

Review

The role of micronutrients in child health: A review of the literature

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The health and well being of children depend upon the interaction between their genetic potential and exogenous factors like adequacy of nutrition, safety of the environment, social interaction and stimulation. Micronutrients which are nutrients that are only needed by the body in minute amounts play leading roles in the production of enzymes, hormones and other substances and also help to regulate growth activity, development and functioning of the immune and reproductive systems. Micronutrient deficiency, which has been considered as a major risk factor in child survival in Nigeria, increases the risk of death from common diseases such as acute gastroenteritis, pneumonia and measles. Dietary practices frequently seen in children from both developed and developing countries such as frequent consumption of nutrient-poor foods (as unhealthy snacks), and the “refusal” to take green leafy vegetables and fruits compromise their intake of micronutrients (such as zinc, iodine, vitamin A, iron, folate and selenium) from dietary sources. This paper reviews the role of micronutrients in child health and the importance of consuming green leafy vegetables, soy beans, seasonal fruits, milk, dairy products, fish, eggs, chicken and other food stuffs. The consumption of these foods will prevent the occurrence of common day to day infections in children, enable the society produce healthy children with solid foundation and ensure optimal human resource development.

Key words: Micronutrients, child health, nutritional deficiency.

INTRODUCTION

The health and well being of children depend upon the interaction between their genetic potential and exogenous factors like adequacy of nutrition, safety of the environment, social interaction and stimulation (Singh, 2004). According to Caballero (2004), almost two-thirds of the deaths of children around the world are directly or indirectly associated with nutritional deficiencies. Both proteins-energy malnutrition and micronutrient deficiencies increase the risk of death from common diseases such as acute gastroenteritis, pneumonia and measles. Iron deficiency anemia, for example, is estimated to affect almost 25% of the world's population resulting in high economic cost by adding to the burden on health care services, affecting learning in school and reducing adult productivity (Caballero, 2004). Dietary practices frequently seen in children from both developed and developing

countries, leading to frequent consumption of nutrient-poor foods, may also put them at risk of micronutrient deficiencies.

UNICEF (1998) defined micronutrients as nutrients that are only needed by the body in minute amounts, which play leading roles in the production of enzymes, hormones and other substances, helping to regulate growth activity, development and the functioning of the immune and reproductive systems. Micronutrients of known public health importance include the following: zinc, iodine, iron, selenium, copper, vitamins A, E, C, D, B₂, B₆ and folate.

Deficiency of these micronutrients has a significant impact on children as well as on the economic development of communities and nations. These deficiencies can lead to serious health problems, including reduced resistance to infectious diseases, blindness, lethargy, reduced learning capacity, mental retardation and in some cases, to death. Among the debilitating consequences of these dietary deficiencies is loss of human

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capital and productivity. The full genetic potential of the child for physical growth and mental development may be compromised due to sub clinical deficiencies of micronutrients, which are commonly referred to as “hidden hunger”. Children with these sub clinical deficiencies of micronutrients are more vulnerable to develop frequent and more severe common day-to-day infections thus triggering a vicious cycle of under nutrition and recurrent infections (Singh, 2004).

According to Singh (2004), vitamins and trace minerals are required for production of various enzymes, hormones, and biochemical mediators for regulation of biological processes. He further stated that micronutrients are required for energy production, synthesis of RNA and DNA and for providing protection against reactive oxygen-free radicals. Micronutrients are also required for promotion of physical growth, sexual maturation and neuromotor development. They are recognized to boost both cell-mediated and humoral immune deficiencies of the body. Micronutrients play significant roles in the health of children. This paper therefore reviews the roles of the various micronutrients in children as found in literature.

ZINC

According to Cousins et al. (2004), zinc is widely recognized as an essential micronutrient with a catalytic role in over 100 specific metabolic enzymes in human metabolism. It is one of the most ubiquitous of all trace elements involved in human metabolism and plays multiple roles in the perpetuation of genetic materials including transcription of DNA, translation of RNA, and ultimately in cellular division. Interest in zinc was stimulated when zinc supplements given to short children and failure to thrive infants in the U.S. city of Denver improved growth (Allen, 2001).

Collective Ability (2004) reported that zinc is found virtually in every tissue in the body and is particularly important for the correct functioning of the immune system, growth and development and the antioxidant system. The major source of zinc intake is through diet and when the supply of dietary zinc is insufficient, biochemical abnormalities and clinical signs may develop (Indian Pediatrics, 2004). The following are the major functions of zinc:

- a) Zinc is a constituent of metalloenzymes and is involved in a large number of biological processes.
- b) Zinc is essential for the metabolism of vitamin A
- c) Zinc is involved in the synthesis of DNA and RNA without which cells cannot reproduce themselves and growth and development would be impossible.
- d) Zinc is needed for cell replication and is thus essential for regeneration of the intestinal mucosa.

- e) Zinc is essential for the healing of wounds and the turnover of epithelial cells necessary to maintain healthy skin.

Zinc is found in a wide range of foods; the richest sources are animal protein (meat, eggs and dairy products) shellfish, pulses, nuts and whole meal grains. White flour is a poor source of zinc because the zinc is mainly found in the outer layers of the grain and because the fibre in grain contains phytates, which inhibits the absorption of minerals.

Zinc plays an important role in the promotion of normal growth and development and is an element in the enzymes that work with red blood cells, which move CO₂ from tissues to lungs. It also helps to maintain an effective immune system.

Zinc deficiency in malnourished children contributes to growth failure and susceptibility to infections. It is also associated with complications of child birth. This deficiency usually occurs where malnutrition is prevalent (UNICEF, 1998). Mid-to- severe zinc deficiency disturbs several biological functions such as gene expression, protein synthesis, immunity, skeletal growth and maturation, gonad development and pregnancy outcomes, including taste perception and appetite (Onyezili et al., 2003). According to Penny (2004) severe zinc deficiency is responsible for dwarfism and failure to mature in young Iranian and Egyptian youths eating a diet consisting largely of whole meal bread. Penny (2004) observed that lesser degrees of zinc deficiency are more common now than was appreciated and the sub clinical deficiency of zinc contributes to an increased incidence and severity of common but important infections such as diarrhea and pneumonia. Diarrhea is associated with an increased loss of zinc in faeces. Onyezili et al. (2003) also stated that zinc deficiency increases the risk of mortality from diarrhea, pneumonia and malaria by 13 to 21 percent and unlike other micronutrients of public health importance has often subtle rather than dramatic clinical features.

Despite the widespread presence of zinc in common foods, dietary deficiency is common because bio-availability of zinc is reduced by the co-existence of inhibitory substances such as fibre and phytate in foods of vegetable origin. These substances inhibit the absorption of zinc. The diets of the poorest populations often lack zinc being dependent on vegetables staples with little access to animal products especially flesh products such as meat, fish and offal which are the richest sources of easily assimilated zinc. Children in poor communities do not manifest obvious signs of zinc deficiency but have often been found to have low plasma zinc levels compatible with sub-clinical zinc deficiency (Penny, 2004). Zinc supplements helped blunt the most severe malaria cases in children. The deficiency of Zinc can be prevented by intake of zinc supplement and foods rich in protein.

VITAMIN A

Vitamin A is a family of fat-soluble compounds that play an important role in vision, bone growth, reproduction cell division and cell differentiation (in which a cell becomes part of the brain, muscle, lungs etc (Gerster, 1997; Futoryan, 1994). Vitamin A helps to regulate the immune system, which helps prevent or fight off infections by producing white blood cells that destroy harmful bacteria and viruses (Ross, 1999; Depee and West, 1996). If children have insufficient vitamin A, their ability to resist diseases such as diarrhoea, measles and acute respiratory infections is greatly hampered. Increasing the vitamin A intake of populations with vitamin A deficiency (VAD) can decrease childhood deaths from such illnesses by 23 percent, or nearly a quarter of childhood deaths (Dwivedi, 2003).

Vitamin A promotes healthy surface linings of the eye and the respiratory, urinary and intestinal tracts (Semba, 1998). When those linings break down, it becomes easier for bacteria to enter the body and cause infection. Vitamin A also helps maintain the integrity of skin and mucous membranes, which also function as a barrier to bacteria and viruses (Ross, 1998; Harbige, 1996).

Retinol is one of the most active or usable forms of vitamin A, and is found in animal foods such as liver and whole milk and in some fortified food products. Retinol is also called preformed vitamin A. It can be converted to retinal and retenoic acid, other active forms of the vitamin A family (National Institute of Health, 2005). Pro-vitamin A carotenoids are darkly coloured pigments found in fruits and vegetables that can be converted to vitamin A. Some carotenoids, in addition to serving as a source of vitamin A have been shown to function as antioxidants in laboratory tests.

The 2000 National Health and Nutrition Examination Survey (NHANES) indicated that major dietary contributions of retinol are milk, margarine, eggs, beef liver and fortified ready-to-eat cereals, whereas major contributors of pro-vitamin A carotenoids are carrot, sweet potatoes and spinach (Harrison, 2005). Animal sources of vitamin A are well absorbed and used efficiently by the body. Plant sources of vitamin A are not as well absorbed as animal sources.

Vitamin A deficiency is common in developing countries. Approximately 250, 000 to 500,000 malnourished children in the developing world go blind each year from a deficiency of vitamin A (Institute of Medicine, Food and Nutrition Board, 2001). The report further stated that zinc is required to synthesize retinol binding protein (RBP) which transports vitamin A. Therefore a deficiency in zinc limits the body's ability to mobilize vitamin A stores from the liver and transport vitamin A to body tissues.

Night blindness is one of the first signs of vitamin A deficiency, which makes the cornea very dry thereby the retina and cornea (Sommer, 1982). Vitamin A deficiency

diminishes the ability to fight infections. In countries where such deficiency is common and immunization programme are limited, millions of children die each year from complications of infectious diseases such as measles, diarrhoea, pneumonia and malaria (Ross, 1992). In vitamin A deficient children, cells lining the lungs lose their ability to remove disease-causing microorganisms and this may contribute to the pneumonia associated with vitamin A deficiency (Gerster, 1997; Ross, 1999). Vitamin A deficiency can be prevented by food fortification and by eating foods that are rich in vitamin A and also by supplementation.

IRON

Iron is one of the trace minerals that play a vital role in the body. The whole body contains about 4 g of iron. Three-fourth of this is found in association with the protein, haemoglobin. In foods, iron occurs in two forms ferrous and ferric but the absorption form of iron is only in the ferrous state. The function of iron in the body cannot be overlooked as it is involved in the synthesis of other compounds in the body. Iron is important in reactions involving energy release in the body (oxidation and reduction reactions). It is a component of oxygen carrying compounds e.g. haemoglobin, myoglobin.

Iron deficiency anaemia is the most common micronutrient problem in the world as it affects more than 2 billion people globally (Onyezili et al., 2003). Iron deficiency among children is common, especially in less developed countries and affects psychomotor development (Pollitt, 1993). However, the potential risk is that improving iron status may stimulate the development of infection (Murray et al., 1978, Oppenheimer, 2001). Pollitt et al. (1989) and Beasley et al. (2000) also observed that although iron supplements improve the cognition and growth of deficient children, they could be harmful as microbial proliferation is influenced by the iron concentration of the culture medium (Kochan, 1997) and iron supplements can produce oxidative stress (Kadiiska et al., 1995).

Infants and young children are the most adversely affected by iron deficiency because they are growing and developing at such a fast rate (Draper, 1996). If iron deficiency is not corrected, it leads to anaemia, which is the most common nutritional disorder in the world. Draper (1996) further stated that iron deficiency anaemia is a major problem affecting more than 2 billion people – more than one-third of the entire world population. The World Health Organization (WHO) also estimated that 51% of children under 4 years old in developing countries are anaemic as a result of iron deficiency. According to Draper (1996) iron deficiency anaemia is more common in situations of:

1. Social disadvantage (e.g. poverty, poor housing and over crowding, and low levels of parental education),
2. Psychological disadvantage (e.g. lack of stimulation), and
3. Biological disadvantage (e.g. low birth weight, high infection rates, and other nutritional deficiencies).

The main nutritional causes of iron deficiency anaemia are diets that provide too little iron, poor absorption of most dietary iron, and the presence of other dietary factors that inhibit iron absorption. Although an inadequate iron diet is by far the major cause of anaemia, it also can occur as a result of parasitic infections, inherited disorders, and deficiencies of other nutrients. Parasitic infections include malaria and helminthes (notably, hookworm). Malaria causes the destruction of red blood cells and hookworms cause blood loss: Inherited disorders that can leave an individual vulnerable to anaemia include sickle cell anaemia. A much less common cause for anaemia results from deficiencies of other nutrients, such as folate (a B-complex vitamin) (Draper, 1996).

Draper (1996) also observed that iron deficiency anaemia is associated with impaired development of mental and physical coordination skills and impaired school achievement in older children. It lowers resistance to disease and weakens a child's learning ability and physical stamina. It also slows mental and motor development and reduces work performance (UNICEF, 1998). There is evidence that iron deficiency anaemia alters the emotional state of infants so that they are more withdrawn, cautious and hesitant, and maintain closer contact with their mothers. These types of behaviour could hinder an infant's ability to interact with and learn from his or her environment thereby contributing to poor intellectual development.

Iron deficiency anaemia can be prevented in children by food fortification such as the addition of iron to food over and above that naturally found in food. Naturally iron-containing foods should not be neglected. Mothers should be encouraged to feed their infants and young children meat and foods rich in vitamin C, such as fruits, and to avoid foods and drinks that inhibit iron absorption, such as tea, during and 2 hours before and after mealtime. Traditional food practices such as germination and/or fermentation can also improve the availability of iron in the diet. Intake of iron supplement can as well help in reducing the prevalence of iron deficiency anaemia. Iron supplements should be initiated as close to 6 months of age as possible, and supplements should be given for 6 months. Supplementation of longer duration, to 15 months of age is likely to be more beneficial (Draper, 1996).

A number of public health activities can lower the risk of iron deficiency anaemia. For example, in areas where malaria is endemic, the use of bed nets should be promo-

ted. According to Onyezili et al. (2003), prolonged breastfeeding confers partial protection against iron deficiency anaemia in infancy, as about 50 percent of the iron in breast milk (0.3 mg/L) is absorbed, compared to about 10 percent from milk or unfortified formula. Deworming is also important, particularly for primary school children, who are more likely to have the heaviest worm burden. Improvement in environmental sanitation will also reduce the risk of repeated infections that indirectly make children susceptible to anaemia (Draper, 1996).

IODINE

According to Australian Nutrition Foundation (2003), iodine is defined as a chemical element that is required for growth and survival.

1. Iodine functions as a component of thyroid hormones, which play a vital role in the regulation of metabolic processes such as growth and energy expenditure.
2. It is essential to the normal development of the foetal nervous system.
3. It may protect against the effect of radioactivity.
4. It regulates the effect of oestrogen on breast tissue.
5. It is a component of a healthy connective tissue.

Iodine is found in sea foods and iodized salt. Plant sources of iodine are totally dependent on where the plant is grown, due to the issue of depleted soils. Iodine is very important in hormonal development and thus when it is deficient in a diet can cause an enlarged thyroid gland (goiter) or other iodine deficiency disorder. Deficiency of iodine may not be indicative of a lack of iodine in the diet, as many things can reduce iodine absorption or iodine utilization in the thyroid. Such substances are called goitrogens. Iodine deficiency is the single most important cause of preventable brain damage and mental retardation including low IQ (intelligent quotient) (UNICEF, 1998) and severe iodine deficiency can lead to cretinism and birth defects as well as miscarriage and stillbirth. According to Onyezili et al. (2003) most children born to iodine-deficient mothers appear normal but have suffered brain damage and loss in IQ points, affecting their ability to develop to their full potential and will later have difficulty learning in school and staying in school.

The deficiency of iodine can be prevented by salt iodization and intake of sea foods. It can also be prevented by intake of iodine supplements which are available in two forms namely iodine and iodides.

FOLATE

Folate is a generic term used to describe a whole family

of complex compounds structurally resembling folic acid (Picciano et al., 1994). Folate is a B vitamin found in a variety of foods and added to many vitamin and mineral supplements as folic acid, a synthetic form of folate (Kurtzweil, 1999). Folate and folic acid are different terms for the same B-vitamin. Folate is the B vitamin form found naturally in foods while folic acid is the synthetic B vitamin form that is used in vitamin supplement and added to fortified foods. The body can absorb and use the folic acid found in vitamin supplements more efficiently than it can convert the food folate into a usable form (Health and Senior Services, 2005).

Folic acid is necessary for proper cell growth and development of the embryo. Folic acid in a vitamin supplement, when taken one month before conception and throughout the first trimester, has been proven to reduce the risk for a *Neural Tube Defect* in children. Folic acid is required for the formation of DNA, which is necessary for rapid cell growth needed to make fetal organs early in pregnancy (Health and Senior Services, 2005). Folate is vulnerable to heat and dissolves in water, so cooking can reduce the levels of folate in foods. Prolonged storage of certain foods is also thought to reduce their folate levels (Victorian Government Health Information, 2005).

Food sources of folate include dark green leafy vegetables, such as pumpkins, spinach, lettuce and liver, bananas, potatoes, legumes. It can be obtained from dietary supplements, such as folic acid tablets and multivitamins with folic acid, and from fortified breakfast cereals.

Deficiency of folate increases the risk of certain serious and common birth defects, which affects the brain and spinal cord. The technical names of the two major neural tube birth defects are spinal bifida and anencephaly. Spinal bifida is the most common form of neural tube defect resulting in continued life after birth. It occurs when the lower part of the neural tube, which develops into the spinal cord and the bones that enclose them, does not close properly, leaving the spinal cord exposed or covered only with skin. Babies born with spinal bifida may have a wide range of physical disabilities, such as loss of bladder and bowel control, paralysis of the legs and associated hydrocephalus (Victorian Government Health Information, 2005).

According to Victorian Government Health Information (2005) anencephaly, which is second neural tube birth defects, occurs when the upper end of the neural tube does not close and the brain fails to completely develop or is entirely absent. Pregnancies affected by anencephaly often results in miscarriages, stillbirths or neonatal deaths.

Folate deficiency and neural tube defects can be prevented by:

1. Taking a daily folate supplement (0.4 – 0.5 mg) which

is cheap and readily available from supermarket, chemist or health food shops.

2. Choosing foods that have added folate (or are fortified with folate) usually breakfast cereals and breads.
3. Eating more foods, which are naturally rich in folate.

SELENIUM

Selenium is a trace mineral that is essential to good health but required only in small amount (Thomas, 2001; Goldhaber, 2003). It has become one of the most exciting nutrients of the 20th and 21st century. Selenium is incorporated into protein to make selenoproteins, which are important antioxidant enzymes called glutathione peroxidase (National Institute of Health, 2004). According to Newswire (2001), antioxidants are a group of substances that protect tissues, cells and important compounds like protein, and DNA against the destructive power of oxygen and its relatives. Antioxidants encompasses vitamins C, E, beta carotene and some minerals and they are essential for good health and can help fight off heart diseases, cancer, age related eye problems, and ageing itself.

The antioxidant properties of selenoproteins help prevent cellular damage from free radicals, regulate thyroid function and play a role in immune system (Mckenzie et al., 1998, Levander, 1997). Selenium and vitamin E work together synergistically in that they carry out antioxidant and immunostimulating function better together than individually (Haas, 2001). Despite its importance, there is less than 1 mg of selenium in our body, most of it in the liver, kidneys and pancreas (Haas, 2001).

The major dietary sources of selenium is plant foods e.g. vegetables, whole grain, brown rice, whole wheat etc and the content in food depends on the selenium content of the soil where plant are grown or animals are raised. It can also be found in some meats and sea food e.g. liver and most fish. Animals that eat grains or plants that were grown in selenium-rich soil have higher levels of selenium in their muscle (National Institute of Health, 2004).

Selenium has a variety of functions, and research is revealing new information (Haas, 2001). The main function of selenium is as an antioxidant in the enzyme selenium-glutathione peroxidase.

1. Selenium helps stimulate antibody formation in response to vaccines.
2. It offers protection against cardiovascular disease possibly by its antioxidant function.
3. It has also being found to have an anti-carcinogenic effect.
4. Selenium protects us from the toxic effects of heavy metals and other substances.
5. It may aid in protein synthesis, growth and development and fertility.

Selenium deficiency is rare but it is seen in countries where soil concentration of selenium is low (Ellis and Salt, 2003) and also in feeding infants fed cow's milk instead of breast milk (Haas, 2001). There is evidence that selenium deficiency may contribute to development of a form of heart disease, hypothyroidism, and a weakened immune system (Combs, 2000; Zimmerman and Kohrle, 2002). According to Singh (2004) selenium deficiency may impair utilization of iodine because it is a key component of the enzyme, which is required to convert thyroxine to triiodothyronine. It can make the body more susceptible to illness caused by other nutritional, biochemical or infectious stresses (Beck et al., 2003).

Three specific diseases have been associated with selenium deficiency:

- a) Keshan Disease, which results in an enlarged heart and poor heart function, occurs in selenium deficient children.
- b) Kashin-Beck Disease, which results in osteoarthropathy and
- c) Myxedematous Endemic Cretinism, which results in mental retardation.

Selenium deficiency has also been seen in people who rely on total parenteral nutrition as their sole source of nutrition (Levander, 1991; Gramm et al., 1995). Total Parenteral Nutrition (TPN) is a method of feeding nutrients through an intravenous (IV) line to people whose digestive systems does not function.

Selenium deficiency can be prevented by eating staple foods such as corn, wheat and soybean as selenomethionine, the organic selenium analogue of the amino acid methionine (Schrauzer, 2001; Schrauzer, 2003), and by eating other plant and animal foods that are rich in selenium. It can also be taken as supplements.

VITAMIN E

Vitamin E is a fat-soluble vitamin that exists in eight different forms. Each form has its own biological activity, which is the measure of potency or functional use in the body (Traber and Paker, 1995). α -Tocopherol is the name of the most active form of vitamin E in humans. It is also powerful biological antioxidants (Traber, 1999; Farrell and Roberts, 1994). Vitamin E in supplements is usually sold as α -tocopheryl acetate, a form that protects its ability to function as an antioxidant (National Institute of Health, 2005).

According to Singh (2004) vitamin E has a sparing effect on vitamin A and ascorbic acid by protecting them from oxidation. Food sources of vitamin E are vegetable oils, nuts, green leafy vegetables and fortified cereals.

Vitamin E deficiency is rare in humans and its deficiency is likely to occur in very low birth weight infants

and premature babies. Necrotizing enterocolitis, a condition sometimes seen in very low birth weight infants that is characterized by inflammation of lining of the intestines, may lead to a vitamin E deficiency (US Department of Agriculture, 2004). Vitamin E deficiency can be prevented by eating foods that are high in vitamin E. Diets should be moderate in fat especially healthful sources of fat, including those oils and nuts that provide vitamin E.

CONCLUSION

All efforts should be made that children take a well balanced nutritious food by encouraging them to consume green leafy vegetables, soy beans, seasonal fruits, milk and dairy products, fish, eggs, chicken and other food stuff. However, the prevailing dogma in nutritional science that a balanced diet is sufficient to meet all the nutritional requirements has been challenged (Singh, 2004). According to the recommendations of United Nations Sub-committee on Nutrition, it is not possible to meet the requirements of 100 percent recommended dietary allowance (RDA) of micronutrients from dietary sources alone (Allen, 2001). Nutritional supplements are thus mandatory to improve physical growth and mental development and prevent occurrence of common day-to-day infections. Healthy children do provide a solid foundation to the society in order to ensure optimal resource development of a country.

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