

# ZINC: THE TRACE ELEMENT OF MAJOR IMPORTANCE IN HUMAN NUTRITION AND HEALTH

Jayant D Deshpande<sup>1</sup>, Mohini M Joshi<sup>2</sup>, Purushottam A Giri<sup>1</sup>

<sup>1</sup>Department of Preventive & Social Medicine, Rural Medical College, Loni, Maharashtra, India

<sup>2</sup>Department of Anatomy, Rural Medical College, Loni, Maharashtra, India

Correspondence to: Jayant D Deshpande (drjayant10@gmail.com)

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## ABSTRACT

Zinc is an essential element whose significance to health is increasingly appreciated. In 1961 essentiality of zinc for humans was recognized. A systematic literature search was done to identify relevant studies investigating the role of zinc in human health. This review concerns the importance of zinc in health and the consequences of its deficiency. Zinc deficiency leads to complications of pregnancy and childbirth, low birth weight and poor growth in childhood, reduced immunocompetence, and increased infectious disease morbidity. Pregnant women with zinc deficiency are at risk of premature labour and miscarriages, inefficient labour and delivery, stillbirths, lower mental ability of the child, retarded foetal growth and low immunity of both mother and baby. Zinc can reduce the duration, severity and incidence of diarrhoea in children. Zinc deficiency was indicated as a risk factor for immune deficiency and susceptibility to infection in the elderly. Zinc is used in preventive trials and treatment of diarrhoea, pneumonia, common cold, respiratory infections and malaria. Sufficient zinc is essential in maintaining immune system function. Supplementation of zinc and with other micronutrients may be beneficial during periods of greatest vulnerability such as early childhood, pregnancy and elderly. Ensuring adequate levels of zinc intake should be a key component in efforts to reduce illness.

**KEY-WORDS:** Zinc; Deficiency; Human Health

## INTRODUCTION

The importance of micronutrients in health and nutrition is undisputable, and among them, zinc is an essential element whose significance to health is increasingly appreciated and whose deficiency may play an important role in the appearance of diseases. Nearly two billion people in the developing world are deficient in zinc.<sup>[1]</sup> In children it causes an increase in infection and diarrhea, contributing to the death of about 800,000 children worldwide per year.<sup>[2]</sup> Zinc is one of the essential trace elements. Importance of zinc and its requirement for the growth of *Aspergillus niger* was first recognized by Raulin in 1869.<sup>[3]</sup> In 1934 the essentiality of zinc as trace element for rats was observed.<sup>[4]</sup> In 1961 essentiality of zinc for humans was recognized.<sup>[5]</sup> Nutritionists have long been concerned that zinc deficiency affects large numbers of women and children worldwide. Several studies have now confirmed that zinc deficiency in the developing countries is fairly prevalent, and that growth

retardation commonly observed in these countries may indeed be due to zinc deficiency.<sup>[6]</sup> Zinc deficiency was indicated as a risk factor for immune deficiency and susceptibility to infection in the elderly. Inadequate stores of zinc might be a risk factor of pneumonia in the elderly.<sup>[7]</sup> Due to the wide prevalence of zinc deficiency and the multitude of zinc's essential biological functions, nutritional correction of zinc deficiency may have a significant impact on different aspects of human health. With this background in mind, present paper is an attempt to review role of zinc in health and disease.

## MAJOR CAUSES OF ZINC DEFICIENCY

Zinc is present in all organs, tissues, and fluids of the body. The total body zinc of an adult human is approximately 1.5–2.0 grams, or about 0.003% of total weight. The physiological requirement for zinc in adult males is 1.4 mg zinc/d; and 1.0 mg/d for females.<sup>[8]</sup> The distinction between intake and absorption is important, because although some

intakes of zinc may be acceptable, the levels of inhibitors (e.g. fiber and phytates) in the diet may mean that inadequate amounts of zinc are absorbed. Low levels of zinc or lack of zinc in the body result in zinc deficiency. Zinc deficiency can develop if the amount of zinc in the diet is insufficient relative to the requirement, or if the patients have such conditions as malabsorption, liver cirrhosis, diabetes mellitus, renal disease, haemolytic anaemia, burns, diarrhoea or intestinal fistula. Furthermore, zinc deficiency can be induced by continued use of low mineral purified foods (minerals are lost during purification), foods containing additives with chelating activity. Gastrointestinal surgery, Crohn's disease, ulcerative colitis, short bowel syndrome, and other digestive diseases can all decrease zinc absorption and increase zinc loss from the body. Acrodermatitis enteropathica, an inherited abnormality of zinc absorption, is rare. Iron can interfere with zinc absorption, to reduce this effect, iron supplements should be taken between meals to allow time for zinc to be absorbed properly. In recent years, it has been suggested that zinc deficiency may be associated with carcinogenesis, senility, and the onset or progression of some lifestyle-related diseases.<sup>[9]</sup> A developing foetus requires a high amount of zinc; likewise, there is a high amount of zinc lost through breast milk after birth. The body requires more zinc during periods of rapid growth like pregnancy, infancy, childhood and adolescence. Children require more zinc to boost their delicate immune systems. Zinc deficiency is more likely to develop during childhood, when the daily requirement of zinc is higher, in adult women (especially young women on weight-reducing diets), and in elderly people whose dietary consumption of nutrients is poor. Long-term high-calorie parenteral therapy is also important cause for zinc deficiency. For unknown reasons 44% of children and 60-70% of adults with sickle cell disease have low levels of zinc. Alcoholics - 30-50% of alcoholics have low levels of zinc because alcohol decreases zinc absorption and increases urinary secretion of zinc. In the USA, suboptimal zinc status has been noted in children of lower socioeconomic groups, low birth weight infants, pregnant teenagers and some of the elderly.<sup>[10]</sup> Research also suggests that the proportion of growth faltering attributable to zinc deficiency is

likely greater in regions characterized by poor water and sanitation and hygiene practices that increase risk for diarrheal and respiratory infections, both of which increase the likelihood of zinc deficiency by increasing body losses or requirements.<sup>[11]</sup>

## SOURCES OF ZINC

Zinc is found in meat, liver, kidney, fish, chicken and cereals, eaten alongside vegetables to enhance zinc absorption. Fats and various non-nutritive foods, Fish, fruits, cakes, Poultry, pork, dairy products and whole grains, cereals, lamb, beef, leafy grains, root vegetables, shell fish , Oysters, lobster and organ meats. Major plant sources of zinc include cooked dried beans, sea vegetables, fortified cereals, soyfoods, nuts, peas, and seeds. It is well known that zinc is present in many foods, but in most developing countries children have a low intake of foods rich in readily absorbable zinc, such as liver, red meat, poultry, fish, oysters, and crabs. Good sources of its mushrooms, day lily flowers, edible fungus, cabbage, black sesame, black rice, dates, hazelnuts, ebony and other vegetables, food crops and fruit. Traditional staple foods, such as cereals, legumes, and tubers, contain zinc, but the presence of phytate, fiber, and lignin reduces its bioavailability. These substances form insoluble complexes with zinc, preventing its absorption. Cow's milk, because of its high concentrations of calcium and casein, and soymilk, because of its phytate content, may further reduce the absorption of zinc from the diet. In contrast, zinc in breast milk is well absorbed. Vegetables and fruits contribute very little to dietary zinc intake, but fruits eaten with cereals may increase the bioavailability of zinc.<sup>[12]</sup> The concentration of zinc in plants varies based on levels of the element in soil. When there is adequate zinc in the soil, the food plants that contain the most zinc are wheat (germ and bran) and various seeds (sesame, poppy, alfalfa, celery and mustard). Zinc is also found in beans, nuts, almonds, whole grains, pumpkin seeds, sunflower seeds and blackcurrant.<sup>[13,14]</sup> Millions of people throughout the world may have inadequate levels of zinc in the diet due to limited access to zinc-rich foods (animal products, oysters and shellfish) and the abundance of zinc inhibitors, such as phytates,

common in plant-based diets.<sup>[15]</sup> Calcium can retard zinc absorption, so calcium and zinc supplements should be taken at different times of the day. Coffee is known to contain tannin which can potentially inhibit zinc absorption.<sup>[16]</sup> Because zinc is not well conserved in the body and because zinc deficiency is directly related to dietary zinc intake, an indirect approach to quantify the prevalence of zinc deficiency would be to examine the adequacy of zinc in the diet in various regions. Dietary surveys are conducted in many countries, but few such surveys exist in developing countries.<sup>[8]</sup> Dietary supplements contain several forms of zinc, including zinc gluconate, zinc sulphate, and zinc acetate. The percentage of elemental zinc varies by form.

### **ROLE OF ZINC IN HEALTH AND DISEASE**

Zinc, an essential trace mineral, is required for the metabolic activity of 300 of the body's enzymes, and is considered essential for cell division and the synthesis of DNA and protein. These enzymes are involved with the metabolism of protein, carbohydrate, fat. Zinc is also critical to tissue growth, wound healing, taste acuity, connective tissue growth and maintenance, immune system function, prostaglandin production, bone mineralization, proper thyroid function, blood clotting, cognitive functions, foetal growth and sperm production. Zinc is necessary to maintain normal serum testosterone. Zinc is found in the vesicles of the mossy fiber system of the brain's hippocampus. Zinc is essential for the immune system and zinc deficiency has dramatic implications for immune function. Zinc supplementation has been shown to improve the cell-mediated immune response of healthy elderly.<sup>[17]</sup> Zinc is essential for healthy skin. Zinc activates areas of the brain that receive and process information from taste and smell sensors. Levels of zinc in plasma were found to influence appetite and taste preference. The deficiency symptoms of zinc include growth retardation, low blood pressure, retarded bones, loss of appetite, loss of sense of smell and taste, weight loss, pale skin, diarrhoea, hair loss, Fatigue ,white spots under finger nails. Zinc deficiency was indicated as a risk factor for immune deficiency and susceptibility to infection in the elderly. Inadequate stores of zinc might be a risk factor of

pneumonia in the elderly.<sup>[18]</sup> In a study carried out in the 1960s in Iran, Prasad et al identified zinc deficiency as an underlying cause of stunting and delayed sexual maturation in humans.<sup>[19]</sup> Zinc deficiency contributes to increased risk of incidence for important childhood diseases that are predominant causes of death among children. Zinc deficiency increases the risk of severity and death during illness with diarrhoea or pneumonia. It is also important to note that maternal or gestational zinc deficiency may affect immunological development in the newborn in ways that compromise immune function throughout the lifespan irrespective of zinc status.<sup>[20,21]</sup> Researchers have suggested that both zinc and antioxidants delay the progression of age-related macular degeneration (AMD) and vision loss, possibly by preventing cellular damage in the retina.<sup>[22]</sup> Zinc is effective in shortening the duration of the common cold, if it is administered no later than 24 h within the onset of the symptoms.<sup>[23]</sup> It is likely that zinc deficiency is widespread in developing countries with particular effects in pregnancy and early childhood. Evidence is accumulating that this deficiency leads to complications of pregnancy and childbirth, lower birth weight and poor growth in childhood, reduced immune-competence, and increased infectious disease morbidity. Pregnant women with zinc deficiency are at risk of premature labour and miscarriages, inefficient labour and delivery, stillbirths, lower mental ability of the child, retarded foetal growth and low immunity of both mother and baby. Since childhood infectious disease morbidity from diarrhoea, pneumonia, and malaria is the cause of most of the childhood deaths in developing countries, it is also plausible that zinc deficiency contributes to the elevated mortality rates still seen in many developing countries. Studies linked the deficiency with a wide range of complications including pregnancy induced hypertension, premature rupture of membrane, placental abruption, prolonged labour, haemorrhage, infections, intrauterine growth retardation, low birth weight, congenital anomalies, increased neonatal morbidity and poor neurobehavioral development.<sup>[24,25]</sup> Zinc deficiency leads to increased risk of maternal and neonate morbidity and mortality. Maternal nutrition status is an important determinant of perinatal and neonatal

well-being. There are many nutrition programs designed to prevent iron-deficiency anaemia during pregnancy, but in the case of zinc, which is also very important for maternal and infant survival, much less has been done. The lactation period poses a different threat to maternal zinc homeostasis because zinc requirements during this period are very high.<sup>[26]</sup> Zinc can reduce the duration, severity and incidence of diarrhoea in children in the developing countries.<sup>[27-29]</sup> Recent studies suggest that replenishing zinc with a 10- to 14-day course of treatment can reduce the duration and severity of diarrheal episodes and may also prevent future episodes for up to three months.<sup>[30]</sup> Chronic diarrhoea causes zinc deficiency, and zinc deficiency in turn can contribute to diarrhoea. Zinc treatment has been shown to decrease the severity of the diarrhoea episode by decreasing the number of stools per day, the volume of stools per day, and the number of episodes lasting beyond 7 days.<sup>[31]</sup> Zinc supplementation in the treatment of childhood diarrhea was well tolerated by patients. Previous researchers reported the beneficial effects of zinc in treatment of shigellosis. Most of these effects are mediated by a modulation of immune function.<sup>[32,33]</sup> Delayed wound healing and skin lesions are among the symptoms of zinc deficiency, and the effect of zinc supplementation on several dermatological conditions has been investigated. All body tissues contain zinc; in skin, it is five to six times more concentrated in the epidermis than the dermis. Zinc is also an anti-inflammatory agent. These unique properties of zinc may have significant therapeutic benefits in several diseases in humans. Beneficial therapeutic response of zinc supplementation has been observed in the diarrhoea of children, chronic hepatitis C, shigellosis, leprosy, tuberculosis, pneumonia, acute lower respiratory tract infection, common cold, and leishmaniasis.<sup>[34]</sup> Zinc is a critical nutrient for central nervous system (CNS) development, which occurs during pre- and postnatal life. Because of the important role of zinc in CNS function, it is clear that maternal and early infant zinc deficiencies are likely to adversely affect foetal and infant neurologic and behavioural development. This is borne out in the work by Golub et al.<sup>[35]</sup> There is evidence associating zinc deficiency with deficits in activity, attention, and motor development and thus

interfering with cognitive performance in humans; however, there is no clear explanation of the mechanisms underlying this relation. In humans, severe zinc deficiency can cause abnormal cerebellar function and impair behavioural and emotional responses.<sup>[36]</sup> The effects of zinc on maternal health and pregnancy outcomes have been studied in multiple observational and interventional studies. Zinc is intimately linked to bone metabolism, thus, zinc acts positively on growth and development. Zinc concentration in bone is very high compared with that in other tissues, and it is considered an essential component of the calcified matrix. Zinc also enhances vitamin D effects on bone metabolism through the stimulation of DNA synthesis in bone cells.<sup>[37]</sup>

### **HEALTH RISKS FROM EXCESSIVE ZINC**

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Zinc toxicity due to acute or chronic ingestion of high quantities of zinc supplements can also occur and lead to impaired immune response, hypocupremia, microcytosis, and neutropenia. Consumption of excess zinc can cause ataxia, lethargy. Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhoea, and headaches. Intakes of 150–450 mg of zinc per day have been associated with such chronic effects as low copper status, altered iron function, reduced immune function, and reduced levels of high-density lipoproteins.<sup>[38]</sup>

### **CONCLUSION**

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Zinc is an essential nutrient for human health. Zinc is used in preventive trials and treatment of diarrhoea, pneumonia, common cold, respiratory infections and malaria. Sufficient zinc is essential in maintaining immune system function. Supplementation of zinc and with other micronutrients may be beneficial during periods of greatest vulnerability such as early childhood, pregnancy and elderly. Adolescents also have very high zinc requirements to maintain skeletal maturation, especially in females after menarche and during pregnancy. Ensuring adequate levels of zinc intake should be a key component in efforts

to reduce illness. It is essential to educate, inform and motivate communities to modify the diet to include animal products and cereals like maize and wheat products alongside vegetables to enhance zinc absorption which are rich in zinc.

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