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Biological availability of minerals and trace elements: a nutritional overview[1,2]

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Nutritional knowledge concerning many of the essential minerals has lagged behind that for proteins, fats, carbohydrates, and vitamins, and the state-of-the science in respect to decisions on requirements and replacement therapy is similarly evolving. The Recommended Dietary Allowances (RDA) has contained a specification for a daily intake of calcium since 1943 (1); since 1974, the RDA committee has detailed daily recommendations for zinc (2); in the 1980 edition, safe and adequate levels of intake for copper as well as chromium, selenium, manganese, and molybdenum were first specified by the Food and Nutrition Board (3).

Many groups of the United States population showed a decrease in calcium consumption in the last United States Food Consumption Survey (4). It has been shown that many self-selected diets consumed in the United States do not provide recommended quantities of zinc (5–9). The limited data available suggest that the consumption of copper in many United States diets is below the RDA estimation of a safe and adequate level (5, 6). The average British diet provides about 60 μg of selenium daily (10). Regular, meat-based hospital diets in the United States were found to contain 85 μg/day (11). These are both at the lower range of the "estimated safe and adequate" daily intake for selenium established by the RDA (3).

An important factor in determining the adequacy of intake of minerals is the efficiency of their absoprtion from different types of meals, different foodstuffs, and under various conditions of health and physiological status. The biological availability is influenced by factors intrinsic to the foods as well as by host factors.

A Symposium on the Bioavailability of Minerals and Trace Elements was held on Saturday, April 25, 1981 under the auspices of the American Society for Clinical Nutrition as part of its annual meeting in San Francisco. Its purpose was to review the current knowledge about factors affecting the biological availability of important mineral nutrients in our diet.

A number of general considerations in intestinal physiology can be brought to the analysis of the absorption of minerals from foods. Factors that might influence the bioavailability of mineral nutrients from food can be divided roughly into those which influence behavior in the intestinal lumen (**Table 1**) and those which occur at the level of the intestinal cell or cell membrane (**Table 2**). In formulating this scheme, the knowledge of factors influencing iron absorption was steadily in view. The "iron standard" of knowledge on mineral bioavailability remains the goal toward which investigators of bioavailability of other minerals continue to strive.

In the lumen, the intrinsic form of the metal or mineral in respect to valence, and the nature of organo-metallic complexes may substantially influence absorption. The pH in the intestinal lumen, determined by gastric, pancreatic and intestinal secretions, may also exert a potent effect on bioavailability. Examples of such influences are seen in the behavior of iron, zinc, and chromium salts. Interactions with exogenous or endogenous macromolecules as well as other nutrients must be part of the analysis of mineral bioavailability. The interactions of proteins, peptides, fatty acids with calcium and zinc are examples of these influences.

At the level of the enterocyte, we observe

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TABLE 1
Intraluminal factors affecting bioavailability of minerals in the intestinal lumen

1. The chemical form of the metal/mineral
Inorganic salts
Valence
Organo-metallic compounds
Covalent complexes
Non-covalent complexes
2. Interactions in the lumen with:
Proteins, peptides, amino acids
Triglycerides, fatty acids
Carbohydrates
Monosaccharides
Disaccharides
Polysaccharides (including fiber)
Anions and anionic substances
Other metals/minerals

TABLE 2
Intra- and Postcellular Factors Affecting Bioavailability of Minerals

At the intestinal membrane
1. Competition for transport
2. "Coadaptation"
Intracelluar binding
Release and transport from the enterocyte
1. Circulating binding proteins
2. Endogenous mediators

competition for specific transport "channels" between trace metals. This sharing of transport systems may be represented also as enhanced transport of a second trace metal as a reflection of an adaptive increase in transport efficiency of another. The improved absorption of lead or cobalt in the face of enhanced iron absorption in iron-depleted subjects is exemplary.

Many, if not all metals, undergo specific binding to macromolecules within the enterocyte. Some of these intracellular binders or proteins such as metallothionein have a spectrum of affinities for metals which may influence the efficiency of uptake as well as transcellular movement. Further, the release of minerals from the cell may be influenced by circulating proteins or other endogenous organic molecules. The importance of such binders in the distribution and disposition of mineral nutrients is only now emerging.

For the symposium, we have chosen calcium, zinc, copper, and selenium as representative of macrominerals, trace metals, and trace elements. Important new information is emerging regarding the bioavailability of all these nutrients which illustrate many of the principles described above.

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