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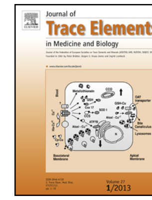

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Review

Global perspectives on trace element requirements

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ABSTRACT

Trace elements are inorganic constituents of the human body present in concentrations less than 50 mg/kg body weight. An exception is iron that is found in slightly higher amounts, 60 mg/kg body weight, but it is classified within this category due to its physiological roles. Requirements of trace elements can vary according to age, gender, growth, body composition, genetics, pregnancy, lactation, wound healing and burns, alcohol abuse, infections, and diseases (anemia, coronary artery, Keshan, Kashin–Beck). Additionally, interactions may occur with dietary factors, such as other minerals (iron versus copper), phytates (zinc), oxalates (iron), fiber (manganese), and polyphenolic compounds (molybdenum). On a global basis, requirements can vary according to soil and geographical location, food preparation and processing, food accessibility, cultural practices (geophagia) and pollution. Furthermore, global differences exist in body composition, ethnicity, and age of menarche.

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Introduction

Trace elements are inorganic constituents present in concentrations less than 50 mg/kg body weight [1]. An exception is iron (Fe) that is found in slightly higher amounts, 60 mg/kg body weight, but it is classified within this category due to its biological roles [1]. Some functions of trace elements include being a structural constituent of hormones, such as thyroid [iodine (I)] and myoglobin [Fe], structural component of a vitamin [cobalt (Co)], co-factor in metalloenzymes, such as arginase [manganese (Mn)] and glutathione peroxidase [selenium (Se)], or a nonenzymatic protein, such as ferritin [Fe] [1]. Requirements for trace elements can be derived from studies of metabolic balance (in relation to intake), depletion–repletion, isotope dilution and turnover, or response of biomarkers to variations in intake [2–4]. When actual data are limited, values may be extrapolated from dietary or human milk levels that are associated with good health [3]. Dietary requirements are a combination of both basal and normative levels [3]. Basal is the level to prevent clinically detectable symptoms of dietary deficiencies; normative refers to quantities needed to maintain optimal stores. Knowledge of factors that influence nutrient bioavailability is essential for translation of physiological consequences to dietary requirements [5].

Physiological variables and the intrinsic nature of the diet and physiological variables influence the availability of minerals for digestion, absorption, and utilization. This paper will summarize factors that influence nutrient bioavailability, and global differences that affect dietary requirements of trace elements. Global differences discussed are soil and geographical location, food preparation and processing, food accessibility, cultural practices (geophagia), pollution, body composition and ethnicity, and age of menarche. Comparison of the global disparities of trace element requirements are illustrated in Canada, China, India, Italy, Japan, New Zealand, Nigeria, Sub-Saharan Africa, South Africa, and United States, as well as in Asian, Caucasian, and Hispanic ethnicities. Trace elements studied include: Fe, I, Se, Mn, Cu and Zn.

Physiological factors influencing nutrient status

Physiological factors are known to influence the absorption and utilization of nutrients. Trace element requirements can vary according to age, gender, growth, body composition, genetics, pregnancy, lactation, wound healing and burns, alcohol abuse, infections, and diseases (anemia, coronary artery, Keshan, Kashin–Beck). Losses can occur through perspiration, menses, semen, hair, nails, exfoliation, exudates, and hemodialysis [3,6–10].

Age and gender

Physiological changes associated with age and development play an important role in requirements. For example, adolescence is a period that is marked by growth spurts and rapid biological changes. This critical window of development is accompanied by an increased trace element needs [6]. Moreover, aging has been associated with deficiencies in trace minerals, such as Zn and Se [11]. Supplementation has been efficacious in improving the clinical consequences of these inadequacies prevalent in elderly individuals [11]. Finally, gender is a key determinant of trace mineral requirements. For example, dietary standards for Fe are set much higher in women due to menstrual losses that occur with the onset of puberty [6].

Body composition and genetics

Body composition and size also is related to the trace element status of individuals. An inverse relationship between Fe status and body composition suggests a need for greater Fe requirements in individuals with a high body mass index (BMI), a condition that is rapidly escalating throughout the world [12]. It is believed that the presence of excessive fat can lead to inflammatory responses and affect Fe status [13]. The Fe-containing protein, hepcidin, mediates this mechanism by which inflammation causes Fe deficiency in individuals with high body fat [13]. Additionally, low serum contents of Zn have been noted in overweight or obese Hispanic children [14], and weight loss helped achieve a 22% increase in plasma Zn in overweight/obese women [15]. Genetic polymorphisms also affect trace element status. Variations in the hemochromatosis (HFE) gene increase Fe uptake, and thus, result in Fe overload in affected individuals [7]. Moreover, polymorphisms of the interleukin-6 (IL-6) gene have been implicated in the development of a Zn deficiency state [16].

Pregnancy and lactation

Physiological adaptations that occur both during pregnancy and lactation create a unique demand for essential nutrients. Expansion of red blood cells, transfer of Fe to fetus and placental formation augment Fe needs during pregnancy [17]. Zn, I, and Se requirements are all elevated in pregnancy in order to provide sustenance for the fetus [6,17]. In lactation, Fe requirements drop substantially and are much lower than in pregnancy. However, demands for Zn, I, Se, copper (Cu) and chromium escalate with breast feeding [6]. Iodine is particularly important during both pregnancy and lactation, as inadequate I intakes have been associated with diminished neurologic and cognitive outcomes in offspring [18,19].

Wound healing and burns

Losses through exudates after major burns adversely affect trace element status. Wound healing is a complex process that involves infiltration of cells from the circulation and adjacent tissues, which in turn requires the presence of nutrients and intact antioxidants [20]. However, micronutrients involved in wound healing, such as Cu, Zn and Se, are severely depleted after major burns [8]. These losses create elevated requirements for these trace elements after burns, and supplementation is vital to restore adequate status [21]. A randomized, placebo-controlled trial in patients with burns on 45% of their body surface area showed that intravenous administration of Cu, Zn, and Se improved antioxidant status, decreased infection rates, and enhanced wound healing [8]. In children with severe burns who were provided Zn and Cu supplements at three times the dietary reference, plasma Zn and Cu remained depleted at admission and discharge [22]. Wound Zn and Cu were greater than plasma levels, indicating that wound exudates were the primary route for excretion [22]. Thus, it is difficult to compensate for severe burn losses [22].

Alcohol abuse

Alcohol abuse is another condition that can alter trace element requirements. Chronic alcohol consumption impairs the antioxidant defense system and induces a state of oxidative stress [9]. Lower plasma Zn concentrations and higher Zn urinary excretion were observed in male alcoholics as compared to controls [23]. Also, Zn levels in the liver and serum were found to be depleted in a group of alcoholic cirrhotic patients [24].

Selenium status is affected by alcohol consumption, as the liver acts as a major storage organ of this element [25]. Thus, it is not surprising that a lower Se status has been reported in patients with liver cirrhosis due to chronic alcohol abuse [25]. Plasma Se