Zinc Nutrition and Tribal Health in India

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INTRODUCTION

Zinc is an essential trace element that contributes immensely to human health and development. It is an important structural component of most proteins and contributes to the function of more than 200 enzymes in humans (Prasad et al., 1971; Sadler 1976; Coleman, 1998). Zinc also plays a central role in cellular growth and differentiation because of its critical role in RNA and DNA synthesis (Wu and Wu, 1987) and it is important for brain function (Sandstead, 1986; Pfeiffer and Braverman, 1997). Body functions affected by zinc nutriture include growth (Brown et al., 1998), immune system development and function (Ripa and Ripa, 1995), normal integrity of intestinal mucosa (Roy et al., 1992), pregnancy outcome (Tamura and Goldenberg, 1996) and neuro-behavioural development (Henkin et al., 1975; Black, 1998).

Zinc deficiency therefore results in adverse consequences on the body, the magnitude of which depends on whether the ensuing deficit is marginal or severe. Marginal zinc deficiency is the most common and, although asymptomatic, it is associated with impaired immune function, anorexia, dysfunction of smell and taste, irritability, depression, anger, sleepiness, reduced sperm production in men and decreased mental ability (Henkin et al., 1975). Severe zinc deficiency, which rarely occurs, is characterized by severely impaired immune function, dermatitis, growth impairment, alopecia, lethargy and recurrent infections such as diarrhoea (Prasad, 1993).

Marginal zinc deficiency appears to be an important public health problem in many developing countries. Data derived from FAO National Food Balance Sheets suggests, for example, that about half of the world's population is at risk of inadequate zinc intake (Brown and Wuehler, 2000). Furthermore, a third of pre-school children (34.0 %) worldwide have stunted physical growth (Carlson and Wardlaw, 1990). The recognition of childhood stunting as an indirect indicator of a population's risk of zinc deficiency (Hotz and Brown, 2004) supports the proposition that inadequate zinc nutriture is a widespread public health problem. Stunting is recognized as an indirect indicator of zinc status in some populations because zinc nutrition has been shown to have a significant impact on growth of young children. A meta-analysis of 25 studies of the effect of zinc supplementation on growth in children less than 13 years of age showed that zinc supplementation has a highly statistically significant effect on linear growth and weight gain (Brown et al., 1998).

About 70 % of the world's stunted children under five years of age live in Asia (Allen and Gillespie, 2001) and each year, zinc deficiency is estimated to contribute to more than a million deaths worldwide with a significant proportion of the zinc related morbidity and mortality occurring in South Asia (Hamer, 2004). However little is known about the zinc status of the Indian population due to a lack of nationally representative data on this micronutrient and the absence of an appropriate indicator for assessing zinc status of individuals. Nevertheless, some studies from different parts of India have suggested that marginal zinc deficiency is common, though these studies used plasma zinc, a measure of zinc status that is affected by the acute phase response, and indirect indicators like stunting (Bamji and Lakshmi 1998; Bhan et al., 2001; Chakravarty and Sinha, 2002). The national prevalence of childhood stunting stands at 42.6% among preschool children (NFHS-2, 1998) and the International Zinc Nutrition Consultative Group estimates that over 25 % of the total population in India is at risk of inadequate zinc intake (Hotz and Brown, 2004).

In a vast and multiethnic country like India, the extent of zinc deficiency is likely to vary from state to state and even within each state, from one area to another, depending upon several factors such as socioeconomic status, food habits, level of literacy, climate, religion and cultural practices. Various tribal populations are among the most underprivileged people since they occupy the lowest part of the socioeconomic strata in Indian society (Mishra, 2005) and therefore have the highest likelihood of any form of malnutrition including zinc deficiency. However the scarcity of data on the zinc status of the Indian tribal populations makes it difficult to draw any conclusive evidence on the extent of the deficiency and the need for programmatic interventions to address this problem. This paper attempts to provide reasons for studying zinc nutriture among tribes, why this is an issue that needs addressing in this indigenous population and possible programmatic approaches to meaningfully address this condition.

DIETARY SOURCES AND ZINC BIOAVAILABILITY

Individual zinc status is influenced by intake of zinc from the diet, its absorption (or bioavailability) and the loss of it from the body. Pertaining to zinc intake, the richest dietary sources of zinc are the organs and flesh of mammals, fowls, fish and crustaceans, and zinc-fortified foods. Organ and flesh meat and poultry do not contain any known specific anti-nutritional factors that hinder zinc absorption (Brown and Wuehler, 2000). Eggs and dairy products are also rich in zinc and free of phytates, but they have slightly lower zinc content than can be found in organ and flesh foods (Brown and Wuehler, 2000). Absorption of zinc takes place in the small intestine and the extent of uptake of this nutrient is determined largely by the presence of specific dietary factors that either inhibit or enhance its absorption. Among the several factors that interfere with digestion and absorption of dietary zinc, the phytate content of the diet is most important. The higher order phytates, like inositol hexaphosphate and pentaphosphates found in most cereal and legumes, are known to bind to zinc and form poorly soluble complexes that lead to reduced absorption from the intestinal lumen (Davies and Nightingale, 1975; Krebs, 2000). Although most cereals and legumes have relatively high amounts of zinc, they contain high concentrations of phytates, which reduce the amount of absorbable zinc from these foods, and therefore they are relatively poor sources of zinc. Starchy roots and tubers have much lower zinc content than legumes and cereals. In general, fruits and vegetables are not considered rich sources of zinc, although some green leafy vegetables like spinach have moderate amounts of zinc but with uncertain bioavailability.

It is clear from the above discussion that a cereal or legume based diet without an adequate inclusion of animal source foods or an external source of zinc often will not allow individuals to meet their daily zinc requirements. The diet of an average Indian is mainly cereal based and is said to be low in zinc and rich in zinc inhibitors that reduce zinc absorption. A study by Chakravarty and Sinha (2002) in rural areas of five Indian states (Assam, Bihar, Orissa, Tripura and West Bengal) found the average consumption of zinc among various age groups to be much lower than their recommended daily allowance (RDA). A large proportion of the families in this study (about 84.0%) had deficient zinc intakes with more than 50.0 % of the families in all the surveyed areas having moderate to severe deficiency in dietary zinc intake.

In general, poor Indian families are often vulnerable to zinc deficiency since majority of Indians are vegetarians and vegetarian diets are often lower in zinc content and contain factors that hinder zinc absorption (Hunt et al., 1998; Donovan and Gibson, 1996) in contrast to meat-based diets. Hence vegetarian families unable to meet their zinc intake through adequate inclusion of non-meat sources of bioavailable zinc in the diet (e.g. eggs and diary products), zinc fortified foods or zinc supplements are at higher risk of zinc deficiency. Such is the case in most tribal communities in India.

TRIBAL POPULATIONS AND ZINC DEFICIENCY

Tribal groups constitute about 8.2 % of the total population in India (Indian Government Census, 2001). According to government statistics, tribes can be found in approximately 461 communities (Ajumder, 2001) with almost 92 % of them residing in rural areas, mostly in remote underserved forest regions with little or no basic civic amenities like transport, roads, markets, health care, safe drinking water or sanitation (Indian Government Census, 2001). Tribal communities therefore lag behind other communities with respect to attainment of income, education, health and other requisites for good community nutrition (Srinivasan and Mohanty, 2004). A study by Mishra (2005) using the National Family Health Survey (NFHS-2) found that in almost all the states of India, tribal households had a higher incidence of childhood stunting (52.3%) than non-tribal households (42.8%). Using the same dataset, Nagda (2004) reported an anemia prevalence of more than 80% among tribal children. Several studies have also reported deficient intake of calories and protein among tribal populations relative to the Indian RDA, which may be an explanation for the high rates of stunting among this group (Rao et al., 1994; Yadav and Singh, 1999; Agte et al., 2005; Mittal and Srivastava, 2006).

Iron deficiency is recognized as the major cause of anemia in tribal communities (Reddy et al., 1995; Vyas and Choudhry, 2005) and several studies have reported that deficiencies of micronutrients such as iron and zinc often occur together.Hence the high rates of anemia among tribal populations provide additional evidence of the possibility of marginal zinc deficiency in tribal areas. This is further supported by the high prevalence of stunting and the highly deficient dietary energy intakes in the tribal populations since intake of both zinc and iron are known to be highly correlated with dietary energy intake (Willett, 1998). At least one study has shown that zinc intake of populations in tribal regions was significantly lower than that of any of the other regions studied (Agte et al., 2005).

Tribal populations still largely depend on agriculture and forest products for their livelihood and they follow a relatively homogenous lifestyle with their food habits, dietary practices and general pattern of living (Patwardhan, 2000). Most tribes still rely on their indigenous foods, which usually consist of wild unconventional forest products although some cultivate grains and other farm products for subsistence (Singh and Arora, 1978). The most frequently used cereals are maize, millet or rice and these form part of a major meal at least once daily (Kapil et al., 2003). Since the tribal diet is usually plant based with significant amounts of anti-nutritional factors, which limit the absorption, and/or bioavailability of zinc and because very limited amounts of animal source foods are consumed, these populations are at high risk for zinc deficiency. Kapil et al. (2003) assessed the serum zinc levels of tribal adults in Jharkhand and found that 53% of the study subjects were zinc deficient (serum zinc < 70 µg/dl), with deficiency occurring more frequently among women (61.3%) than men (38.7%). The authors recommended the need to assess the zinc status of tribals in other parts of the country in order to establish the magnitude of the problem. Despite the fact that most tribals are vegetarians as is much of the Indian population as a whole, the non-vegetarian tribals still find it difficult to afford frequent consumption of animal products (Nagda, 2004).

The nutritional value of most of the wild plants used in tribal diets has been evaluated in recent years but a review of the literature reveals that, although most of these plants contain significant amounts of micronutrients, they also contain large amounts of anti-nutritional components that inhibit absorption of such minerals from the diet. Sundriyal and Sundriyal (2004) analyzed the nutritional content of 27 of the most frequently used wild edible plants among tribal groups in Sikkim and found that the zinc content of some of these plants ranged from as high as 1490 µg/g to as low as 212 µg/g; however, the fiber contents of these plants ranged from 5.1% to as high as 39.9%.

Apart from low supply and poor bioavailability of dietary zinc, increased urinary and fecal excretion and high needs of zinc under certain physiologic conditions such as infection also contribute to zinc deficiency. Earlier studies indicated that, comparatively, the overall health of the tribal population is inferior to that of people elsewhere in India and that poor environmental sanitation and unhygienic personal practices predispose tribal populations to high risk of infection (Nagda, 2004; Mishra, 2005). Findings from a recent national survey showed that 82.4% of tribal households did not have latrines and 78.1% did not have drainage facilities in their homes (NFHS-2, 1998), a situation that predisposes children to diarrhoeal disease. The survey also found that the prevalence of diarrhoea and acute respiratory infection (ARI) was higher among tribal children than children of non-tribal mothers. Similarly, the study by Nagda (2004) suggested that childhood diarrhoea, ARI, anemia and fever were major causes of infant mortality in tribal areas. Diarrhoea for instance leads to reduced intake of dietary zinc as a result of anorexia and increased loss of body zinc as a result of malabsorption or rapid gut transit time, since the main route by which zinc is lost from the body is through the gastrointestinal tract. Another highly prevalent infection that may negatively affect zinc status in tribal areas is intestinal helminthes. Zinc is also lost from the body through urine, menstrual flow, semen and sloughed skin, nails, and hair, but the quantity lost through these routes are small and may not significantly contribute to zinc deficiency (Brown and Wuehler, 2000).

Potential Advantages in Improving Zinc Nutrition in Tribal Communities

In populations similar to the tribal groups of India where zinc deficiency is prevalent, several studies have shown improvements in zinc status after supplementation and significant improvements in immune function with subsequent reduction in infection-related morbidity (Sazawal et al., 1995; Sempertegui et al., 1996; Sazawal et al., 1997; Sazawal et al., 1998). Zinc's impact on morbidity has been observed both in terms of prevention and as an adjunct to treatment of these diseases. A pooled analysis of studies of zinc supplementation for the prevention of diarrhoea and pneumonia in children in developing countries found that, in trials that provided 1-2 times the RDA of elemental zinc 5 to 7 times per week, there was a significant reduction in both diarrhoeal incidence and prevalence by 18% and 25% respectively (Zinc Investigators' Collaborative Group, 1999). Pneumonia incidence was reduced by 49% (95% CI 0.41 to 0.83) for zinc-supplemented children. Another study demonstrated reductions in the duration and incidence of diarrhoea, and incidence of ARI upon provision of zinc supplements for two weeks each time a child had an episode of diarrhoea (Baqui et al., 2002). Several studies have even suggested that zinc supplementation might reduce childhood mortality (Muller et al., 2001; Sazawal et al., 2001; Baqui et al., 2002).

The use of zinc as an adjunct to the treatment of serious infections in young children has also provided encouraging results. Zinc supplementation, as an adjunct to oral rehydration therapy, reduced the duration and severity of acute and persistent diarrhoea in several randomized controlled trials (Sachdev et al.,1988; Sachdev et al., 1990; Sazawal et al., 1995; Sazawal et al., 1997; Roy et al., 1997; Bhutta et al., 1999). A pooled analysis of randomized, controlled trials of zinc for acute diarrhoea treatment found that zinc significantly reduced the mean duration of diarrhoea by 16% (Zinc Investigators' Collaborative Group, 2000). Zinc-supplemented children also had a 15% lower probability of continuing diarrhoea on a given day in acute diarrhoea studies and a 24% lower probability of continuing diarrhoea in the persistent diarrhoea trials. There was also a 42% lower rate of death or treatment failure in the persistent diarrhoea studies.

In a related study where children with severe pneumonia received 20 mg of zinc per day plus standard antibiotics until hospital discharge, the zinc supplemented children had reduced duration of clinical signs of pneumonia including shorter duration of tachypnea, hypoxia, and chest in-drawing (Brooks et al., 2004). There is also mounting evidence that zinc supplementation could be helpful in the prevention of malaria.A zinc supplementation trial in The Gambia found zinc supplementation to be associated with a 32% reduction in health centre visits for slide-confirmed malaria, though this difference did not attain statistical significance (Bates et al., 1993).A 46-week period of zinc supplementation in preschool children in Papua New Guinea significantly reduced *Plasmodium falciparum*-attributable health centre attendance by 38% (p=0.037) (Shankar et al., 2000). Malarial episodes accompanied by any level of parasitemia were also reduced by 38% (p=0.028) and episodes with parasitemia >100, 000 per µL were reduced by 69% (p=0.009) in this study. On the contrary, a community-based trial of zinc supplementation in Burkina Faso among children aged 6 to 31 months failed to demonstrated any benefit of zinc on the incidence of clinical malaria episodes although the study showed that the cross-sectional prevalence of falciparum malaria and of *P. falciparum*, *P. malariae*, and *P. ovale* parasitemia were all significantly lower in zinc supplemented children (p=0.001 for all comparisons to placebo). In addition, the mean density of *P. falciparum* increased significantly (p=0.001) during the study in the placebo group relative to the zinc group (Muller et al., 2001).

In order to evaluate the potential role of zinc as an adjunct in the treatment of acute, uncomplicated falciparum malaria, a randomized, placebo-controlled, multi-centre trial was undertaken (ZAP Study Group, 2002). Children (n = 1087) between the ages of 6 months and 5 years with fever and > 2,000/mL asexual forms of *P. falciparum* in a thick blood smear were enrolled at sites in Ecuador, Ghana, Tanzania, Uganda, and Zambia. Children were randomized to receive zinc (20 mg/d for infants, 40 mg/d for older children) or placebo for four days as well as chloroquine, the standard first line treatment for malaria in all sites at the time of study initiation. There was no effect of zinc on the median time to reduction of fever (zinc = 24.2 h vs. placebo = 24.0 h, p= 0.37), reduction of parasitemia by >75% in the first 72 h (zinc group = 73.4%; placebo group = 77.6%, p=

0.11), or hemoglobin concentration during the three day period of hospitalization or four week follow-up period.

The utility of zinc supplementation for the treatment of measles has also been evaluated (Mahalanabis et al., 2002). Children aged 9 months to 15 years who were hospitalized in India for measles were randomized to zinc or placebo in addition to routine supportive care. Treatment with zinc had no impact on the time to recovery or the proportion of children who were judged to be cured by day six.

These studies provide evidence for the efficacy of zinc in prevention and treatment of some common childhood infections and a potential reduction of related mortality in resource-poor areas. Therefore several potential advantages exist in improving zinc status of tribal populations, especially in terms of prevention and treatment of common childhood diseases that plague these resource-limited settings.

STRATEGIES TO CONTROL ZINC DEFICIENCY IN TRIBAL AREAS

From the above discussions, it appears the major causes of zinc deficiency among the Indian tribal population are the low intake and poor bioavailability of zinc as a result of limited amounts of foods that are rich in bioavailable zinc in the tribal diet and the increased losses of the nutrient due to high rates of infection within this population. Intervention strategies aimed at improving zinc status of the tribal population should therefore include both direct approaches that will boost zinc intake and indirect public health approaches aimed at reducing the burden of infectious diseases.

Direct approaches to boost the zinc status of tribal populations should aim at increasing the amount of zinc intake either through dietary diversification, fortification or supplementation, or reducing the intake of inhibitors of zinc absorption through processing techniques. Dietary diversification to include more micronutrient rich foods in the diet is generally considered to be a sustainable approach in addressing most micronutrient deficiencies. However, in the context of tribal areas of India, advocating the increased inclusion of foods rich in bioavailable zinc in the diet will be difficult to achieve since zinc rich foods are usually of animal origin and the relatively high cost of animal source foods make them less accessible to most poor families.Moreover, the inclusion of meat products, which are recognized as the most bioavailable source of zinc, cannot be practiced in vegetarian tribal areas. Hence any attempts to embark on zinc related dietary diversification would be difficult to achieve in these areas.

Processing techniques such as soaking, germination or fermentation should be encouraged in tribal areas since cereal and legume consumption is substantial in these areas and the proposed techniques reduce the phytate content of the diet through production of phytases that breakdown the phytates, thereby increasing the bioavailability of zinc from these foods. Through these processing techniques, the inositol hexaphosphate and pentaphosphates, which bind to zinc and prevent its absorption are broken down to lower inositol phosphates (i.e. inositol phosphate-1, inositol phosphate-2 and inositol phosphate-3), which no longer have the capability to interfere with absorption (Lonnerdal et al., 1989; Gibson and Ferguson, 1998). These processing techniques are simple, easy to perform, and require no cost and therefore should be encouraged to improve zinc nutrition in tribal areas.

Improving intake of dietary zinc could also be achieved through food fortification, which involves augmenting the zinc content of foods through the addition of the mineral to food after processing. Food fortification has been used in large-scale programs to address various micronutrient deficiencies including iron, folate, vitamin A, and iodine (Mejia and Arroyave, 1982; Hurrell, 1997; Quinlivan and Gregory, 2003; Zimmermann et al., 2003). Although most of the experience with zinc fortification has derived from zinc efficacy studies, there is still reason to believe that large-scale fortification to address zinc deficiency in resource-poor settings might still be feasible when certain technical barriers can be addressed. In areas where fortification has been implemented, major programmatic concerns include the selection of a universally consumed food vehicle and a specific mineral fortificant that is bioavailable and possesses few adverse effects with respect to sensory qualities (such as taste, appearance and shelf life) of the food vehicle.The level of the mineral fortificant that is added should also be adequate to meet the requirements of individuals who are at risk of the specific mineral deficiency and should not pose any risk of excessive intake to other members of the population that are not deficient in the added micronutrient who consume the fortified product (Hurrell, 1997). In order to ensure adequate monitoring with respect to dose and proper addition of the fortificant, most fortification programs also employ central processing of the food vehicle. With the exception of this latter requirement, most of the aforementioned criteria could be met in poor settings like tribal areas. For example, cereals have been the most frequently used food vehicle since they are widely consumed in developing countries. But since tribal areas are usually poor areas with limited infrastructure for processing and distribution of food, central processing of food is a less feasible option. Despite the difficulty in overcoming this technical barrier, fortification is still possible in these poor areas as a result of the recent development of micronutrient sprinkles, which can be used to fortify meals at home. Fortification with the use of zinc sprinkles has proven to be feasible in certain areas and could also be employed in tribal areas to address zinc deficiency at least in young children (Sharieff et al., 2006; Zlotkin et al., 2003).

Supplementation with micronutrients has been employed in numerous countries to address various micronutrient deficiencies. Supplementation involves the provision of an additional amount of the nutrient, usually in a chemical form instead of food, to a targeted group of a given population to address a specific micronutrient deficiency.Most of the evidence supporting the utility of zinc supplementation has derived from clinical trials with very few attempts to deliver zinc supplements in large-scale interventions. Nevertheless providing zinc supplements to tribal groups seems feasible and given the low cost of the supplements relative to the potential benefits, this approach is an appealing option. However, the lack of adequate compliance in supplementation programs represents one potential barrier to its effective implementation.

CONCLUSIONS AND RECOMMENDATIONS

It is evident from the above discussions that tribal populations are affected by various social, economic and developmental constraints that potentially expose them to high rates of malnutrition and infections. The high intake of cereal-based diets with relatively poor intake of animal source foods makes deficiencies of micronutrients such as zinc a potentially pressing problem in these communities. Such potential deficiencies require urgent attention in terms of assessing the relative prevalence, identifying possible causes and implementation of programs to block the potential causal routes. The first step should therefore involve performing prevalence studies to establish whether zinc and other micronutrient deficiencies are common, and based on these results, enhancing awareness among the indigenous population about their current micronutrient status, its negative implications on overall well being, and the steps that can be taken to tackle the problem. On the program implementation front, a mixture of strategies should be employed in addressing zinc and other micronutrient deficiency problems in tribal areas as each of the aforementioned strategies has its own potential advantages and disadvantages and most of these strategies are complementary.

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ABSTRACT Tribal populations in India are affected by various social, economic and developmental constraints that potentially expose them to high rates of malnutrition and infections.The high intake of cereal-based diets with relatively poor intake of animal source foods makes deficiencies of micronutrients such as zinc a potentially pressing problem in these communities.Such potential deficiencies require urgent attention in terms of assessing the relative prevalence, identifying possible causes and implementation of programs to block the potential causal routes.The first step should therefore involve performing prevalence studies to establish whether zinc and other micronutrient deficiencies are common, and based on these results, enhancing awareness among the indigenous population about their current micronutrient status, its negative implications on overall well being, and the steps that can be taken to tackle the problem.On the program implementation front, a mixture of strategies should be employed in addressing zinc and other micronutrient deficiency problems in tribal areas.

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