Trace Elements in Aging

Walter Mertz

Beltsville Human Nutrition Research Center, Agricultural Research Service, USDA, Beltsville, Maryland 20705, USA

Knowledge of mineral element status and requirements in older people is incomplete and, for most elements, derived by extrapolation from younger age groups. Yet some valid conclusions can be drawn on the basis of known age-related changes in body composition, in energy needs, and in food intake to meet these requirements. In the following discussion I shall first deal with iron, the requirement for which changes abruptly in women with menopause, and then I shall deal with other elements, according to their changes in concentration in the human body through life.

IRON

The requirement for iron is sharply reduced in postmenopausal women, and their iron nutrition is correspondingly improved (1). Iron has special nutritional interest because of the high incidence of iron deficiency worldwide in infants, children, adolescents, and women. Because the biological availability of dietary iron depends heavily on the composition of the diet eaten, dietary recommendations vary according to the nature of the national diet. An Expert Consultation of the Food and Agricultural Organization/World Health Organization (2) set a median requirement to prevent anemia in women of childbearing age at 17, 8, and 5.6 mg per day for diets of low, intermediate, and high iron bioavailability. These high recommendations, difficult to implement in all but high bioavailability diets, are sharply reduced in postmenopausal women, to 10, 6.5, and 3.4 mg, respectively. These amounts are easily obtained from almost all diets; consequently, iron status of postmenopausal women improves markedly. Because adult men generally have no problem in meeting their iron requirements, it can be stated that as a general rule iron status improves as people get older. Anemia in older individuals is rarely caused by iron deficiency; when it occurs, chronic blood loss or deficiency of folacin or vitamin B$_{12}$ should be looked for. Whether iron plays a substantial role in the aging process is not known. As is true for most essential elements, iron is required for normal functioning of the immune system; on the other hand, high iron stores in relation to levels of other essential elements have been implicated as risk factors in malnourished children (3), as well as in adults with hemochromatosis. Therefore, concern about the iron status

145
of older people should rather be with the avoidance of overexposure than with the prevention of deficiency.

OTHER TRACE ELEMENTS

For other trace elements, including fluorine, manganese, copper, zinc, selenium, molybdenum, and iodine, there is either direct knowledge that tissue concentrations remain steady during life or a lack of data suggesting consistent changes. Of these elements, all except manganese and molybdenum may present problems of nutritional deficiencies in some parts of the world, and these have led to corrective public health measures (4). It must be noted, however, that by far the greatest risk of deficiency for these elements is found during the early periods of life, including intrauterine development, rather than in old age. Dietary copper deficiency has been described only in children, growth retardation and dwarfism due to zinc deficiency between infancy and adolescence, Keshan disease in children and young pregnant women, and the deleterious effects of lack of fluorine on dental health only during the years during which the permanent teeth are formed. There is no information indicating similar deficiencies in older people.

PHYSIOLOGICAL REQUIREMENT FOR TRACE ELEMENTS DURING AGING

The trace element nutritional status of older people may be jeopardized by the decline in total food intake and by the decreasing efficiency of intestinal absorption, especially in areas where the concentration of essential elements in the diet and in the environment is marginal. On the other hand, the reduction in food intake is often accompanied by a reduction in lean body mass (5), resulting in physiological reduction in the pool size for trace elements. To maintain a reduced pool size requires a smaller intake than would be necessary to maintain a larger pool. The fact that there is no evidence for a substantial decline in tissue concentrations of the elements with age suggests that age per se does not jeopardize the trace element status. Neither does it protect against inadequate intakes of elements that are marginal at other ages. Therefore, the adequacy of selenium or iodine intake in the various low-selenium or low-iodine areas of the world, and the adequacy of copper and zinc intake from diets of predominant cereal origin, should remain a matter of concern, regardless of age.

IMMUNE FUNCTION

The physiological functions of elements such as copper, zinc, and iron deserve special study because of their relevance to aspects of the aging process. All three elements are essential for proper functioning of many components of immune defense
(6). Judging from animal experiments, the requirement to maintain optimal immune function appears to be greater than that needed for prevention of the other well established signs of deficiency (7). The function of the immune system is known to decline with age, but convincing data for a protective effect of supplementation with any one trace element in humans are still sparse.

Manganese, copper, zinc, and selenium, in addition, play essential roles in the antioxidant defense system through their function in superoxide dismutases and glutathione peroxidase (4). Since free-radical damage to cellular constituents has been hypothesized as one process responsible for aging, it could be postulated that a deficiency of any of these elements might hasten the aging process. There are, however, no solid data that would indicate a decline in the enzyme functions discussed above.

**TOXICITY OF TRACE ELEMENTS DURING AGING**

Although the organism has effective mechanisms protecting against accumulation of most essential elements, the protection is relatively weak against accumulation of the anionic forms in which fluorine, iodine, selenium, and molybdenum often occur. Toxic accumulation of all of these is known, reflecting excessive concentrations in the geochemical environment. Here again, the medical consequences are much more important for the young than for the older age groups.

Under conditions that might exist in many industrialized societies, three elements, fluorine, lead, and cadmium, are known to accumulate in human tissues with increasing age. Except for greatly excessive exposure, fluorine and lead are deposited in the bones and pose no particular health problem to the aging organism. Cadmium, on the other hand, accumulates predominantly in the kidney and has been connected with declining renal function (4).

The biological actions of arsenic and mercury depend on their chemical forms and on their interactions with the essential trace element selenium (4). Historically, it is well known that the slow accumulation of low doses of arsenic not only creates a tolerance against higher doses but is also claimed to confer increased physical performance in both man and animals. Arsenic toxicity is known only from criminal, accidental, or very occasionally environmental overexposure. An example of the first was the wide use of arsenic as a poison during the Middle Ages; of the second, the accidental use for human consumption of the arsenic-treated seeds in Iraq some years ago; and of the third, the consumption of drinking water contaminated with arsenic in Argentina, Chile, Mexico, and Taiwan (4). It is unlikely that under most normal circumstances arsenic presents a health problem specifically to the aging organism.

The toxicity of mercury depends strongly on its valency state and on its chemical form (4). A methylated form, methyl mercury, has a high affinity for the central nervous system and is very toxic. On the other hand, poorly defined forms, such as compounds of selenium and mercury, which occur in nature, are believed to be
TRACE ELEMENTS IN AGING

practically inert. Because many natural sources of dietary mercury contain the mercury–selenium combination, mercury is not believed to be an exceptional hazard to the aging organism. For this element, as with many others, it is important to judge toxicity not by simple analytical values but by data based on speciation.

CHROMIUM AND SILICON: POSSIBLE AGE-RELATED DEFICIENCY

Two essential elements, chromium and silicon, appear to decline with age in human tissues, although much more is known about chromium than about silicon. A thorough analytical study by Schroeder et al. demonstrated a gradual decline in chromium in human autopsy material from industrialized societies, although not in the lungs in which that element accumulates (8). Livers from diabetics contain less chromium than those from healthy subjects and aortas from patients who died from heart disease less than those of normal individuals. Chromium has been defined as a cofactor for the interaction of insulin with its tissue receptors; chromium deficiency in humans and experimental animals results in a relative insulin resistance that manifests itself by impaired glucose tolerance in the presence of normal or even increased insulin concentrations (4,9). It has been postulated that chromium deficiency contributes to the gradual decline in glucose tolerance with age in the great majority of people living in the United States. A safe and adequate range of dietary chromium intake has been recommended at between 50 and 200 μg per day (10); the minimum requirement for adults can be estimated at between 25 and 30 μg. This amount is not always furnished by typical Western-style diets, especially those high in refined products. Experimental diets furnishing between 15 and 20 μg per day to human volunteers with slightly impaired glucose tolerance have produced a progressive further impairment of glucose tolerance in the presence of gradually increasing serum insulin concentrations, changes that were reversed by daily supplementation with 200 μg of chromium (11). Because impaired glucose tolerance and raised circulating insulin levels are independent risk factors for cardiovascular disease (12), it is possible that chromium deficiency may be contributing a significant risk to that group of disorders. Although chromium deficiency has been described in malnourished children and in patients on low chromium total parenteral nutrition (4), the predominant public health importance of that element lies with the large number of older people with impaired glucose tolerance. Intervention studies on a large scale in older people promise to produce tangible benefits.

Much less is known about the biochemical role, metabolism, and requirement of silicon (4). Its essentiality for bone health has been established independently in rats and chickens. Both species develop gross bone deformities when raised on low silicon diets (1–7 μg/g), associated with abnormalities in the formation of cartilage and connective tissue in general. The requirement for the prevention of these signs may lie between 50 and 250 μg of soluble Si/g diet (4).

Silicon appears to decline with age in the aortas of human subjects, as well as in aortas affected by atherosclerosis (13). A requirement for man has not been estab-
lished; thus, it is not known whether the habitual intake from Western-type diets of 20 to 50 mg/day is adequate, or whether higher intakes might maintain tissue concentrations. In view of the role of silicon in bone formation and in connective tissue metabolism in general, its accumulation in the brain of patients with Alzheimer's disease, and its potential carcinogenicity in the form of special insoluble compounds such as asbestos, human studies of the metabolism, mode of action, and requirement of silicon are of high priority.

REFERENCES


DISCUSSION

Dr. Kritchevsky: Could you cite the data that now make arsenic essential?

Dr. Mertz: The data come from F.H. Nielsen in Grand Forks, North Dakota, who is working with chickens and rats and from Manfred Anke in Jena, Germany, who uses minipigs and goats. References in two good review articles by these authors are given below (1,2).

REFERENCES