TRACE ELEMENT NUTRITION IN THE DEVELOPING WORLD: A REVIEW

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ABSTRACT

Several elements are required for the nutritional well-being of animals and humans. The trace elements recognized currently as dietary essentials are arsenic, boron, chromium, copper, fluorine, iodine, manganese, molybdenum, nickel, selenium, Silicon, vanadium and zinc. Aluminium, cadmium, lithium, lead and tin are thought to be dietary essentials also, but the evidence is less extensive than for the other elements listed. A dietary deficiency of any of the trace elements will produce the specific symptoms because each element serves a specific function(s). Trace element malnutrition is now a rapidly growing public health problem among nearly all poor people in many developing nations. This pernicious but preventable human health crisis calls for an awareness for the developing world to not only focus on the production of staple food but also food of high nutritional quality and diversity to satisfy a balanced diet for all people thereby ensuring healthy and productive lives. The food chain remains the major pathway through which the trace elements enter the human body. With the exception of iron and iodine, information on trace element intakes in developing countries is limited because of paucity of data on the trace elements content of local staple foods. Substitution of trace element values for staple foods grown in Western countries is not advisable because the trace elements content of plant-based foods tend to reflect the trace element levels of the local soil.

INTRODUCTION

Everyone agrees that nutrition in the developing world is in a sorry state. Government officials, industry executives, educators, and policy makers, who might angrily attack each other over a variety of economic, social, or political issues, join forces when it comes to complaining that citizens lack good nutrition. Trace elements are those elements of the Periodic Table that occur in the body in µg/g amounts or less. They may be essential, that is indispensable for growth, reproduction, and health, or they may be nonessential, fortuitous reminders of our geochemical origins or indicators of environmental exposure. Some nonessential trace elements can be beneficial to health through pharmacologic action. All the trace elements are toxic when intake is excessive. Since the early 1970s there has been much speculation that trace element deficiencies or imbalances are involved in some human diseases, without complete understanding as to their cause. The understanding of adequate trace element nutrition is a key factor to designing a better nutrition that protects humans from infections. Trace elements function as cofactors to enzymes, carrier proteins, hormones, and other metabolic proteins. In the recent past, trace elements, numbered about ten, include: iodine, cobalt, copper, zinc, molybdenum, manganese, selenium, fluorine, vanadium and chromium[1]. Due to concerted efforts of researchers in the developed world, there is increasing evidence that many other elements, hitherto considered nonessential, are actually required for optimum healthy functioning of animals and even humans. Nielson[2] reported that boron, nickel, silicon, lithium, and arsenic are such elements that are shown to have beneficial effects at nutritionally relevant intakes in animals and sometimes in humans.

Nube and Voortman[3] noted that there is a growing interest in the occurrence of trace element deficiencies in recent years, for several reasons. In the first place, trace element deficiencies appear to be much more widely spread than previously thought and information on their geographical distribution is rapidly increasing[4]. Secondly, there is a considerable amount of new information on the adverse health effects of various trace element deficiencies[5]. For example, over past decades it has become increasingly clear that iodine deficiency, apart from causing an enlarged thyroid gland (goitre), can also cause impaired intellectual development of infants and children[6]. Similarly, some years ago there was only limited public health interest in zinc, now it is widely recognized that zinc deficiency is associated with sub-optimal growth and reduced immunocompetence in children[5]. Thirdly, there is continual increase in evidence for certain trace elements that marginal intakes can have adverse health effects, with, for example, a marginal selenium intake playing a role in the aetiology of certain types of cancer[7]. We are now facing a growing population that is not starving in great numbers from energy deprivation, but that is becoming more malnourished with passing day (hidden hunger). Thus, eliminating trace element malnutrition should be a high priority goal for many developing nations. Achieving it would contribute greatly to economic growth by directly enhancing health and labour productivity, and indirectly, by improving cognitive achievement in all individuals within a society. Therefore, adequate nutrition is an indispensable, but often overlooked component of individual and family health, livelihood and well-being, as well as an important factor in sustainable national development efforts. The aim of this paper is to educate the reader about the magnitude and profound consequences of trace element malnutrition to human health and well-being which demands for a concerted effort to combat the ugly trend in the developing world. This effort should explicitly link food production to human nutrition and health with the goal of eliminating trace element deficiencies in the developing world.

THE TRACE ELEMENTS AND HEALTH

Nutritional importance of trace elements has grown rapidly during the last four decades, mainly due to a better understanding of their biological functions. Except for iron and iodine, whose essentiality for man was recognized almost a century ago, the role of some of the other trace elements in human metabolism has been established only during the last few decades. In deficiency states, essential trace elements are bound to lead to health problems. Iron deficiency anaemia and goitre due to iodine deficiency are some examples among others. The known trace elements (As, B, Cr, Cu, F, I, Mn, Mo, Ni, Se, Si, V, and Zn) , their functions, deficiency symptoms, dietary needs and sources of foods rich in each are given in Table 1. Only the estimated daily requirements for adult males are given.

Table 1. Essential trace elements: examples of some deficiency implications, functions, estimated dietary needs and rich food sources[1,2]

Element	Deficiency and Function(s) in Animals and Humans	Human dietary Need; Rich Food Sources
Arsenic	Impaired fertility and increased perinatal mortality; depressed growth, conversion of methionine to its metabolites, methylation of	12µg/day; fish, grain and cereal products

	biomolecules	
Boron	Impaired Ca utilization in bone; more severe signs of vitamin D related rickets; decreased apparent absorption of Ca, Mg, and P; impaired mental functions in older women and men (>45 years old); *cis*-hydroxyl reactions with biomolecules; cell membrane integrity	0.5-1.0mg/day; noncitrus fruits, leafy vegetables, nuts, and pulses
Chromium	Impaired glucose tolerance; impaired growth; elevated serum cholesterol and triglycerides; increased incidence of aortic plaques; corneal lesions; decreased fertility and sperm count; potentiates insulin action	33µg/day; processed meat, whole grain products, pulses, and spices.
Copper	hypo chromic anaemia; neutropenia; hypo pigmentation of hair and skin; impaired bone formation with skeletal fragility and osteoporosis; vascular abnormalities; steely hair; metal cofactor in numerous metalloenzymes, e.g., cytochrome oxidase, ceruloplasmin, superoxide dismutase, etc.	1.5-3.0mg/day; organ meat, seafood, nuts and seeds; in drinking water from Cu plumbing in urban areas
Fluorine	Status as an essential trace element debated; beneficial element because of its effects on dental health	1.5-4.0mg/day; tea marine fish consumed with bones
Iodine	Wide spectrum of diseases including severe cretinism with mental retardation; enlarged thyroid (goitre); essential constituent of the thyroid hormones	150µg/day; seafood, iodized table salt; mild; I concentrations in plant foods vary greatly depending on various environmental factors including the geochemical environment, fertilizer, food processing and feeding practices.
Iron	iron deficiency erythropoiesis with low iron stores and with work capacity performance impaired; iron deficiency anaemia with reduced haemoglobin levels and small red blood cells; impaired immune function; apathy; short attention span; reduced learning ability; constituent of haemoglobin, myoglobin and a number of enzymes	15 mg day; meats, eggs, vegetables and iron-fortified cereals
Manganese	poor reproductive performance; growth	2.0 - 5.0 mg/day ;

	retardation; congenital malformations; abnormal bone and cartilage formation; impaired glucose tolerance; metal activator of many enzymes, e.g., decarboxylases, hydrolases, kinases, and transferases; constituent of pyruvate carboxylase and superoxide dismutase in mitochondria	whole grain and cereal products, fruits and vegetables, tea
Molybdenum	retarded weight gain; decreased food consumption; impaired reproduction; shortened life expectancy; neurological dysfunction; dislocated ocular lenses, mental retardation; cofactor (molybdopterin) in sulphite oxidase and xanthine dehydrogenase	75 - 250 µg/day ; milk, beans, breads and cereals
Nickel	depressed growth and reproductive performance; impaired functioning and body distribution of several nutrients e.g., Ca, Fe, Zn, vitamin B 12 ; cofactor for an enzyme that affects amino acids and odd-chained fatty acids derived from the propionate metabolic pathways	<100 µg /day ; chocolate, nuts, dried beans, peas and grains
Selenium	endemic cardiomyopathy (Keshan disease); white muscle disease; endemic osteoarthoropathy (Kashin-Beck disease) with enlargement and deformity of the joints; liver necrosis; exudative diathesis; pancreatic atrophy; growth depression; depressed activity of 5'-deiodinase enzymes that produce triiodothyronine (T 3) from thyroxin (T 4); impaired immune response to viral infections; anticarcinogenic activity; essential component of glutathione peroxidase and "selenoprotein-P"	55 - 70 µg/day; seafood, organ meats; meats; cereal grains grown on Se-rich soils; Brazil nuts; Se concentrations in plant foods can vary greatly depending on the available Se content of the soil where grown and the plant species grown
Silicon	depressed collagen content in bone with skull structure abnormalities; long bone abnormalities; decreased articular cartilage, water, hexosamine, and collagen; decreased levels of Ca, Mg, and P in tibias and skulls under Ca deficiency conditions	5 - 20 µg/day; unrefined grains, cereal products; root and tuber crops
Vanadium	death proceeded by convulsions; skeletal deformities; increased thyroid weight; participates in oxidation of halide ions and/or the phosphorylation of receptor proteins	<10 µg /day; shellfish, mushrooms, black pepper, dill seed
Zinc	loss of appetite; growth retardation; skin changes; immunological abnormalities; difficulty in parturition; teratogenesis, hypogonadism; dwarfism; impaired wound healing; suboptimal growth, and impaired taste acuity in infants and	15 mg/day; animal products especially red meats, cheese, legume seeds and pulses

	children; diarrhoea; impaired immune function; constituent of numerous enzymes; cellular membrane stability function	

1. **Sources of information included: National Research Council[8], 1989; Nielsen[9], 1992; World Health Organization[10], 1996. 2. Reported daily allowances are for adult men.**

The trace elements include those that are sometimes called *ultra trace* elements for which there is only circumstantial experimental evidence (usually from animal models), which suggests that they are essential for humans, and thus their nutritional importance has not been clearly established. These elements are boron, silicon, vanadium, and arsenic. Undoubtedly, other trace elements (especially Al, Cd, Li, Pb, and Sn)[11] will be discovered to be essential in the future. A deficiency in any of the essential trace elements will have adverse effects on human health, livelihood and well-being. Assuring dietary diversity and food abundance for all are currently the most advantageous ways of providing optimum nutrition. The more diverse the sources of food in a diet, the more likely that adequate and balanced amount of all micronutrients will be consumed[12].

CONCLUSION

Rural diets in developing countries are predominantly plant-based; consumption of cellular animal-protein foods such as meat, poultry and fish is often small because of economic, cultural and/or religious constraints. As a result, the content and/or amount of trace elements available for absorption from such is low, and is probably the primary cause of trace element deficiency[13]. To overcome this, balanced and controlled application of micronutrient fertilizers (biofortification) to improve the content of trace elements such as Zn, Fe and I in staple food crops (e.g. wheat, maize, sorghum, beans) as practised in Turkey[14], should be adopted. Previously, only the deficiency of two elements, namely that of iron and iodine have been recognized as being of widespread public health significance from a nutritional standpoint. Now, genuine concern arises as to the necessity of adding zinc (and even selenium) to this list, especially in those population groups in developing countries[15,16] whose diets contain complex substances that limit the bioavailability of zinc. In addition, high levels of lead in the environment may further aggravate the situation. It is important to collect reliable data on trace element intake in developing countries in order to assess the adequacy of trace element nutrition.

In summary, there are a number of issues that need to be addressed in developing countries regarding trace element nutrition. These include: (a) studies leading to the identification of areas where essential trace element deficiencies and toxicities from toxic metals are common, (b) analysis of trace elements in individual foods and in water supplies, to provide greater reliability when assessing the trace element intake by indirect methods, (c) studies of relationships between biochemical parameters for the diagnosis of marginal deficiency of trace elements, and (d) the impact of pollution on the bioavailability of trace elements. Allowing trace element malnutrition to go unchecked in a society would lead to more unhealthy people, reduced labour productivity, lower educational attainments in children, reduced school enrolments and attendance, increased morbidity and mortality, lower standards of living, higher health care costs and civil discontent. This is a recipe for governmental instability.

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