Trace elements in nutrition of the elderly

1. Established RDAs for iron, zinc, and iodine

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Preview

The role of trace elements in human nutrition is only beginning to be understood, especially as it pertains to the elderly. These elements, each of which constitutes less than 0.01% of total-body weight, have diverse physiologic functions, a number of which could theoretically be influenced by the normal aging process.

Currently, 16 trace elements are thought to be biologically important in metabolism and nutrition. The Food and Nutrition Board of the National Research Council,has established a recommended daily allowance (RDA) for only three of these—iron, zinc, and iodine. These are discussed in the first part of this article. The second part, beginning on page 251, deals with trace elements for which the board has suggested a safe and adequate daily dietary intake (SADDI)—copper, manganese, selenium, chromium, molybdenum, and fluoride.

The trace elements represent one of the newest areas of nutritional inquiry. An understanding of their role in human nutrition has only begun to emerge during the past two decades. Our knowledge of the nutritional requirements of the elderly, in particular, is rudimentary. This article provides an overview of our present knowledge on this subject. The information presented here is complemented by several recent review articles concerning trace element nutriture in the elderly.[1-3] An obvious immediate research priority is a more precise definition of how advancing age influences the nutritional requirements for the various trace elements in humans.

Biologically important trace elements

The trace elements are those elements found in the human body in amounts that constitute less than 0.01% of total-body weight. For a 70-kg (154-lb) man, this represents 7 gm or less. Although any minor elemental constituent of the body is considered to be a trace element, only 16 are currently believed to have a biologically important role in metabolism and nutrition (table 1).

Well-defined deficiency syndromes in humans have been described for iron, zinc, iodine, copper, selenium, chromium, and molybdenum. Only suggestive evidence of human manganese deficiency has been presented, but no one seriously doubts its essentiality. Cobalt is an essential element, but only as a component of cobalamine (vitamin B_{12}). The remaining trace elements listed in table 1 have been shown to be essential to one or more mammalian species and, by extension, are probably essential to humans as well.

The likelihood exists that more elements will be found to be important to human nutrition. Natural foods, by virtue of their contact with sea or soil, are apt to contain trace quantities of most of the naturally occurring elements of the periodic table. Heavily processed, synthetic, or purified foods might omit some elements that are essential but so ubiquitous in nature that spontaneous deficiencies have not yet been observed.

Elements that are nutrients pose another potential issue—toxic overload. Unlike water-soluble vitamins and fuels, which can be oxidized or degraded, elemental nutrients cannot be converted to a more elemental state. Thus, the amount of total-body accumulation is dependent on the level of consumption, the efficiency of intestinal absorption, and the presence of readily accessible excretory pathways. Not only need we be concerned with

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Table 1. Trace elements with biologically important roles in mammalian metabolism and nutrition

Definitely essential	Probably essential
Iron	Vanadium
Zinc	Silicon
Iodine	Fluoride
Copper	Nickel
Manganese	Lithium*
Selenium	Tin*
Chromium	Arsenic*
Molybdenum	
Cobalt (as component of vitamin B_{12})	

*Evidence for essentiality in mammalian animals derived from a single research laboratory.

states of marginal depletion and clinical deficiency of the trace elements, but also with conditions of marginal overload and overt toxicity.[4] Iron, zinc, and copper can accumulate to a harmful total-body level with excessive dietary intake.

Functions of trace elements in human metabolism

Trace elements participate in human physiology in diverse ways. A dominant motif, however, is their role as the mineral components of metalloenzymes or metalloproteins. A metalloenzyme contains a fixed number of atoms of one or more minerals attached firmly to the protein at the active site or in a structural capacity; enzymatic activity is lost when the mineral is removed from the protein. Alkaline phosphatase, ceruloplasmin, and xanthine oxidase are metalloenzymes containing zinc, copper, and molybdenum, respectively. Hemoglobin and myoglobin are iron-containing metalloproteins.

Certain trace elements form part of nonprotein molecules. Iodine has its role in thyroid hormones. Chromium, in its chromic (Cr^{+++}) form, constitutes the core of glucose tolerance factor, a poorly characterized entity that assists the action of insulin at the cellular level.[5]

Finally, certain trace elements function in a soluble ionic form. These include zinc, which is known to stabilize polyribosomes and cellular membranes,[6] and manganese, which is believed to be a cofactor in several reactions involved in the formation of cartilage. Fluorine has its major role as fluoride, inserted in the crystal matrix of bone and the enamel of teeth.

Table 2. Factors in the physiology of aging that could affect trace element nutriture

Decreased energy output
Decreased lean-body mass
Increased relative fat mass
Relative glucose intolerance
Reduced renal function
Hypochlorhydria
Reduced small-intestine surface

Factors that affect trace mineral requirements of the elderly

A number of physiologic features of the normal aging process (table 2) could theoretically influence trace mineral requirements. Energy expenditure and total food intake are diminished in aging. For the intake of trace minerals to remain constant, therefore, their density in the diet must increase.

Aging is accompanied by a change in body composition, ie, a reduction in lean body mass and a relative increase in body fat. A true reduction in the need for nutrients related primarily to muscle metabolism, such as iron, may occur. The physiologic decrease in glucose tolerance that occurs with aging might

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The elderly are prone to chronic diseases that require medication, and both the disease process and drug-nutrient interactions may complicate trace element nutriture.

provoke changes in the retention of or the need for chromium. The decline in renal function with age might influence balance with respect to those trace minerals whose primary route of excretion is the kidneys.

Relative hypochlorhydria occurs with aging. Trace minerals that require a more acidic intraluminal milieu for maximal biologic availability may be more poorly absorbed in the elderly. Finally, senescent changes in intestinal mucosal surface area and digestive exocrine secretions could theoretically limit the efficiency of absorption of some trace minerals.

In addition to undergoing physiologic changes, the elderly are prone to a variety of chronic diseases and in many cases are taking a number of pharmacologic agents daily. Both the underlying disease processes and drug-nutrient interactions could further complicate trace element nutriture in this age-group.

Current recommendations of the Committee on Recommended Dietary Allowances

The Food and Nutrition Board of the National Research Council, through its Committee on Recommended Dietary Allowances, periodically publishes a monograph[7] defining the nutrient intake needed to cover the nutritional requirements of almost all of the healthy US population. The intake levels recommended by this Committee are often used as standards for evaluation of the adequacy of diets consumed by various groups and subgroups of the US population.

The Committee has two categories of intake recommendations: (1) recommended dietary allowance (RDA) and (2) safe and adequate daily dietary intake (SADDI). RDAs are established when the Committee considers a nutrient to be essential and judges the available data to be sufficiently firm to derive an intake level that will cover the nutritional needs of 97.5% of the healthy US population. SADDIs represent a range of intakes and are considered tentative, lacking firm scientific evidence on which to fix a recommended consumption level. Recommendations for iron, zinc, and iodine have been addressed in the most recent (1980) edition of the RDA booklet[7] (table 3).

Table 3. Daily recommended dietary allowance (RDA) and critical nutrient density for iron, zinc, and iodine in the elderly*

Nutrient	RDA level (mg)	Critical nutrient density† (mg/1,000 kcal)	
		Men	Women
Iron	10	6.1	8.3
Zinc	15	9.1	12.5
Iodine	0.150	0.09	0.125

*Defined as all US residents 51 years of age and older. Recommendations apply only to "healthy" persons.
†Assumes 1,650 kcal intake for men and 1,200 kcal for women.

The pronouncements of the RDA Committee have a number of limitations with respect to nutrient intake requirements for the elderly. Most important is the Committee's categorization of all US residents 51 years of age and older in a single age-group. The same levels of RDA or SADDI for micronutrients are unlikely to obtain in a 51-, a 71-, and a 91-year-old person. (Interestingly, RDA levels for *energy* have been broken down further for the population 51 years of age and older.) Moreover, the RDA provides for intake in "healthy" persons. Since most US residents over the age of 65

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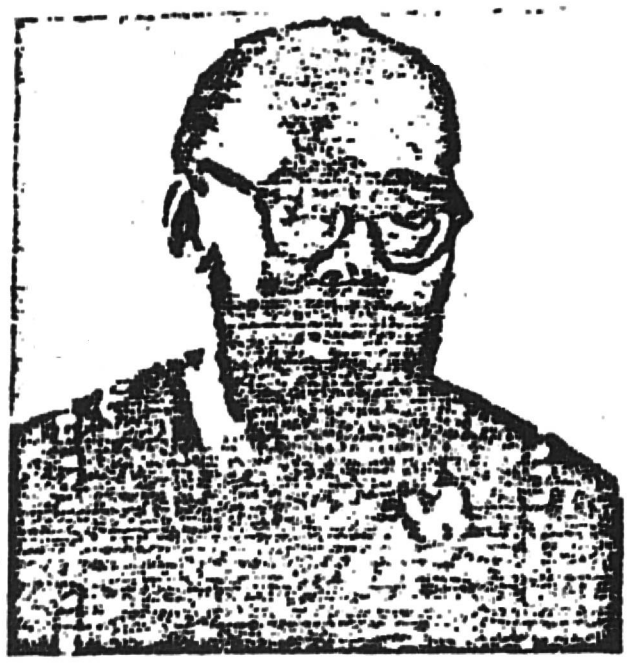
Iron deficiency can adversely affect hemoglobin, muscle metabolism, CNS alertness, and white blood cell function.



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years have one or more chronic diseases, their intake requirements are theoretically not covered by the standard RDAs and SADDIs.

The RDA Committee's standards for persons 51 years of age and older have been used in this discussion because of the regrettable lack of more precise and articulated figures for well and for chronically ill elderly. While these standards serve as a framework, I do not consider them to represent the final approximation.

Concept of critical nutrient density

Although the RDA refers to intake of *nutrients*, people consume *meals* made up of foods and beverages. Selection of the food and beverage components of the diet determines whether or not the intake of a given trace element is met. This requires introduction of the concept of *nutrient density*, or the amount of a given micronutrient contained in 1,000 kcal of a given individual's diet. The minimum daily intake of energy compatible with good health for persons over 74 years of age, as specified by the RDA Committee, is 1,200 kcal for women and 1,650 kcal for men. With respect to trace elements, therefore, we can define critical nutrient density as the level of a trace element in 1,000 kcal of a diet that will provide the RDA (or the lower limit of the SADDI) when an individual meets his or her daily energy needs with the minimal caloric intake compatible with good health.

The calculated critical nutrient densities for iron, zinc, and iodine established by the RDA Committee are presented in table 3. These elements are discussed in the remainder of part 1.

Iron

The primary function of iron is the transport of oxygen from the lungs to actively metabolizing tissues. As a consequence, two thirds of all body iron is incorporated into the hemoglobin of red blood cells. Iron, however, forms part of many other metalloproteins, including myoglobin, the cytochromes, and various cellular dehydrogenases. Apart from its effect on hemoglobin, iron deficiency can adversely affect muscle metabolism, CNS alertness, and white blood cell function.

For the elderly, the RDA of iron is 10 mg; thus, the critical nutrient density is 6.1 mg/1,000 kcal for men and 8.3 mg/1,000 kcal for women. Usual daily intake of iron in this age-group is 10.4 to 11.3 mg in men and 7.4 to 9.6 mg in women.[7]

Iron is most easily absorbed from meals that contain meat because the iron in meat is more absorbable than that in other foods and because meat enhances the biologic availability of inorganic iron. Ascorbic acid exceeding 50 mg in a meal also enhances the bioavailability of inorganic iron. Since the con-

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In the absence of demonstrated iron depletion in the elderly, no reasonable indications exist for iron intake much above the recommended dietary allowance.

sumption of both meat and vitamin C may be reduced in the diet of older persons, the potential bioavailability of the iron they consume is probably, in general, low.

On the other hand, older persons are likely to have a full complement of storage iron from lifelong accumulation of iron reserves. Men achieve this status early in life, while women do so only after menopause.[8] Thus, the need for iron in the majority of the elderly—especially women—probably is less than that for younger persons.

Total lean-body mass is reduced in old age, and the overall demand for oxygen to serve metabolically active tissues is diminished. Earlier survey data[9] suggested that senescence decreases intestinal absorption of iron. Recent evidence,[10] however, has shown that iron-deficient elderly persons have a compensatory increase in intestinal iron uptake equal to that of younger iron-depleted subjects. The tendency to absorb less iron with age[11] may, indeed, be an appropriate adaptation to the higher total-body iron stores. In a curious finding, Meinz and associates[12] demonstrated that low serum iron concentrations in a cohort of elderly Missouri residents were more prevalent among those who died during a four-year follow-up period than among the survivors. The magnitude of risk conferred by an isolated finding of hypoferremia cannot be established from this study, but it is probably small.

The only way to lose significant quantities of iron is via blood loss. Elderly persons with diseases that produce occult or acute blood loss will, of course, have higher requirements for iron both during and after the cause of the bleeding has been treated. Gastric resection reduces the capacity to absorb iron and predisposes to iron deficiency.

In the absence of demonstrated iron depletion, no reasonable indications exist for iron intake much above the RDA levels. Excessive iron consumption is accompanied by tissue overload (siderosis), which is usually benign. Iron overload, however, can predispose to amebiasis and other intracellular infections[13] and increases the destruction of ascorbic acid.[14] Excessive amounts of iron in the diet can also reduce the effective absorption of zinc, manganese, and copper.

Zinc

Zinc is a component of many mammalian metalloenzymes. It also has a role in protein synthesis and in stabilization of cellular membranes. Its physiologic

Evidence from several studies supports an immune-system stimulatory effect in the elderly after zinc supplementation.

roles include growth and cell division, wound healing, retinal function, taste acuity, immune protection, and reproduction. The last function is less relevant in the elderly than in younger persons. However, zinc deficiency reduces the production of testosterone,[15] which tends to alter the libido and sexual capacity of older men.

The RDA of zinc for the elderly is 15 mg; thus, the critical nutrient density is 9.1 mg/1,000 kcal for men and 12.5 mg/1,000 kcal for women. On the basis of two national nutrition surveys of the dietary composition and mean energy intake of elderly subjects, Sandstead and associates[16] estimated the average daily requirements of zinc in the US population 65 to 74 years of age to be 10.1 mg for men and 6.5 mg for women. These derived data agree with actual measurements made in regional surveys in Indiana. In essence, the elderly consume from 50% to 67% of their RDA for zinc.

On the basis of studies in young subjects who consume a mixed diet, Sandstead and associates[16] estimated that an intake of as little as 5.3 mg of zinc daily may be sufficient for those on a low-protein, low-phosphorus diet, while as much as 17.4 mg might be needed for those on a high-protein, high-phosphorus diet. The diet of elderly Americans is more likely to approximate the former pattern, but the extrapolation of these data to an aged population can be only tentative at best.

Indexes of zinc nutriture often indicate a low-zinc status in elderly populations. Lindeman and associates[17] noted a progressive fall in plasma zinc levels from age 20 through 80 years in a cross-section of healthy adults, but red-cell zinc levels remained stable through adult life. Kohrs and associates[18] found serum zinc levels below 70 µg/dl in 57% of a sample of white elderly subjects in Missouri. Wagner and associates[19] found deficient circulating zinc levels in a comparable percentage of rural black elderly subjects in Florida. However, a variable incidence of low circulating zinc levels in elderly populations has been documented overall in the sundry reports reviewed by Sandstead and associates.[16]

As lean-body mass is reduced and cell turnover rates are slowed by the aging process, the tissue requirements for zinc might theoretically be reduced. For certain cell lines, however, aging may impair vital physiologic processes. This is notable for T cells, which direct the cellular immune response.[20,21] A large number of elderly persons have abnormal T cell responses in vitro and cutaneous anergy to tests of delayed hypersensitivity. Phagocytic responses are depressed in the presence of a low plasma zinc level,[22] which might increase susceptibility to infection.

Platelet aggregation is also depressed by low zinc levels.[23] This might either protect against propagation of intravascular thrombi or predispose to damaging vascular microhemorrhages. Conditioned zinc deficiency is associated with a number of diseases likely to affect older subjects.[24] These include cancer, malabsorption, diabetes, alcoholism, celiac disease or sprue, and uremia.

A number of rationales have been offered for the routine administration of pharmacologic doses of zinc to the elderly. One of these suggests that zinc supplementation promotes wound healing. However, this effect is observed only when a preexisting zinc deficiency is present.[16] Another rationale is based on speculation that a reduced gustatory sense may contribute to apathy toward food and reduced dietary intake in elderly persons with hypogeusia. In the one well-designed trial of zinc supplementation in the elderly,[7] no beneficial effect on taste acuity was detected. Thus, neither of these two rationales justifies excessive zinc intake.

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Iodine is important to the thyroid gland's physiologic regulation of oxidative tissue metabolism.

A more challenging rationale has recently evolved in the context of the depressed cellular immune response of aging. Belgian investigators were the first to report an immune-system stimulatory effect in the elderly after short-term administration of therapeutic doses of zinc, ranging from 100 to 150 mg/day for four weeks.[26,27] Zinc supplementation significantly increased the number of positive results of skin tests to a battery of antigens (PPD, streptokinase-streptodornase, *Candida*) in 15 healthy institutionalized subjects over 70 years of age compared with a placebo group matched for age and sex.[26] This increase was associated with an increase in total number of T cells within the lymphocyte pool and an enhanced amnestic IgG response to tetanus vaccination. Circulating zinc was not measured.

In a subsequent report,[27] the in vitro response to the T cell mitogen concanavalin A was enhanced by zinc supplementation in women aged 40 to 60 years but not in younger women. Serum zinc levels were not depressed initially in any of the groups; supplementation produced a significant increment in mean zinc concentration but did not affect serum copper.

In the United States, Wagner and associates[28] recently reported a study conducted in Florida among 173 rural elderly subjects aged 60 to 97. Of these, 38 (22%) were anergic to four recall antigens. Supplementation with 55 mg of zinc for four weeks restored reactivity in some.

Excessive intake of oral zinc can produce toxic side effects. An occasional subject has bleeding gastric erosion.[29] Several studies[30,31] have shown that consumption of 150 mg/day of elemental zinc for prolonged periods results in frank copper deficiency anemia. Therapeutic doses of zinc occasionally produce epigastric distress and nausea when taken on an empty stomach, but this reaction usually subsides with continued administration, and thereafter the zinc is well tolerated.

Iodine

Iodine is a component of the thyroid hormone thyroxine (T_4) and the biologically active moiety triiodothyronine (T_3). Thus, iodine is important to the thyroid gland's physiologic regulation of oxidative tissue metabolism. Adequate intake of iodine is necessary to prevent the development of simple (endemic) goiter, which was common in areas with a low environmental content of iodine before initiation of iodine fortification programs.

The RDA of iodine for the el-

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derly is 150 µg: thus, the critical nutrient density is 90 µg/1,000 kcal for men and 125 µg/1,000 kcal for women. Usual intake of iodine depends on geographical location, spontaneous consumption of iodine-rich foods such as shellfish, and ingestion of iodized table salt. Iodine is readily absorbed from food or from potassium iodide, the compound usually used to fortify table salt.

No specific factors of aging appear to stress the requirement for iodine. This trace element is stored abundantly in the thyroid gland, and an iodine-replete elderly person could probably continue on an iodine-poor diet for many years without exhausting accumulated reserves. No diseases of aging specifically deplete iodine stores, and there are no reasonable indications for extra intake of iodine by elderly persons. However, iodine is a relatively innocuous element: in the coastal population of Japan, regular daily intake of 1 mg or more from seaweed and shellfish has no apparent detrimental consequences to health.[7]

Summary

Trace elements play a poorly understood role in human metabolism and nutrition. In the elderly, the normal effects of aging further complicate an understanding of trace element nutriture. The RDA standards established to date for the elderly have important limitations in that "healthy" persons 51 years of age and older constitute a single, regrettably imprecise category.

Although any minor elemental constituent of the body is considered to be a trace element, only 16 are currently believed to be of biologic importance to humans. A recommended dietary allowance (RDA) has been established for only three of these—iron, zinc, and iodine. PGM

Part 2, on trace elements with only tentative dietary recommendations, begins on page 251.

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