as follows:

[1] Is knowledge of relationships among nutrients sufficient to consider when establishing the RDAs?
[2] Are available data sufficient to permit the use of bioavailability algorithms in establishing the RDAs?

Bioavailability algorithms, or mathematical models to estimate nutrient bioavailability from different diets, have great appeal because of the potential to apply general principles to a complex dietary matrix, increase predictability without direct measurement of absorption and retention, and facilitate dietary assessments and recommendations. Useful algorithms require regular revision and refinement to incorporate new research data. Some of the challenges of developing bioavailability algorithms include applying the results of controlled, reductionist experimental observations.
Iron bioavailability algorithms derived from short-term studies of absorption

Iron bioavailability has been extensively studied in humans, by using isotopic tracers to determine absorption from test meals. An algorithm for estimating iron bioavailability published by Monsen et al. [1978] was well accepted and cited in the 1980 and 1989 editions of the RDA. This algorithm (Table 1) considered the inverse relationship between iron stores and iron absorption, and three dietary factors enhancing iron absorption: (1) the heme form of iron found in meat, fish and poultry, and the enhancement of nonheme iron absorption by (2) ascorbic acid and by (3) unidentified factors in meat, fish and poultry.

Of course, a primary challenge in developing algorithms to evaluate whole diets is the inclusion of all relevant variables. Additional research on iron bioavailability supports revision of the 1978 iron bioavailability algorithm [Monsen et al. 1978] to include several inhibitors of iron absorption. Cook et al. [1991a] included both enhancers (meat and ascorbate) and inhibitors (tea, coffee, whole grains and eggs) of nonheme iron absorption in an iron bioavailability scoring system. Calcium is an additional factor inhibiting iron absorption in common diets which should be included in algorithm revisions [Cook et al. 1991b, Dawson-Hughes et al. 1986, Gleerup et al. 1995, Hallberg et al. 1991, Hallberg et al. 1992, Monsen and Cook 1976]. The inclusion of enhancers but not inhibitors in the 1978 algorithm reflects the sequence of iron bioavailability investigations, rather than the relative importance of these dietary factors, and there is no reason to believe that all relevant dietary factors affecting iron bioavailability have been discovered.

Ideally, bioavailability algorithms would use continuous dose-response functions. Monsen and Balintfy [1982] modified the 1978 iron bioavailability algorithm, using a continuous logarithmic function to relate the sum of enhancing factors to nonheme iron bioavailability (within a specified range of 3–8% nonheme iron absorption for persons with 500 mg body iron stores). This approach allows greater application of an algorithm to varied diets and food quantities, and facilitates computer estimation of bioavailable iron. Continuous functions have the advantage of avertting generalizations based on standard serving sizes of food (iron absorption does not follow stepwise functions related to the nearest ounce of meat or cup of tea). However, extensive dose-response data are required to obtain accurate continuous functions, and such functions may have the disadvantage of implying a higher degree of predictive accuracy than is justified. Certainly, continuous functions in algorithms must be confined to specified ranges that limit extrapolation. Computerized approaches to decision making may help in the future development of bioavailability algorithms that consider continuous, nonlinear relationships and complex interactions.

Another consideration in the development of bioavailability algorithms is the influence of various basal conditions, or the background dietary matrix. Ascorbic acid enhancement of nonheme iron follows a continuous logarithmic function up to quantities as high as 1000 mg ascorbic acid [Cook and Monsen 1977, Hallberg et al. 1986]. However, the slope of this logarithmic function depends on the type of meal, the enhancement being greater with semisynthetic meals, maize porridge, or Latin American (maize, rice and beans) meals than with hamburger (with potatoes, string beans and tossed salad) or breakfast (refined wheat roll with marmalade, cheese, and coffee) meals [Fig. 1] [Hallberg et al. 1986]. While the addition of 100 mg ascorbic acid results in a fourfold enhancement of nonheme iron absorption from a semisynthetic meal, the 1.7-fold enhancement associated with a meal of hamburger, potatoes, peaches and ice-milk [Cook and Monsen 1977]
FIGURE 1 The enhancement of nonheme iron absorption by ascorbic acid varies with the basal meal characteristics; the relationship between the amount of ascorbic acid added and the ratio of the absorption of nonheme iron when different meals are given with or without ascorbic acid (Hallberg et al. 1986).

...may be more generally applicable to U.S. diets. This interaction between an enhancer and the background diet raises a significant concern about development of algorithms based on highly reductionist experimental conditions with single variables.

Another challenge of applying reductionist experimental conditions to algorithms for whole diets is the appropriate interpretation of experimental comparisons. How do results from deletion or addition of the experimental dietary variable compare with results from substitution with other foods? What comparisons are most likely with common diets? Should comparisons be isocaloric? Isonitrogenous? Identical in total iron content? As an example, beef and other meats have been designated as enhancers of nonheme iron absorption in bioavailability algorithms. When isonitrogenously substituted for other proteins, the degree of enhancement depended on the other components of the meal: beef enhanced nonheme iron absorption ~ threefold with cornmeal [Hurrell et al. 1988], twofold with a hamburger sandwich and milkshake [Reddy and Cook 1991], and showed no enhancement with Egyptian baladi wheat bread [Hurrell et al. 1988][Table 2]. Revised iron bioavailability algorithms should perhaps indicate a more modest enhancement of nonheme iron absorption by meat, fish and poultry, and an inhibition by protein sources such as egg albumin, whole egg, milk and cheese [Cook and Monsen 1976].

Absorption of nonheme iron varies by at least 15-fold with iron status [Lynch et al. 1989], a difference much greater than most differences related to dietary iron bioavailability. The 1978 iron bioavailability algorithm suggests an interaction between dietary bioavailability and iron status, which indicates greater enhancement of nonheme iron by enhancers (ascorbic acid and meat, fish and poultry) when iron stores are low (fourfold enhancement) than when they are high (twofold enhancement) [Table 1]. Although such a hypothesized interaction is attractive because it implies a greater range of absorptive control, the experimental data suggest that the relative influence of dietary factors is independent of, and substantially less than the influence of iron stores on nonheme iron absorption. For instance, in a study using a standard hamburger-and-potatoes meal [Cook and Monsen 1977], nonheme iron absorption between individuals varied by eight-to tenfold, and was inversely related to iron status, with or without ascorbic acid [Fig. 2, using data from Cook and Monsen 1977]. The addition of 100 mg ascorbic acid enhanced nonheme iron absorption from this meal by an average of 1.7-fold, a ratio that was relatively constant across a range of iron status, as indicated by serum ferritin [Fig. 2] [Cook and Monsen 1977]. Similarly, no interaction between iron status and the degree of dietary enhancement of nonheme iron absorption is detectable with the use of several other data sets from Cook and Monsen 1976 and 1977], who carefully documented serum ferritin and absorption results of individual subjects. While absolute differences in nonheme iron absorbed (with enhancer minus without enhancer) are greater with low iron stores, the ratio of enhancement (with enhancer to without enhancer) does not vary with iron stores.

To summarize, any revision of the 1978 iron bioavailability algorithm should (1) include dietary factors known to inhibit nonheme iron absorption, including phytic acid from whole grains, egg, calcium from dairy products or fortification, and tannins or other polyphenols from tea and coffee, (2) reduce the degree of enhancement or inhibition of nonheme iron absorption by basing recommendations on results obtained by using test meals that are most similar to common diets, (3) attempt to employ continuous functions within a specified range of intake, and (4) replace any suggested...
interaction between iron status and enhancement of nonheme iron absorption with a relatively constant degree of enhancement/inhibition across a wide range of iron status. Unfortunately, such revision of the algorithm based on short-term research with radiolabeled meals will not resolve a larger difficulty in applying this algorithm: lack of verification of the algorithm with long-term indices of iron status.

Limited effect of iron bioavailability in prospective studies of iron status

A study by Cook et al. (1984) was the first to highlight the difficulty of verifying iron bioavailability results from isotopically labeled meals with results using clinical indices of iron status. Supplementation with 2000 mg ascorbic acid daily with meals did not affect serum ferritin after 16 wk (20 mo in 9 subjects) (Cook et al. 1984). The enhancement of iron absorption with ascorbic acid added to single meals was demonstrated with the subjects at the beginning and the end of the 16-wk supplementation, indicating that there was no adaptation to the enhancement of ascorbic acid with continuing supplementation. Although absorption both with and without ascorbic acid was reduced ~25% (a difference which was not statistically significant) at the end of supplementation in comparison to the beginning of supplementation, this reduction only partially explained the lack of response in serum ferritin. Two additional studies replicated this negative finding: 300 mg ascorbic acid daily with meals did not affect serum ferritin after 8 wk (Malone et al. 1986), and 300 mg ascorbic acid daily with meals did not affect serum ferritin of menstruating women after 9 mo (Monsen et al. 1991). These studies suggest that the substantial changes in dietary bioavailability observed in single meals may have minimal influence in relation to homestatic control of iron stores.

Iron bioavailability algorithms may be most applicable to groups at the extremes of iron status where biological adaptation may be maximized. In women recovering from phlebotomy who were fed controlled diets with predicted poor iron bioavailability, ascorbic acid supplementation (1500 mg daily with meals for 5 wk) improved both apparent iron absorption (balance method) and several indices of iron status, including hemoglobin, erythrocyte protoporphyrin and serum iron, but not serum ferritin (Hunt et al. 1990). However, in a similar controlled study of women with low iron stores (serum ferritin <18 μg/L) without anemia, ascorbic acid supplementation had minimal or no effect on iron status indices or on apparent iron absorption [balance method] (Hunt et al. 1994). Ascorbic acid [50, 100 or 150 mg daily with meals for 8 wk] significantly improved serum ferritin, hemoglobin, hematocrit and erythrocyte protoporphyrin in a placebo-controlled study of anemic Chinese children with low dietary ascorbic acid (who also showed a very large placebo effect) (Mao and Yao 1992).
Serum ferritin results have also failed to confirm enhancement or inhibition of iron bioavailability by other dietary variables found to be influential using isotopically labeled meals. Calcium, 500 mg daily as calcium carbonate with meals, did not affect serum ferritin after 12 wk (Sokoll and Dawson-Hughes 1992).

Meat, fish, and poultry, with an estimated 40% of iron in the heme form, are perhaps the most likely foods to influence iron status. While the biological control of nonheme iron absorption varies 15- to 20-fold, the control of heme iron absorption varies only 3-fold, from ~45 to 15% absorption across the same range of ferritin values (Lynch et al. 1989).

We have conducted two studies of controlled meat intake with minimal blood removal to test the influence of meat intake on serum ferritin. In the first study, a high meat diet, containing 10 oz meat daily from beef, pork, chicken, and fish was compared with low meat diets containing 1.5 oz meat daily with or without mineral supplements to reduce the meat content from the high to the low meat diets, simple carbohydrates were isocalorically substituted for meat protein and vegetable fats were isocalorically substituted for meat fat. In comparison to the low meat diets, the high meat diet unexpectedly reduced serum ferritin and increased iron-binding capacity (both variables changed ~10%, within a normal range) after 7 wk, in postmenopausal women who served as their own controls under metabolic diet conditions (Hunt et al. 1995). In the second controlled study of meat intake, serum ferritin of women of childbearing age was not affected in a comparison of a high fiber, lacto-ovo-vegetarian diet vs. a nonvegetarian diet containing 6 oz meat daily as beef and chicken, with each diet consumed under controlled conditions for 8 wk. This negative result occurred despite a threefold reduction in nonheme iron absorption determined during the same study by isotopic labeling of the diets, and a fivefold reduction in calculated absorption of total heme plus nonheme iron (Hunt, unpublished data).

Thus, controlled studies suggest that the effect of dietary iron bioavailability on iron status, as indicated by serum ferritin, is quite limited. Dietary iron bioavailability may be most influential in those with iron deficiency, such as the women of childbearing age recovering from phlebotomy (Hunt et al. 1990) or the Chinese children with iron-deficiency anemia and limited diets (Mao and Yao 1992). The apparent discrepancy between isotopic absorption results and iron status raises doubts about the usefulness of bioavailability algorithms to evaluate differences in diets of Western countries with low rates of iron deficiency anemia.

**Descriptive associations of dietary iron bioavailability with iron status**

A concern about the results of prospective experiments to evaluate the influence of bioavailability on iron status is the short-term nature of such experiments. To evaluate whether iron bioavailability may have a more gradual, long-term effect on iron stores across a full range of iron status, it is useful to examine possible associations in large surveys. Unfortunately, the trade-off for examining long-term effects using survey data is loss of experimental controls, especially the accurate determination of long-term dietary variables. In addition, survey literature may tend to report only significant associations, especially those that confirm the short-term absorption studies.

In a Finnish survey of 7000 persons completing a dietary history interview, men and women with low iron status (low hemoglobin or elevated iron binding capacity) generally had reduced meat consumption, and women with low iron status had greater milk consumption (Takkunen and Seppanen 1975). Ferritin was not measured. Absorbable iron was estimated in the same study by applying a mean percentage absorption of iron from each of 16 food groups. Men and women with low hemoglobin or elevated iron binding capacity consumed less absorbable iron using this model.

Neither available dietary iron, estimated using the 1978 algorithm, nor total dietary iron were associated with hemoglobin or transferrin saturation in the first National Health and Nutrition Examination Survey (NHANES-I), except in young children (Singer et al. 1982). Dietary intakes in NHANES-I were determined by 24-h recall, and the extensive limitations of this method may account for this negative finding. Serum ferritin was not determined in NHANES-I; however, the possibility that dietary iron bioavailability is most influential in persons with iron deficiency anemia suggests that hemoglobin was an appropriate variable for comparison.

Meat consumption determined from a 4-d food record was weakly correlated ($r^2 = 0.032$, $P < 0.01$) with serum ferritin in 1931 Finnish men (Salonen et al. 1992). The frequency of meat consumption was associated with serum ferritin in 643 female ($r^2 = 0.062$, $P < 0.01$), but not in 724 male, Australian bankers after accounting for age and the frequency of blood donation (Leggett et al. 1990). In a study of 867 Swedish adolescents, employing a 7-d food record for dietary assessment, the risk of a low serum ferritin ($<12 \mu g/L$) was not associated with intake of total iron, fiber, calcium, phosphorus, or vitamin C (Bergstrom et al. 1995). Low intakes of iron from foods categorized as meat/fish/egg increased the risk of low serum ferritin in females but not males (Bergstrom et al. 1995).

Finally, a report from China emphasizes the difficulties of interpretation of, and the possibilities for confounding of, epidemiological associations between dietary and biological variables. Cervical cancer mortality rates in 2392 counties in China were associated with higher ferritin ($r^2 = 0.11$), but lower consumption of animal foods (times/y) ($r^2 = 0.16$) and of meat ($r^2 =$...
0.18), a finding likely confounded by financial status [Guo et al. 1994].

In summary, meat consumption was positively related to iron status in four large studies (Bergstrom et al. 1995, Leggett et al. 1990, Salonen et al. 1992, Takkunen and Seppanen 1975), the relationship occurred only in women and not in men in two of those studies (Bergstrom et al. 1995, Leggett et al. 1990), did not occur in one other large study (Singer et al. 1982), and an inverse relationship was suggested in another large study (Guo et al. 1994). In studies presenting regression analyses to predict ferritin, positive associations with meat intake accounted for only 3–6% of the total variance in serum ferritin [Leggett et al. 1990, Salonen et al. 1992].

Application of iron bioavailability algorithms to setting the RDA

The text accompanying the 1980 edition of the Recommended Dietary Allowances recommended 1.8 mg of absorbable iron [using the Monsen (1988) algorithm] for adult women, independent of total dietary iron. This quantitative application of an algorithm was appropriately discontinued in the 1989 edition. Continuing research has indicated that such algorithms may be useful in attempting to summarize the relative influence of several dietary factors on iron absorption. However, it is unlikely that all influential dietary factors have been identified and elucidated, or that algorithms based on current research can be quantitatively applied to a variety of whole diets with accuracy. Furthermore, the long-term validation of bioavailability algorithms against indices of iron status is lacking. This is especially true in Western populations with a low risk of iron deficiency anemia. In U.S. diets, iron is generally highly bioavailable, and small differences in bioavailability are likely to be overshadowed by absorption differences reflecting biological control of body iron stores. While algorithms may be useful in suggesting the relative influence of dietary changes, such as changing consumption of meat, dairy products or whole grains, they are not sufficiently predictive to be useful in quantitative recommendations of intake.

Zinc bioavailability and possible application of algorithms

Although there has been considerably less research on zinc, compared with iron bioavailability, the existing data and the potential importance of zinc bioavailability in human diets make zinc a likely candidate for development of bioavailability algorithms. The proportion of phytic acid to zinc in whole diets has been proposed as an index of dietary zinc bioavailability [Ellis et al. 1987, Oberleas and Prasad 1975], with the suggestion that a phytate:zinc molar ratio >10 or a phytate × calcium:zinc millimolar ratio > 200 would be associated with poor zinc bioavailability in human diets [Ellis et al. 1987]. Data from animals suggest that these are not stepwise relationships, but continuous nonlinear relationships [Fordyce et al. 1987]; however, there are insufficient data to further define the relationship in humans. Attempts to validate these proposed phytate:zinc and phytate × calcium:zinc ratios have generally been positive. A study indicating no difference in zinc balance or plasma zinc of men fed controlled diets with phytate:zinc molar ratios of 1 or 10 can probably be attributed to the relative insensitivity of these methods [Morris and Ellis 1983]. With more sensitive measurements using isotopic tracers, zinc absorption was reduced ~50%, and urinary zinc excretion was also reduced when sodium phytate was added to a formula diet, raising the phytate:zinc molar ratio from 0 to 15 and the phytate × calcium:zinc millimolar ratio from 0 to 308 [Turnland et al. 1984]. Serum zinc concentration was unaffected [Turnland et al. 1984]. In a recent study, 11 adult women consuming controlled vegetarian and nonvegetarian diets absorbed 26 and 33% [P < 0.01] of the 9.1 and 11.1 mg zinc in these diets, respectively, which had phytate:zinc molar ratios of 5 and 18, and phytate × calcium:zinc millimolar ratios of 119 and 437 [Hunt, unpublished observations]. In a crossover design study, plasma zinc of these women was significantly less after 8 wk consuming the vegetarian diet than after the same length of time consuming the nonvegetarian control diet [Hunt, unpublished observations].

Whole grain products with considerable phytic acid contain substantial amounts of zinc, thus the practical influence of phytic acid on total zinc absorbed is generally less than the influence on absorptive efficiency. Consequently, although percentage zinc absorption was considerably greater from white bread without added zinc than from whole meal bread, the amount absorbed was greater from whole meal bread (Table 3) [Sandström et al. 1980]. As another example, phytate:zinc molar ratios of 20, in comparison to 0, reduced zinc absorption from single meals by ~40%, but reduced the amount absorbed by a more modest 10%, because of the higher zinc content of the high phytate-containing meal [Couzy et al. 1993].
Zinc absorption from single meals has been generally better when phytate:zinc molar ratios were <10 [Cousy et al. 1993, Hunt et al. 1991, Sandström et al. 1987], but the meal protein and zinc content were additional important factors influencing absorption [Sandström et al. 1980]. With more zinc in a meal, the percentage of zinc absorption was reduced, moderating the increase in the absolute amount of zinc absorbed [Sandström et al. 1980] (Table 3). Added protein enhanced zinc absorption from meals with low or high contents of phytic acid [Hunt et al. 1991] and appeared to counteract the negative effect of phytic acid in whole meal bread, even when the protein source was also a source of calcium [Sandström et al. 1980] (Table 3).

Algorithms for estimating dietary zinc bioavailability will have to include the effects of, and the interactions between phytic acid, protein, and the amount of zinc in the diet, preferably describing continuous relationships among these variables. Additional research is required to further define the influence of other elements such as calcium, iron and copper on zinc absorption and utilization by humans. Again, caution is necessary when applying conclusions from reductionist experiments to whole diets. Algorithms based on experimental data defining the effects of single variables are unlikely to be accurate without including interactions. For instance, the enhancing effect of dietary protein on zinc absorption when zinc intake is controlled may be relatively unimportant in common diets, because the protein and zinc content of foods are highly correlated. When the zinc content was allowed to vary naturally with high and low amounts of meat in controlled diets, the percentage of zinc absorbed from the diets was similar, making the quantity of zinc in the diets (which were low in phytate and fiber) much more influential than zinc bioavailability [Hunt et al. 1995]. However, protein sources with a higher ratio of protein:zinc may provide greater enhancement of zinc absorption [Sandström et al. 1989]. Protein may also be an important factor predicting zinc bioavailability in three-way interactions among phytate, protein, and zinc, influencing the solubility of zinc in the intestinal lumen. Such complex interactions have not been adequately investigated to formulate quantitatively accurate algorithms that would be useful in setting Recommended Dietary Allowances for zinc.

Rather than using algorithms for zinc bioavailability at this time, zinc recommendations should use absorption estimates based on isotopic labeling measurements of zinc absorption from diets and meals typical of those in the U.S. The previous RDA for zinc was based on an assumption of 20% absorptive efficiency, set to include a generous safety factor and to take into account the lower absorption of zinc from fiber-rich diets. Sandström (1995) has estimated zinc absorptive efficiency of 30–40% from refined diets containing animal protein, 20–30% from mixed diets or vegetarian diets containing a moderate amount of unrefined cereals, and <15% from diets with negligible animal protein and the majority of total energy from phytate-rich foods. In controlled feeding studies of zinc absorption from whole diets, we have observed 29% zinc absorption by women and 22% by men from foods that had been designated to represent U.S. diets in the FDA Total Diet Study [Hunt et al. 1992]; 28 and 30% zinc absorption by postmenopausal women from refined diets containing high [10 oz] or low [1.5 oz] amounts of meat, respectively [Hunt et al. 1995]; and 26 vs. 33% zinc absorption by premenopausal women from a lacto-ovo-vegetarian diet, compared with a non-vegetarian control diet containing ~6 oz meat and one third as much fiber and phytate, respectively [Hunt, unpublished observations]. Zinc absorption from a typical hamburger meal with French fried potatoes and milk shake was 24% [Gallaher et al. 1988].

The above data suggest typical zinc absorption of 25–30% from U.S. diets. It follows that the 20% absorptive efficiency used to derive the current RDA provides an adequate to excessive safety factor. Use of the factorial method together with estimation of typical zinc absorption has resulted in an RDA for zinc that is frequently not achieved in common U.S. diets. Considerably lower zinc recommendations have been made in Canada [12 mg for adult males and 9 mg for adult females] [Health and Welfare Canada Scientific Review Committee 1990] and the UK [9.5 mg for adult males and 7 mg for adult females] [Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Policy 1991]. Unfortunately, the lack of sensitive and specific indicators of zinc status severely limits the evaluation of human zinc requirements and of the importance of zinc bioavailability in Western diets.

Conclusions: application of bioavailability algorithms

The biological control of mineral absorption, utilization and excretion may outweigh the importance of mineral bioavailability from diets in affluent countries with a varied and abundant food supply. Until further verification with nutrient status indices (preferably functional indices), applications of mineral bioavailability algorithms may be limited. With verification, algorithms may be most applicable to populations at risk of nutrient deficiencies or excesses. Algorithms may be helpful in estimating the effects of dietary changes or recommendations, but are not sufficiently validated for setting quantitative recommendations for “bioavailable” mineral intake. In affluent countries, emphasis should be on a variety of foods, without over-concern about food combinations. Revision of the Recommended Dietary Allowances should be based on estimates of typical mineral absorption, with adjustments for cases in which there is sufficient data to indicate different absorption and nutrient status with
specific kinds of diets. Continued research is needed to further elucidate dietary factors and interactions affecting bioavailability. For application to U.S. diets, special attention should be given to the influence of dietary changes, such as the recommended increased consumption of grains, legumes, fruits and vegetables or changes in food fortification and supplementation practices.

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