Introduction

Nutrition the sum of processes involved in taking in nutrients and assimilating and using them to maintain body tissue and provide energy; a foundation for life and health. Health is defined by the World Health Organisation (WHO) as the state of optimal physical, mental and social well being and not merely the absence of disease and infirmity (Nix, 2005).

Health is related to the food consumed. Food consists of macro and micro-nutrients. Macro-nutrients are carbohydrates, proteins and fats, which are needed in grams and perform the function of energy yielding, body building and repair of worn out tissues and defending body against infections where as micro-nutrients are vitamins and minerals, which are needed in milligrams and micrograms by the body and perform the protective and regulatory function in the body. To maintain good health, ingesting a diet containing macro and micro-nutrients in correct proportion is essential, deficiency or excess of any nutrient causes malnutrition and affects the health of an individual.

Malnutrition is a major factor in 54 per cent of deaths among children under the age of five in the developing countries. Moreover, 83 per cent of these deaths are attributable to mild to moderate, rather than severe malnutrition. According to UNICEF (2010) report India is one among the country that has the highest incidence of under-nutrition in the world. Almost 50 per cent of children under five are under weight (weight for age) and stunted (height for age). Above 30 per cent of adults are also undernourished. Besides deficiency of calories and protein, deficiency of micro-nutrients vitamins and minerals is rampant (NFHS-3, 2006). Moderate and severe malnutrition were also observed in 11-13 and 13-15 age group of girls in Tamil Nadu (NNMB, 2012).

Health policy makers and health portfolio tend to distillate on infectious diseases such as vaccination, oral rehydration treatment of infections and non-communicable diseases like cancer and cardiovascular diseases. Important
Introduction

as these are, nutrition cannot be listed under these. Good nutrition is needed to control communicable as well as non-communicable diseases. Malnutrition is the worst form of non-communicable disease and is an important risk factor for chronic diseases at a later date. Maternal malnutrition adversely affects human health and development.

The human body requires 48 different nutrients for its function. The important micro-nutrients are Vitamin A, E, D, K, C Vitamin B- (Pyridoxine, cyanocobalmine, thiamine, riboflavin, niacin, folate) and minerals such as iron, zinc, selenium, chromium, manganese, magnesium and cobalt. Though micro-nutrients are needed in smaller quantities in the body it plays an important role in the production of hormones, enzymes and other substances that help in the functioning of reproductive and immune system and act as co-enzymes and cofactors in the metabolic reactions.

The complex aetiology for micro-nutrient deficiency is poor diet due to poverty, ignorance, low agricultural productivity, and cultural factors; inadequate access to safe drinking water, clean disease-free environment, and health-care outreach also contribute. Infections result in loss of appetite, impaired absorption and utilisation of nutrients, particularly micro-nutrients. Environmental xenobiotics also impair micro-nutrient utilisation (Peter, 2015).

Micro-nutrient deficiency is referred as hidden hunger is not an obvious killer or cripper, but causes specific diseases and also act as aggravating factors in infectious and chronic diseases, greatly impacting morbidity, mortality, and quality of life (Tulchinsky, 2010). The adverse effect can be seen in the growth and development, particularly mental health and immune status. Children, adolescents and expectant mothers are vulnerable groups where food security and economic stress are matters of concern (Kapil, 2014).

Insufficient micro-nutrient is a global problem. In United States more than 8 in 10 children aged 2-18 years have inadequate vitamin D and E intake from food alone and 50 percent had inadequate calcium intake. The Dietary Guidelines for Americans Committee (2015) identified eight under consumed essential nutrients (Bird, 2015).
Introduction

Low dietary intake and poor iron and folic acid intake, absorption and utilization, increased requirement, increased blood loss or excretion, defects in release from stores are major factors responsible for high prevalence of anaemia in India. Poor bioavailability of iron in Indian diet aggravates the situation. High levels of infection such as water and food-borne infections, malaria, and hookworm infestations further precipitate the condition. It is evident from the above data that anaemia is the major problem among the women of reproductive age group. Among them adolescent girls are the most vulnerable population for anaemia.

The World Health Report (Codex Alimentarius Commission, 2001) identified iron, zinc, iodine and vitamin A deficiencies are among the world’s most serious health risk factors. Nearly two billion people worldwide are affected by Vitamin and mineral deficiencies and contribute substantially to global burden of disease.

The health consequences of iodine deficiency disorder goitre are mental retardation, cretinism, deaf mutism, reproductive failure and decreased child survival. Nevertheless the milder deficiency adversely affects mental development, the magnitude of the problem declined in recent years after the introduction of iodine fortified salt (Bamji et al., 2011).

The earliest ocular manifestation of Vitamin A Deficiency (VAD) is night blindness and Bitot’s spot on the eye. Severe vitamin A deficiency leads to keratomalacia (Ulceration and sloughing of cornea) and total blindness. Though kerotamalacia is no longer a public health problem, night blindness is prevalent particularly in pregnant mothers and subclinical deficiency (low Serum levels of Vitamin A) is still encountered. In addition to the ocular manifestations, vitamin A deficiency has been shown to cause growth retardation, decreased resistance to infections, and even death (Bamji et al, 2011). Opinion regarding efficacy of vitamin A supplementation in reducing mortality even in populations with subclinical vitamin A deficiency is however divided (Latham et al., 2010). Blindness due to vitamin A deficiency and rickets due to vitamin D deficiency remain as clinical rather than public health problems (Peter, 2015).
Introduction

Zinc is essential for growth and development. Zinc supplementation has been reported to help linear growth, reduce severity and duration of diarrhoeas and respiratory infections and reduce child mortality. (http://www.icmr.nic.in/pricepubl/content/11.htm). The magnitude and consequences of zinc deficiency in India is required to be studied in detail.

Zinc deficiency, the risk being highest in populations that consume predominantly cereal based diets with little or no meat consumption. Based on food balance data, it is estimated that a large section of the world population is at risk of mild to moderate zinc deficiency. In India, severe zinc deficiency is rare, but the mild and moderate forms are believed to be widespread.

The mortality data of WHO evidences that 0.8 million deaths are accredited to iron deficiency every year globally. In terms of loss of healthy life, expressed in Disability- Adjusted Life Years (DALYs), iron deficiency anaemia results in 25 million DALYs lost (2.4% of the global total), vitamin A deficiency in 18 million DALYs lost (1.8% of the global total) and iodine deficiency in 2.5 million DALYs lost (0.2% of the global total) (Kapil, 2014).

Nutrients in haemoglobin synthesis are proteins- all essential amino acids are necessary. Methionine, vitamins B_{12} and folic acid are required to prevent megaloblastic anaemia. Vitamin- C is needed for the conversion of ferric to ferrous iron and release of iron from stores. Vitamin A is needed for mobilization of iron from stores and improves utilization. Vitamin B_{6} is associated with the prevention of macro/microcytic anaemia. Vitamin B_{2} helps to prevent bone marrow-hypoplasia. Poor intake of these nutrients, chronic low grade inflammation and infections and malaria also contribute significantly to iron malnutrition. The average iron density of an Indian diet is not more than 10 mg/1000 Kcal, with the lowest density of 4.3 and the highest of 15.6 mg/1000 Kcal (NIN, 2010).

Anaemia is the word derived from Greek An – without, Haima – blood and they called it as “Anaimia” and in early 19th century via modern Latin the term coined as “Anaemia’ (anaemia, 2014). It is defined as a condition in which the number of red blood cells and consequently their oxygen carrying capacity is
Introduction

insufficient to meet the body’s physiologic needs. Specific physiologic needs may vary with age, gender, altitude, smoking habit and different stages of pregnancy (WHO, 2011). It is the most common nutritional disorder world-wide. In 2008 WHO reported that anaemia affected 24.8 per cent of world’s population of which 42 per cent were pregnant women, 30 per cent were non-pregnant women, and 47 per cent were preschool children. According to 2010 global data, the prevalence of anaemia was 29 per cent in pregnant women, 38 per cent in non-pregnant women, and 43 per cent in children. Globally South Asian countries accounted for 37.5 per cent of anaemia burden followed by Sub-Saharan Africa which contributed 23.9 per cent (Pasricha, (2014) and http://www.who.int/topics/anaemia/en/).

Iron deficiency is the result of long-term negative iron balance. Iron Deficiency Anaemia (IDA) should be regarded as a subset of iron deficiency, that is, it represents the extreme lower end of the distribution of iron deficiency.

Chronic and severe forms of folic acid deficiency lead to abnormal hemopoiesis and megaloblastic anaemia which promptly responds to treatment with the vitamin. This anaemia remains indistinguishable from that produced by vitamin B\(_{12}\) deficiency. In addition, lack of folate at critical stages of conception was found to be an important cause of Neural Tube Defects (NTD) in the neonates. In India megaloblastic anaemia is not encountered frequently in general population, but occurs occasionally in pregnant women from poor income groups.

While clinical deficiency of B\(_{12}\) is not manifested, sub-clinical deficiency is reported to exist in the country. Studies from Pune indicate appreciable extent of vitamin B\(_{12}\) deficiency occurring in women (>50 per cent) and is reported to be an etiological factor in the metabolic syndrome. Supplementation of pregnant women with vitamin B\(_{12}\) was shown to improve birth weight and reduce the risk of metabolic syndrome. Reports from other parts of the country also show that vitamin B\(_{12}\) deficiency could be more than 30 per cent in adults and in children. According to a study done in Hyderabad, sub-clinical deficiency of vitamin B\(_{12}\) was about 45 per cent in school-age children (Sivakumar, 2006).
Introduction

The term Adolescence originated from a Latin word “Adolescere” meaning ad-‘to’+alescere –‘grow’ is otherwise called ‘coming to maturity’ (Nayar,2007 Biradar,2012), According to WHO Adolescent age group is defined as life span between 10-19 years (SEARO,2014). This is the period of transition from childhood to adulthood which is formative years when the maximum amount of physical, physiological and behavioural changes takes place.

Since adolescence is a period of growth spurt, higher nutrient intake is essential to meet their demands. The nutritional needs of girls during this period are generally ignored, leading to stunting and poor health. For girls, adolescence is a extremely crucial period as menarche and menstruation are bound to crop great psychological response in them. This also causes added burden to the increased nutritional requirement in them. During this period, blood volume and muscle mass increase and this in turn is found to increase the need for haemoglobin formation.

One of the major consequences of the physiological changes and the nutritional neglect, which happens during this period, is anaemia. In a tropical country like India, helminthic infestation is very common which can lead to chronic blood loss, which in turn results in anaemia. In India, the prevalence of anaemia amongst adolescent girls varies between 50-82 per cent (Nair 2001). Such a high prevalence of anaemia among adolescent girls is a matter of great concern as these girls enter reproductive life.

Anaemia causes adverse consequences as the disease progress. It not only affects the growth of adolescent girls but also affect their attentiveness, memory and school performance and retention in school and attendance. It also causes delay in onset of menarche, affects immune system leading to infections. If the anaemic adolescent girl becomes pregnant, it may increase foetal morbidity and mortality, increase the perinatal risk, increase incidence of Low Birth Weight (LBW), Infant Mortality Rate (IMR) and Maternal Mortality Rate (MMR). As growing pregnant adolescents compete with the growing foetus for nutrients anaemia in pregnancy will be worse than in older women (SEARO-IDA, 2014).
Introduction

A less obvious but significant condition affecting millions due to micro-nutrient deficiency is retarded psychomotor development, a condition characterized by slow concentration, impaired coordination, sluggishness and a lack of motivation. All these result in poor scholastic performance, adverse effects on energy and socio-economic productivity. Such individuals appear normal but have mild neurological and mental abnormalities. Children from iodine deficient areas score 13-15 IQ points lower than children from iodine sufficient areas.

Micro-nutrient deficiencies short and long-term consequences negatively impact a country’s Gross Domestic Product (GDP). As affirmed by the 2008 and 2013 Lancet Series on Maternal and Child Nutrition, the 2012 Copenhagen Consensus and the global Scaling up Nutrition (SUN) Movement, multi-micro-nutrient fortification is among the most cost-effective strategies to reduce under nutrition (Scaling up fortification in Asia, 2014).

Iron Deficiency Anaemia (IDA) in children has been associated with retardation in growth and the cognitive development (Bandhu et al., 2003 and Aqaoqlu et al., 2007). Since micro-nutrient deficiencies often co-exist and synergistic effects of micro-nutrients on physical functions may indirectly affect cognition, supplementing children with multiple micro-nutrients could have greater advantages over single micro-nutrient supplementation (Eliander et al., 2010).

Anaemia is the second leading cause of disability in the world and responsible for nearly one million deaths a year, the majority comes from Africa and South-East Asia. World Bank has ranked iron deficiency anaemia the third leading cause of DALYs lost for females aged 15-44 years. It accounts for 4.05 per cent loss in GDP per annum by causing physical and cognitive losses. In India, it corresponds to 1.18 per cent loss in GDP (Pasricha, 2014).

The prevalence of anaemia among adolescent girls in the age group 15–19 years and in the older age group 20–29 years remains almost stagnant at 55.8 per cent and 56.1 per cent respectively. On the other hand, among adolescent boys, prevalence of anaemia in the age group 15–19 years is higher
Introduction

(30.2%) than the post-adolescent age group 20–29 years (19.3%) (Guideline to control IDA, 2013).

Iron deficiency anaemia not only affects the work capacity of the population but also it brings obstacles to national development. Timely intervention can restore the health as well as increase the national productivity by 20 per cent (http://www.who.int/nutrition/topics/ida/en/). The long-term measure to combat includes diet diversification and behaviour change communication while the short-term measures include medical supplementation, which is not a sustainable one, and food fortification is an important intervention and it is sustainable and cost effective measure (www.iapsmupuk.org).

In Copenhagen Consensus, 2008, five out of top ten priorities selected for advancing global welfare using methodologies by the panel of Nobel laureates based on the theory of welfare economics was concerned to nutrition micro-nutrient supplements, micro-nutrient fortification, bio fortification, de-worming and other nutritional related programmes at school and community level.

Three-pronged strategy has been visualized for prevention and control of hidden hunger, which can be deployed individually or in combination: short-term supplementation, medium-term food fortification, and a long-term focus on dietary diversification (Nair, 2016).

Even though the best way of preventing micro-nutrient malnutrition is to ensure consumption of a balanced diet that is adequate in every nutrient, unfortunately, this is far from being achievable everywhere since it requires universal access to adequate food and appropriate dietary habits. From this standpoint, food fortification has the dual advantage of being able to deliver nutrients to large segments of the population without requiring radical changes in food consumption patterns. In fact, fortification has been used for more than 80 years in industrialized countries as a means of restoring micro-nutrients lost by food processing. In particular, some of the B vitamins, and has been a major contributory factor in the eradication of diseases associated with deficiencies in these vitamins (http://www.unicef.org/azerbaijan/media_17912.html).
Food Fortification means addition of one or more essential nutrients to food, for the purpose of preventing or correcting the deficiency of one or more nutrients at the population level or specific groups. Food fortification has played a major role in the health of the populations in several developed and developing countries over the last 70 years and many nutritional deficiencies have been eliminated. Multiple studies have demonstrated the effectiveness of food fortification in eliminating micro-nutrient deficiencies. Almost one forth of iron intakes in the USA diet come from fortified sources, much of that from flour products (Mannar, 2014).

In Canada, flour fortification with B vitamins began in Newfoundland in 1944. Within four years, deficiencies that were earlier found in nearly 20% of the population had dropped to negligible levels. After 1998, following the introduction of mandatory folic acid fortification of cereal-grain products in USA, Canada and Chile, there has been a 30 to 70% reduction of neural tube defects in newborns. In Europe, fortified foods, especially voluntarily fortified breakfast cereals in France, Ireland, the United Kingdom, and Spain have contributed to increasing vitamin and mineral intakes during childhood and adolescence. The effective global fortification experience is the fortification of salt with iodine. Double fortification of salt with iodine and iron is gaining ground but for correction of nutritional anaemia requires multiple micro-nutrients (Mannar, 2014).

Iron fortification by means of adding iron to regularly consumed foods is now generally considered the most cost-effective and sustainable public health approach to improve iron status and prevent Iron deficiency during childhood (Baltussen and WHO, 2004). The cost of iron fortification varies depending on the iron compound, the food vehicle used and packing, but is estimated to be approximately 0.10 – 0.12 USD /person/year (Horton, 2006).

The vehicle used for iron fortification is a food regularly consumed by the majority of children in the target population and is selected depending on the geographic region. Staple food such as flour, rice, pasta, noodles or daily consumed condiments such as salt, sugar, soy and fish sauce are vehicles commonly used for mass fortification (Hurrel and WHO 2007). Flour is the most commonly used vehicle for iron and mass fortification of flour is implemented in 78
countries. Further vehicles specifically aimed at children and adolescents are breakfast cereals, dried cow’s milk powder, yoghurt, biscuits and fruit drinks (Hurrel, 2007).

The Food Safety and Standards Authority of India (FSSAI) permit fortification of foods. National Nutrition Mission highlights the need to focus on micro-nutrient fortification. India’s 10th, 11th and 12th Five Year Plans recommend food fortification as an important strategy to tackle micro-nutrient malnutrition. Ministry of Food Processing Industry, Government of India, provides financial assistance to the Food Industry for capital equipment and its installation for undertaking fortification, and value addition. According to the World Bank, “probably no other technology available today offers as large as an opportunity to improve lives and accelerate development at such low cost and in such a short time” as fortification, along with other interventions to control micro-nutrient deficiencies.

India’s history of fortification began in 1953 when fortification of hydrogenised vegetable oil with Vitamin A and D was mandated. Mandatory salt iodisation began in 1998. In 2000, wheat flour fortification started in west Bengal since then 11 other states introduced fortification.

Micro-nutrient deficiency costs India 1.18 per cent loss of GDP per annum in terms of productivity, illness, increased health care cost and death. In India over the last five decades there has not been any reduction in prevalence of anaemia. Even though multi channels and strategies are required to address the problem fortification of rice with Rice premix was selected as an adjunct or alternative supplementation strategy in the present study.

Adolescent age group is the window of opportunity to correct nutritional status of the children, because the intervening correction during this period can prevent the future consequences of nutritional deficiencies. As compared to studies on pregnant women and under five, only a few studies are available on the nutritional status and anaemia of adolescents, especially in rural areas. Evidence shows that fortification of multiple micro-nutrients increases the haemoglobin level and decreases the prevalence of anaemia (www.iapsmupuk.org). Therefore, the
Introduction

The present study was aimed to study the impact of supplementing iron, zinc, folate and vitamin B\textsubscript{12} fortified rice on the nutritional status and cognitive performance of adolescents in the age group of 10-18 years. Thus the objectives of the study are to

- identify anaemic adolescents in the age group of 10-18 years
- formulate and supplement micro-nutrient fortified rice to the anaemic adolescents and
- assess the impact of supplementing fortified rice on the nutritional status and cognitive performance of anaemic adolescents.