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Micronutrient deficiencies in South Asia — Current status and strategies

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This article provides a comprehensive review of the extent of prevalence of micronutrient deficiencies (vitamin A & D, iron, zinc and iodine) among different population groups in India, Pakistan, Bangladesh and Sri Lanka. The article also covers several health implications associated with these deficiencies, their economic impact and numerous strategies to combat this issue in low income South Asian countries. An extensive computer-based bibliographic review of the literature was performed via PubMed, Web of Science, Scopus, and Google Scholar by using keywords “micronutrients”, “vitamin A and D”, “iron”, “zinc”, “iodine” and “South Asia”. Data were identified under various sections and the most relevant full-text articles and abstracts were selected and screened for inclusion in this review. The results indicate that micronutrient deficiencies are widely prevalent in these regions and are now a significant public health problem. Preschool-age and school children, pregnant women and women of childbearing age are at the risk of these deficiencies. Vitamin A deficiency (VAD) was found among school-age children and adolescents in Bangladesh and Sri Lanka. Vitamin D deficiency (VDD) seemed to affect 84% of pregnant women in India, 70% of healthy volunteers in Pakistan, 26% of male children in Sri Lanka and 8% of children in Bangladesh. Data illustrate that iron deficiency anemia (IDA), zinc and iodine deficiency affect all population groups, suggesting immediate measures to be taken to address the issue. Restricted dietary intake of these nutrients associated with a number of socioeconomic constraints exacerbates the problem of micronutrient malnutrition. Dietary diversification, food fortification and supplementation are the pragmatic and recommended approaches to overcome these nutritional deficiencies. However, the goal to virtually eliminate micronutrient deficiencies in these poorer societies demands a series of well integrated actions at all levels.

Introduction
Recent estimate shows that 870 million people, constituting 12.5 percent of the global population, are undernourished and 852 million of these live in the developing countries. Global estimates of undernutrition among children under 5 years of age suggest that 178 million children are stunted, while wasting is reported among 55 million children (Bhatta & Haider, 2008; Ejaz & Latif, 2011; FAO, 2012; Khor, 2005; WHO, 2004). Deficiencies of iron, iodine, vitamin A and zinc have been more damaging and predominantly affect pregnant women, women of reproductive age, infants and children below 5 years of age and adolescents especially those belonging to developing countries. In particular, vitamin A, iron and iodine deficiencies have been recognized as public health problems in many Asian countries, while precise national data on prevalence of vitamin D and zinc deficiencies are not available in many developing countries. Despite many efforts to reduce the proportion of children, suffering from malnutrition in developing countries, it still continues to affect a large number of children resulting in poor health, low cognitive performance and productivity.

Moderate to severe deficiencies of iron and zinc affect growth, cognitive and reproductive performance and provoke pregnancy complications, leading to low birth weight and birth defects. Health implications associated with VAD include xerophthalmia (night blindness and Bitot’s spots), eventually resulting in the development of corneal xerosis, corneal ulceration and keratomalacia. VDD results in
rickets and osteomalacia and is also considered a major risk factor for cephalopelvic disproportion (Haskell & Brown, 1999; Seshadri, 2001; Sommer, 1995; Talat, Perry, Parsonnet, Dawood, & Hussein, 2010).

Micronutrient deficiencies continue to be a major public health problem in India, Pakistan, Bangladesh and Sri Lanka. Estimated economic cost associated with micronutrient malnutrition in India accounts for 0.8%—2.4% of the GDP (OMNI, 2005; Stein & Qaim, 2007; UNICEF, 2008; Vijayaraghavan, 2002). Similarly, micronutrient deficiencies are widespread in Pakistan and pregnant women constitute the most vulnerable group. Maternal undernutrition and intrauterine growth retardation have been potentially associated with these deficiencies (Bhutta et al., 2009).

Undeniably, micronutrient deficiencies hamper productivity and economic growth and provoke poverty by reducing physical work capacity, loss of cognitive development and school absenteeism. Economic cost of micronutrient deficiencies is reported to involve billions of dollars and this cost is aggravated in the developing countries where this situation seems to prevail for an unknown length of time. Predictably, malnutrition in South Asian developing societies will paralyze the entire health and economic infrastructure if corrective measures are not taken in a timely manner.

**Micronutrient deficiencies in South Asia**

Child malnutrition in South Asian developing countries particularly in India, Pakistan and Bangladesh has been the highest in the world and is a substantial barrier to economic growth and wellbeing of these communities. Poverty is severely prevalent in these regions and is an underlying cause of child undernutrition. Deficiencies of vitamins A and D, iron, iodine and zinc in these countries exacerbate the disease burden resulting in multiple health implications and higher mortality.

**Vitamin A deficiency (VAD)**

Global estimates show that one third of world’s preschool-age population suffers from VAD and the populations from South Asian developing countries are the most vulnerable groups. Around 44–50% preschool-age children are severely affected by VAD and 1 to 2 million pregnant women have been reported to die of childbirth-related complications (Kaleem, 2004; WHO, 2009).

India has the largest number of vitamin A deficient children in the world (World Bank, 2005). Nearly, 62% of preschool-age children in India are deficient in vitamin A (Laxmaiah et al., 2011; MI, 2012a). Diets of rural preschool-age children were grossly deficit in terms of vitamin A, where the median intakes were deficit by 66–81% as against the RDA of 400 µg. About 84% of preschool-age children were not even meeting 50% of their RDA (NNMB, 2006).

VAD has been reported to be much damaging in Pakistan as 9.4% of the population tolerated night blindness and 60% child deaths are attributable to diarrheal and respiratory infections associated with VAD (Mahmood et al., 2008). Restricted availability of balanced and diversified diets is another potential determinant of VAD among economically constrained population groups in Pakistan (Bharmal & Omair, 2001; Bhutta & Haider, 2008; WHO, 1995). Various studies and surveys have demonstrated 5.7 million children under 5 to be affected with VAD and 0.057 million manifested xerophthalmia in Pakistan. Pregnancy complications due to VAD result in 25% underweight birth owing to mothers’ poor nutrition during pregnancy (Kazi & Qurashi, 1998; Mahmood et al., 2008). Recent National Nutritional Survey of Pakistan indicates a gigantic increase in VAD prevalence among women in Pakistan from 2001 (5.9%) to 2011 (30.3%) (NNS, 2011). However, coverage through National Nutrition Survey has been insufficient (study population comprising a few thousand subjects only) to truly represent the gravity of VAD hence, more concerted efforts are needed to appraise the magnitude of VAD in Pakistan.

Sri Lanka has been considered a model country among South Asian developing economies and the country has shown exceptional success to achieve high literacy rate and health outcomes even with limited resources. However, a significant development could not be seen in the realm of public health and nutrition (Rajapaksia, Arambepola, Gunawardena, Rosa, & Opatha, 2011, p. 1). The magnitude of the problem of VAD in Sri Lanka was assessed in a national survey during the period 1995/1996 (MRI, 1998) which showed that although the prevalence of clinical manifestations of VAD did not exceed the cutoff values, the percentage of children having subclinical deficiency (serum vitamin A <20 µg/dl) was very high (36.3%). Subsequently, VAD control program in the form of vitamin A supplementation was formulated with a focus on improving the vitamin A status of pregnant and lactating mothers, preschool-age and primary school children, and adults.

Around 51% of pregnant women in Bangladesh had vitamin A deficit in diets and 18.5% suffered from VAD (serum retinol <0.70 µmol/l). Likewise, 1.5% of 381 (ages 11–16 years) school children in Dhaka manifested serum retinol level <0.70 µmol/l (Ahmed, Rahman, Noor, Akhtaruzzaman, & Hughes, 2006; Ahmed et al., 2012; Lee et al., 2008). The intervention programs of vitamin A supplementation launched in the past (HKI, 1999a, 2006; NIPORT, 2009, p. 346) yielded encouraging results to control VAD in Bangladesh. However, population coverage for vitamin A supplementation still remains a significant challenge and more strenuous efforts to scale up vitamin A supplementation programs are required to cover the entire vulnerable population in Bangladesh.

Prevalence of VAD in South Asian developing countries is possibility higher than the reported data as several cases go unreported due to the absence of precise monitoring, appropriate health services and inadequate nutritional education. Extreme poverty in these regions seems to be one of
the most significant markers for severe VAD prevalence. Numerous success stories for elimination of VAD such as sugar fortification in Guatemala and Honduras (Mora, Gueri, & Mora, 1998) show the possibility to get rid of this menace through sagacious planning and serious actions.

Vitamin D deficiency (VDD)

Sufficient literature demonstrates worldwide prevalence of vitamin D deficiency. One billion people have been suffering from VDD. The problem is more common among purdah [veil] observing women of childbearing age (Tare et al., 2011). VDD is epidemic in India despite of the plenty of sunshine. Almost 75% of the study population had hypovitaminosis D [25(OH) D] \(<20\) ng/ml (Shivane, Sarathi, Bandgar, Menon, & Shah, 2011). Prevalence of VDD was shown to be 76% and 70% respectively among women of reproductive and postmenopausal-age groups in South India (Harinarayan et al., 2011). Several studies indicate that VDD is very common among males and females of all age groups in India (Harinarayan & Joshi, 2009; Marwaha & Sripathy, 2008). Many groups of researchers have reported 16.5% of women of reproductive age group to be affected with VDD in South India and the prevalence was estimated to be about 84% among pregnant women in North India (Harinarayan et al., 2011; Marwaha et al., 2011; Sachan et al., 2005).

Studies covering large samples of Pakistani population to assess the magnitude of VDD prevalence are scant however, numerous representative studies (Bhatty et al., 2010; Qamar, Akbani, Shamim, & Khan, 2011; Sahibzada, Khan, & Javed., 2004) illustrate that VDD is negatively correlated with several health implications targeting almost all population groups. Nearly, 95% of the children, 48% of nursing mothers and 52% of breastfed infants are reportedly the victims of VDD in Pakistan (Karim, Nusrat, & Aziz, 2011).

Multiple micronutrient deficiencies are prevalent in various Sri Lankan population factions. Epidemiological studies are scant to validate the gravity of prevalence of vitamin D in Sri Lanka however; numerous small studies have demonstrated that VDD prevails in the country. Serum concentration of 25(OH)D \(<35\) nmol/L among male (26%) and female (25%) was reported, respectively. Sri Lankans residing in Norway manifested lower 25(OH) D (31.5 nmol/L) as compared with those living in Sri Lanka (54.2 nmol/L). The study suggested that season had a significant effect on vitamin D status among Sri Lankans living in Kandy and those Sri Lankans living in Oslo, Norway. Relatively lower prevalence of VDD noted among Sri Lankans living in Sri Lanka could be due to increased endogenous synthesis as a result of exposure to sunlight. In fact, promotion of outdoor physical activity in Sri Lanka would have the dual benefit of increasing endogenous vitamin D synthesis and also maintaining desirable body weight (Hettiarachchi & Liyanage, 2012; Meyer, Holvik, Lofthus, & Tennakoon, 2008).

Bangladesh is mainly a Muslim society where purdah (veil) is a common practice of women in almost all socio-economical classes. Amongst several determinants of VDD, restricted exposure to sunlight and intake of vitamin D deficient diets have been shown to affect Bangladeshi population especially those living in poorer settings (Ahmed et al., 2012; Islam et al., 2002). Lactating mothers, having inadequate dietary intake of vitamin D, are at a higher risk of bone loss. Rickets is primarily caused by the clinical deficiency of calcium, hence a curative treatment by supplementing calcium at a level of 350–1000 mg elemental calcium per day is generally recommended (Craviari et al., 2008).

Iron deficiency anemia (IDA)

Iron deficiency anemia (IDA) is the most widely prevalent nutritional problem across the world, affecting almost all age, sex and physiological groups. Preschool-age children, adolescent girls, pregnant women and lactating mothers are vulnerable groups. IDA significantly contributes to heighten morbidity and mortality among children. A plethora of publications in the literature is available to suggest anemia to be highly prevalent and poses an increased risk for maternal and child mortality (WHO, 2011) in low income developing countries. IDA exerts a deleterious effect on productivity and cognition among children (Fuglestad et al., 2012) suggesting immediate actions to be taken to overcome iron deficiency in South Asian developing countries.

Nearly, 66% nonpregnant women, 85% pregnant women and 90% adolescent girls in 16-districts of India were reported to be iron deficient. Malnutrition is the underlying cause of higher IDA prevalence among these vulnerable population groups particularly the diets of preschool-age children are grossly deficient in iron and the pregnant and menstruating women do not meet additional iron requirements in India (Menon et al., 2010; Toteja et al., 2006). Similarly, IDA has been shown to affect 90.5% pregnant women and 65% children below 5 years in Pakistan (Baig-Ansari et al., 2008; Nestel & Ritu, 2000). In addition to iron deficiency, prevalence of folate and vitamin B_{12} deficiencies in Pakistan have also been very common (Hashim & Tahir, 2006; Iqbal & Kakepoto, 2009; Kakepoto, Iqbal, & Iqbal, 2000). Numerous determinants have been recognized for high prevalence of IDA in Pakistan including poverty, consumption of cereal based diets, incorrect dietary habits, poor hygiene and sanitation. There is hardly any study conducted with a target population in Pakistan showing any reduction in the prevalence of IDA.

Bangladesh Bureau of Statistics and National Surveys confirmed that 40% adolescent girls were anemic in Bangladesh (HKI, 1999b, 38 p., 2006) associating IDA with early age pregnancies (BBS, 2005). Low dietary intake of iron, bioavailability in the presence of phytates, failure to meet iron needs during rapid growth and pregnancy,
menstrual blood loss and parasitic infections are some of the substantial determinants to provoke the risk of IDA among Bangladeshi populations.

Iron deficiency is the commonest cause of anemia in Sri Lanka and it has been used as a proxy for iron deficiency in the national surveys. The prevalence of anemia is relatively higher among nonpregnant women of childbearing age than pregnant women in Sri Lanka, highlighting the need to target this group for interventions. One survey conducted in 2009 revealed that an individual dietary diversity score of 4 or more was significantly associated with a lower risk of anemia in Sri Lanka (Piyasena & Mahamithawa, 2003).

Zinc deficiency

Zinc deficiency, an important public health problem, affects almost half of the population worldwide, and it is estimated that 1–13% of the population in Europe and 68–95% in North America have low dietary intakes of zinc. Children from developing economies are more prone to zinc deficiency as 61% are at the risk of low zinc intake. Zinc deficiency is a major risk factor for morbidity and mortality contributing nearly 800,000 additional mortality cases every year among children under 5 years (Brown & Wuehler, 2000; Brown, Wuehler, & Peerson, 2001; Haider & Bhutta, 2009; Yakooob et al., 2011).

Prevalence of zinc deficiency among preschool-age children of five states in India was 43.8% (Kapil & Jain, 2011), 49.4% among adolescent girls in Delhi (Kapil, Toteja, Rao, & Pandey, 2011) and 52% among non-pregnant women of central India (Menon et al., 2010).

Assessment of the extent of prevalence of zinc deficiency in Pakistan is hard due to the paucity of data as no surveys or studies have been conducted at national level. National nutrition survey conducted in 2011, however gives a comprehensive picture of prevalence of zinc deficiency in Pakistani population. The survey exhibited that major population fractions (41.6% nonpregnant and 48.3% pregnant women) had zinc deficiency (NNS, 2011). Limited studies revealed zinc deficiency to be prevalent among children at 54.2% in addition to 37.1% of preschool-age children in Pakistan. Approximately, 54% pregnant women from Sindh province were reported to suffer from zinc deficiency. High incidence of foodborne illness has been reported in developing countries, therefore mortality associated with infections like diarrhea, pneumonia and malaria is heightened among zinc deficient children (Abdulla & Suck, 1998; Akhtar, 2012; Akhter, Mahfur, & Hossain, 2012; Bhutta, 2000; Yakooob et al., 2011). Preventive zinc supplementation can be exploited to reduce this mortality due to these common infections. Similarly, zinc supplementation has shown to exert a positive effect on linear growth (Imdad & Bhutta, 2011).

Studies on zinc status in Sri Lanka are limited. Several studies at small scale (de Silva & Atukorala, 1996; Hettiarachchi & Liyanage, 2012) depicted high prevalence of zinc deficiency that could be partly due to low intake of animal foods and low bioavailability of zinc in plant based diets that are commonly consumed.

Zinc deficiency at early pregnancy has been associated with complications in pregnancy outcomes at later stages (Lindstrom et al., 2011). Relatively serious outcomes are observed in lactating mothers already experiencing zinc deficiency and they are more prone to infectious diseases. Supplementing zinc and iron as a multiple micronutrient strategy can reduce morbidity and mortality rates in such populations (Akhtar, Anjum & Anjum, 2011; Baqui et al., 2003). Sufficient evidence indicates that intervening zinc can prevent 30,000 to 75,000 child deaths by preventing diarrhea in Bangladesh (Ahmed et al., 2012; Jones, Steketee, Black, Bhutta, & Morris, 2003; Ruel, Rivera, Santizo, Lonnerdal, & Brown, 1997). Iodine deficiency

Estimates indicate that 60% of almost 600 million people in Europe suffer from iodine deficiency (de Benoist, McLean, Egli, & Cogswell, 2008; Vitti, Delange, Pinchera, Zimmermann, & Dunn, 2003). Similarly, iodine deficiency, resulting mostly from an insufficient dietary supply of iodine is also a major public health problem in most parts of India (Kapil, 2000). Iodine deficiency is widely prevalent in Pakistan as well and a large part of population is at the risk of iodine deficiency. Pregnant women suffer from iodine deficiency and expose their newborns at high risk of disorders caused by iodine deficiency. Salt iodization program initiated in Pakistan in 1995, appears to be a viable approach and this project has shown promise for the future with an increase in the production of iodized salt from a mere 17 percent to as much as 67 percent (Anon, 2007). Similarly, 250,000 MT of adequately iodized salt, is being processed in Punjab, the most populous province of Pakistan. The availability of iodized salt benefits more than 90 million people in the region (Rose, Khan, Larik, & Mohammad, 2007).

There have been several national surveys on prevalence of iodine deficiency in Sri Lanka. Universal salt iodization was launched in 1995 in Sri Lanka as the main approach to control iodine deficiency. The impact of mandatory salt iodization was assessed in a survey carried out among 8–10 year old children (Jayatissa, Gunathilaka, & Fernando, 2005). Iodine deficiency control program was strengthened by more effective monitoring of salt iodization and distribution. Awareness and education about the correct use of iodized salt is an important factor to ensure success in overcoming iodine deficiency.

Prevalence of iodine deficiency was measured up to 71% in different study population groups in Bangladesh in 1993 and a national salt iodization program was also initiated to overcome the endemic iodine deficiency. Successful execution of the salt iodization program remarkably reduced iodine deficiency therefore, a significant decline in total goiter rate among children and women of ages 6–12 and...
Interventions to combat micronutrient deficiencies

Dietary diversification, supplementation and food fortification have been considered three potential approaches to address micronutrient malnutrition in developing countries. Successful application of these strategies demands a complete knowledge of the foods, supplements, fortificants and bioavailability (Akhtar et al., 2011).

Dietary diversification

Dietary diversification means consuming a variety of foods to meet nutrients requirement. Economic, social and cultural barriers substantially limit the consumption of diversified foods that normally carry vital minerals and vitamins to effectively lower micronutrient deficiency burden among vulnerable groups. Dietary diversification is more advantageous for being sustainable and does not call for any external support. India being a vast and extensively multicultural state, has been attempting to control micronutrient deficiencies by exploiting dietary diversification strategy. Recent studies reported significant success through food-based approaches to combat micronutrient deficiencies (Arlappa, Balakrishna, Laxmaiah, Nair, & Brahman, 2011; Kapil & Tyagi, 2012).

Homestead gardening projects were initiated in 1999 by HKI to promote fruits and vegetables production with an aim of increasing micronutrient intake in Bangladesh. The approach yielded outstanding results. About 719 beneficiaries of the project revealed a significant increment in the serum retinol level including mothers from 30 to 230 retinol equivalents (RE) (Faber, Phungula, Venter, Dhansay, & Benade, 2002). Nevertheless, it appeared to be a demanding task to carry on this practice in the absence of adequate counseling in nutrition (Faber & Laurie, 2011; Tontisirin, Nantel, & Bhattacharjee, 2002).

Food fortification

Being more economical, cost effective and socially acceptable, food fortification has gained tremendous popularity among nations facing micronutrient deficiencies. In South Asian developing countries where wheat is the staple food, emphasis is being laid down to fortify the wheat flour with multiple micronutrients, therefore multiple fortification of whole wheat flour is gaining much popularity in this region. Flour fortification program was initiated in Pakistan in 2007 and was centered in Khyber Pakhtunkhwa province where half million people now have access to fortified flour (MI, 2012b) and coverage remains to be 11% of the entire population.

Supplementation

Two significant determinants ensure the success of supplementation programs namely, level of coverage and compliance. Iron, zinc and vitamin A supplementation for target population has been a successful approach in the developing nations.

Iron supplementation was suggested in communities with high prevalence of anemia. The strategy was found to be more effective in improving iron status and reducing morbidity from upper respiratory tract infections in children aged 5–10 years (de Silva, Atukorala, Weerasinghe, & Ahluwalia, 2003; Malkanthi, Silva, & Jayasinghe-Mudalige, 2010). Educational intervention alone resulted in a significant improvement in nutrition knowledge and iron status in Sri Lanka. Evidently iron supplementation seems more effective in communities with better health education, therefore this approach has been recommended in

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<th>Country</th>
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<th>Vitamin A deficiency</th>
<th>Iodine deficiency</th>
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<td>Children &lt; 6 w/ VAD</td>
<td>Children born mentally impaired</td>
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iron supplementation programs (Senanayake, Premaratne, Palihawadana, & Wijeratne, 2010).

Progressive development of iron deficiency during pregnancy was reported in Bangladesh. Iron deficiency appears to be low, during early pregnancy and can develop into iron deficiency anemia as the pregnancy progresses (Lindstrom et al., 2011). One group of researchers demonstrated the ameliorating effect of early supplementation in pregnancy on the occurrence of stunting among boys aged 0–54 months. The study further elucidated food supplementation to women during early pregnancy to be a pragmatic approach to reduce early childhood malnutrition, especially stunting (Khan et al., 2011).

A practical strategy to control anemia and deficiencies of vitamin A & D, iodine and zinc in Bangladesh is critically needed in addition to launching of large scale training programs for workers. Community awareness campaigns can play a vital role to reduce the extent of micronutrient deficiencies in addition to routine approaches like dietary diversification, supplementation and fortification of staple foods.

Conclusions and future research needs

High prevalence of micronutrient deficiencies, especially in low income countries, has led the world’s scientific community and international organizations to critically appraise health and economic consequences associated with micronutrient malnutrition. South Asia constitutes an important region in today’s world. Extreme poverty and malnutrition remain two instrumental determinants that hamper economic growth of this region. Compelling evidence suggest high prevalence of vitamin A & D, iron, zinc and iodine deficiency in India, Pakistan, Sri Lanka and Bangladesh, afflicting a substantial segment of the population especially children and pregnant women. High maternal and infant mortality rate has been documented as a corollary of the deficiency of these vital nutrients in this region. This situation warrants immediate actions and implementation of several potential approaches that can go long way towards enhancing nutritional status of vulnerable and the neediest population of these poverty stricken economies. Priority setting for elimination of micronutrient deficiencies, conducting extensive national level surveys to assess and document the real burden of micronutrient deficiencies and putting existing strategies and solutions into action are a few widely accepted approaches to combat micronutrient deficiencies. Besides, launching media advocacy campaigns, making huge investment and new legislation to successfully implement fortification and supplementation programs, promoting dietary diversification as an effective approach to minimize the dependence upon fortification and supplementation would play a pivotal role to successfully address the issue. Further research and development is needed especially in the realm of bio-fortification and crop production with enhanced micronutrient status through exploiting biotechnology, to overcome this multipronged issue of hidden hunger in the region.

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